Title	The Oligocene Floras from the Kushiro Coal Field, Hokkaido, Japan
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Citation	Journal of the Faculty of Science, Hokkaido University. Series 4, Geology and mineralogy, 14(4), 383-514
Issue Date	1970-11
Doc URL	http://hdl.handle.net/2115/36000
Type	bulletin (article)
File Information	14(4)_383-514.pdf

THE OLIGOCENE FLORAS FROM THE KUSHIRO COAL FIELD, HOKKAIDO, JAPAN

by

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(with 8 Text-figures and 18 plates)

(Contribution from Department of Geology and Mineralogy, Faculty of Science, Hokkaido University, No. 1158)

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Abstract

The Kushiro coal field is situated at southeastern Hokkaido along the Pacific coast, and a number of well-preserved plants have been found from four coal-bearing formations: the Harutori, Tenneru, Yubetsu and Shakubetsu formations in ascending order. The fossil plants are preserved largely in shale of the roof strata of the coal seams, and are especially most abundant in the Harutori. In this paper the four floras from the Urahoro group are described in detail as to their geologic occurrence, composition, paleoecology and age. They represent a standard floral sequence in northern Japan during Oligocene time.

The Harutori flora composing a major part of this paper, is made up of 58 species, which include six pteridophytes, three conifers and 49 angiosperms. Most of these fossil plants resemble the modern trees and shrubs that contribute to the Mixed Mesophytic Forest in East Asia and to its counterpart of the eastern United States, while some of them are similar to the plants living in the Rain Forest and the Evergreen Sclerophyllous Broad-leafed Forest of East Asia. The Harutori plants are assigned to five communities, which lived in the extensive coastal plain with swampy areas and on its bordering mountain slopes. (1) An aquatic association was represented by *Equisetum* and *Nelumbo* which lived in shallow, quiet water close to the lake shore; (2) a swampy community (*Acer*, *Alnus*, *Glyptostrobus*, *Planera*) lived behind the beach zone, chiefly in ponds and poorly drained flats with permanently high water tables; (3) a lake- and stream-border community was dominated by *Metasequoia* and alders whose associates included *Alangium*, *Canarium*, *Cordia*, *Mallotus*, *Musophyllum*, *Platanus* and *Ulmus*. Deciduous hardwood forest consists of two communities: (4) a valley community was made up of very mesic to near-hydric plants such as *Alnus*, *Carpinus*, *Cercidiphyllum*, *Cocculus*, *Corylus* and *Zelkova*; on moister tracts such as valley bottom *Acer*, *Alnus*, *Disanthus*, *Platanus* and *Ulmus* were common, associated with such ferns as *Osmunda* and *Woodwardia*;

(5) a slope community was dominated by *Acer*, *Actinidia*, *Alangium*, *Cercidiphyllum*, *Idesia*, *Platycarya*, *Viburnum*, *Zanthoxylum* and *Zelkova*.

Climate under Early Oligocene age (Harutori time) was warm-temperate. A mean annual temperature was from 16° to 20°C., with winter mean monthly temperature 8° to 12°C; winter temperature seems usually not to have fallen below freezing; a mean annual precipitation was from 1200 to 1500 mm., with summer the rainiest season. The Harutori climate is characterized by the warmth index of 140° to 160° and the coldness index of zero, having a higher precipitation.

The three minor floras, the Tenneru, Yubetsu and Shakubetsu, are described as to geologic occurrence and composition. These three floras are made up largely of deciduous hardwoods, associating with *Metasequoia*, nearly all of which species are represented in the Harutori flora. The warm-temperate plants gradually decreased in occurrence from the Tenneru to the Shakubetsu flora, and the Shakubetsu is most temperate in aspect than others. These three floras from the formations including extensively coal seams, represent also the coastal plain vegetation. Thus, it is suggested that the forest which lived from the Harutori to the Shakubetsu time have become gradually temperate. Evidences provided by the stratigraphic and paleontological considerations, and by paleobotanical comparison with Paleogene floras of western North America, reveal the age-assignment of these four floras: the Harutori flora is dated as Early Oligocene age, the Tenneru is probably of late Early Oligocene, and the Yubetsu and Shakubetsu are Middle to Late Oligocene, probably Middle Oligocene in age.

The Early Oligocene forest represented by the Harutori consisted largely of temperate Arcto-Tertiary members, with a minority of Paleotropical-Tertiary members. Due to climatic deterioration toward Late Oligocene time, subtropical and warm-temperate plants were gradually eliminated, as shown by the Yubetsu and Shakubetsu floras. Such vegetational history is also recorded in the Oligocene of western North American and central Europe.

I. INTRODUCTION

There is wide distribution of Paleogene coal-bearing formations in Hokkaido, along with North Kyushu, which is the most important coal-producing province in Japan. The Ishikari in the central and the Kushiro in the southeastern part are the largest and most coal-producing in Hokkaido. Well-preserved plant fossils are found at several horizons in the coal-bearing formations of these two fields, and the present study may be expected to establish a standard floral sequence of the Paleogene of Japan and elswhere in East Asia.

It is the purpose of this paper to describe the floras of the Kushiro coal field, and to discuss briefly the environmental conditions under which they lived, as well as their stratigraphic relationships. Though abundant occurrence of plant fossils has been long known from the Kushiro field, surprisingly little detailed work has been done with them. OISHI and HUZIOKA (1941, 1943, 1945) have described several species of *Woodwardia*, *Acer*, *Tilia*, *Platanus*, and some genera of the Ulmaceae. The author has collected the plants from the whole area of the Kushiro coal field since 1955. Lately his collection has been greatly increased by financial support from National Science Foundation of the United States. His work is a part of a project which is designed to summarize existing knowledge of the Tertiary floras of Japan in cooperation with Dr. Ralph W. CHANEY, Professor of Paleontology at University of California.

All type specimens and some duplicates are stored in the Museum of Paleontology, Hokkaido University, Sapporo.

1. PRESENT PHYSICAL CONDITIONS

The Kushiro coal field is situated in southeastern Hokkaido, along the Pacific coast, and occupies a wide area of about 2500 square kilometers in Kushiro and Tokachi provinces. This field is made up largely of hills of less than 400 meters elevation and their adjacent alluvial plains. These hills extend generally northward with gradual increase in height, and connect with the Chishima volcanic range including Mt. Meakan and Mt. Oakan. They gradually decrease in elevation southeastward, and connect with the so-called widespread " Kushiro plain ". To the west the Kushiro-Tokachi divide trending NNE-SSW trend, averages 400 to 700 meters in elevation, with a peak of 745 meters (Mt. Ukotakinupuri). Along the Pacific coast there are wide plains which are largely low moors. Major drainage develops toward the south or southeast from the above-noted mountain ranges, and enters the Pacific Ocean.

Since this region is bounded by mountain ranges to the north and westward, climate is considerably influenced by sea currents of the Pacific Ocean. Summers are rather cool, and temperatures average from 15° to 18°C (from July to September). Winters are severely cold, and average temperatures are from —3° to —7°C (from December to February) on the average. Meteorological stations in this region indicate that it receives approximately 800 to 1200 mm. of precipitation annually. It is well distributed from May to November with a maximum peak of September, and is rather sparse from December through April. Compared with other regions of Hokkaido, snowfall is rather lighter with annual maximum depth of less than 1.5 meters. In late spring and summer sea fog frequently covers the coastal area, due to the Oyashio (cold) current. Owing to the above-described climatic condition, the growing season is scarcely of 3 months duration.

Modern forests of this region show a mixed type of subarctic and temperate forests. The broad-leafed forest is closely related to that of northern Honshu, though several characteristic trees such as beeches, chestnuts, two-needled pines, horse-chestnuts and wingnuts are not found. The conifer forest contains many member of the subarctic forest, which grows typically in Kurile and southern Saghalien. On lowlands and hillsides of the Kushiro field, there occur desciduous broad-leafed forests consisting dominantly of *Acer mono*, *Alnus hirsuta*, *Carpinus cordata*, *Cercidiphyllum japonicum*, *Euonymus oxycarpa*, *Fraxinus mandshurica* var., *Hydrangea paniculata*, *Juglans ailanthifolia*, *Ostrya japonica*, *Prunus sargentii*, *Quercus mongolica* var. *grosseserrata*, *Salix* spp., *Sambucus sieboldiana* var., *Tilia japonica*, *T. maximowicziana*, *Ulmus davidiana* var. *japonica*. On somewhat higher hills several subalpine conifers such as *Abies sachalinensis*, *Picea jessoensis*, *P. glehni* and *Taxus cuspidata* are mixed with broad-leafed trees. In this mixed forest there are also found predominantly the following deciduous broad-leafed trees: *Acer mono*, *Betula maximowicziana*, *Cercidiphyllum japonicum*, *Kalopanax pictus*, *Magnolia obovata*, *M. kobus* var., *Phellodendron amurense*, *Quercus mongolica* var., *Tilia japonica*, *Ulmus davidiana* var. *japonica* and *U. laciniata*. On the northern mountain ranges at more than 1000 meters elevation, there are conifer forests which consist dominantly of *Abies sachalinensis*, *Picea jessoensis*, *P. glehni and Betula ermani.*

2. ACKNOWLEDGMENTS

The author wishes to express his great appreciation to Dr. Ralph W. CHANEY, Prefessor Emeritus of University of California, who has devoted much time to afford valuable advice on theoretical considerations, and to read this manuscript. He also provided facilities for studies of related modern forests in Taiwan in 1964. Acknowledgment is due to Dr. Yasou SASA, Professor of Hokkaido University, and to Dr. Kazuo HUZIOKA, Professor of Akita University, who have given their valuable suggestions and continuous encouragement during this study. The author is also indebted to Dr. Yoshio OKAZAKI, Professor of Hokkaido University of Education, for information regarding his current playnological studies, and to Dr. Nobuo SUZUKI of same University for competent assistance in collecting fossils during the years of 1960 to 1963.

This study has been made possible through the support of several institutions and companies to which the author owes a real debt of gratitude. The National Science Foundation of the United States provided the principal funds for field trips to collect fossils during the years of 1960 to 1963. This study has been partly aided by a Grant for Fundamental Scientific Research from the Ministry of Education, and by the Geological Survey of Japan for field work. The Taiheiyo Coal Mining Company and the Yubetsu Coal Mining Company afforded many facilities for collecting fossils in the field.

II. General Geology of the Kushiro Coal Field

Geology of the Kushiro coal field has been investigated in detail by various authors, and were summarized by Y. Sasa (1940, 1943), S. Mabuchi (1962), M. Matsui (1962) and S. Sato (1967). Geological sheet maps (1: 50,000) by Geological Survey and Hokkaido Development Agency have been published since 1956, and 15 maps cover the whole area of this field. A number of papers on Tertiary paleontology and sedimentology have been published by many authors; among these studies of Paleogene molluscan faunas by H. Takeda (1953) and A. Mizuno (1964), of foraminifera by K. Asano (1952) and T. Uchio (1961, MS), and of sedimentary rocks by A. Iijima (1959), are especially noteworthy. Lately, Y. Okazaki (1966) has cleverly summarized geology, paleontology and other topics on the basis of papers by various authors.

In the Kushiro field Tertiary and Quaternary sediments are widely distributed on the Late Cretaceous Nemuro group with angular unconformity. Tertiary sediments are divided into four groups: the Urahoro and the Onbetsu groups of the Paleogene, and the Atsunai and Honbetsu (Akan) group of Neogene time. The general stratigraphy of the Kushiro field is shown in Table 1. The fossil floras here discussed come from the Urahoro group. The following statement summarizes only the general geology in this coal field, chiefly of the Urahoro, since most of the above-noted publications are readily available for reference.

Table 1. General Stratigraphy of the Kushiro Coal Field.

Neogene	Tokachi group Atsunai group	
	Unconformity	
Paleogene	Onbetsu group	Nuibetsu formation Charo formation
	Unconformity	
	Urahoro group	Shakubetsu formation Shitakara formation Yubetsu formation Tenneru formation Harutori formation Beppo formation
	Unconformity	
Cretaceous	Nemuro group	

1. PRE-TERTIARY SEDIMENTS

The oldest rocks, which occupy a limited area in the northwestern margin of this field, are schalstein, black slate and hard shale, with accompanying limestone, red chert and hard sandstone. These rocks are overlain by Paleogene or Neogene sediments, lacking the Cretaceous which is widely distributed to the south and southeast. They are similar in lithology to the Sorachi group of presumed Jurassic age, which is typically distributed in central Hokkaido. The Nemuro group of Late Cretaceous age forms the basement of Paleogene coal basin; it is principally distributed on the western and eastern sides, and occurs in the central part only as cores of anticlinal structures. This group consists mainly of blackish gray shale, dark gray siltstone and greenish gray sandstone, intercalated sometimes with tuff and conglomerate. It is all of marine origin, and may contain marine fossils such as ammonites, *Inoceramus* and other molluscs. Most of the Nemuro is considered to range from Campanian to Maastrichtian in age, but the uppermost is lately considered to be of Danian age by several authors.

2. OLDER TERTIARY SEDIMENTS

URAHORO GROUP

The Cretaceous sediments are overlain unconformably by the Paleogene Urahoro group, which is widely distributed with many anticlinal and dome structures over the whole of this field (Text-fig. 1). It is composed mainly of lacustrine sediments containing many mineable coal seams, and is partly interbedded with marine sediments. It is 600 to 900 meters in total thickness, and is divided into seven formations: the Beppo, the Harutori, the Tenneru, the Yubetsu, the Shitakara and the Shakubetsu formations in ascending order. These six formations are piled up with conformity.

The Beppo formation forms the basal deposits of the Urahoro groups, and consists mainly of dark-coloured conglomerate, which includes predominantly black slate, black quartzite, gray sandstone, schalstein and dioritic rocks. It is well developed to the east, varying from 5 to 60 meters in thickness, but is not well-defined in the western part.

The Harutori formation consists pricipally of grayish white or gray arkosic sandstone and dark gray siltstone, with intercalated white tuff and coal seams. It varies from 10 to 120 meters in thickness, but is not defined at the west. Coal seams are well developed in the eastern part, especially around Kushiro City, and are most important in this field. Associated with the coal seams are the plant fossils, whose study is composed the principal part of this paper.

The Tenneru formation is composed of alternation of conglomerate, sandstone and siltstone; these rocks are generally of dark green colour, partly of purplish brown. It is characterized by predominant conglomerate which contain abundant pebble-cobbles of reddish chert and green rocks. A few coal seams are interbedded in the middle part of this formation, but they are not important. Accompanying

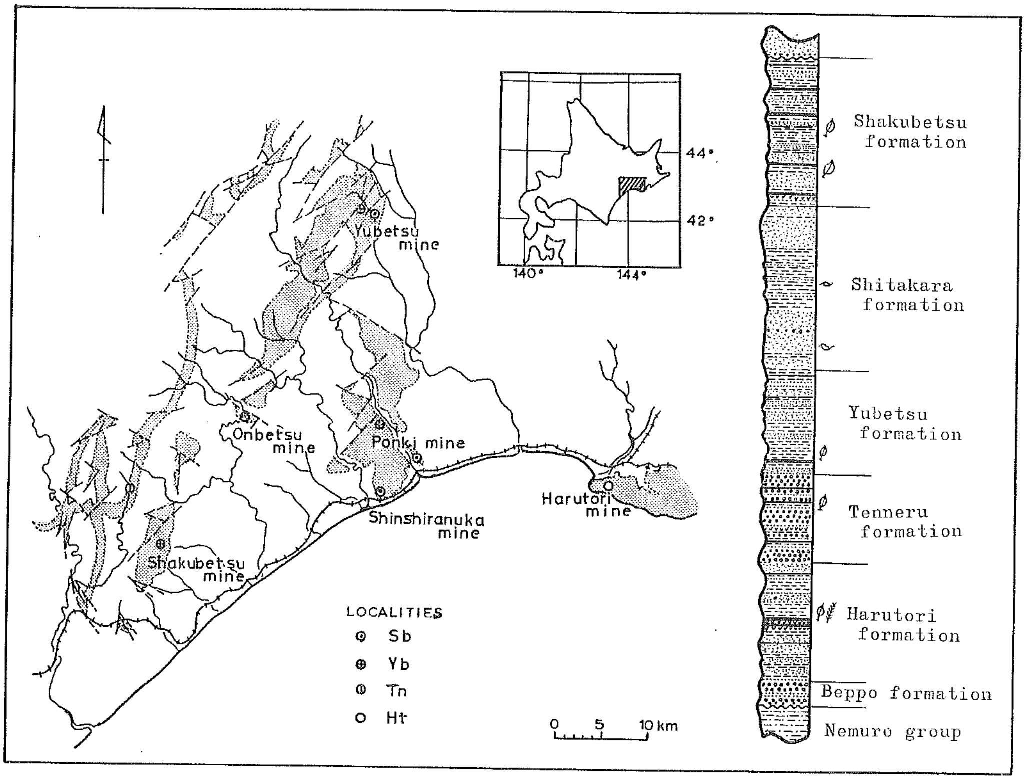

Fig. 1
Distribution of the Urahoro group and Localities of Paleogene Plants in the Kushiro Coal Field.
Sb : Shakubetsu formation Yb : Yubetsu formation Tn : Tenneru formation
Ht : Harutori formation

these coals, plant fossils including silicified wood are sometimes found, though not well-preserved. This formation shows a thickness of more than 300 meters and becomes gradually thinner eastward.

The Yubetsu formation is an important coal-bearing formation in the central and western parts of this field. It ranges from 130 to 250 meters in thickness, but is considerably reduced on the margins. The formation consists mainly of alternation of bluish gray or gray sandstone and dark gray siltstone, with several intercalated coal seams. Plant fossils are of frequent occurrence from the siltstone near the coal seams. Several brackish molluscs such as *Batissa*, *Corbicula* and *Ostrea* are usually found from the uppermost part of this formation.

The Shitakara formation is characterized by brackish or marine sediments containing a number of molluscs and foraminifera. It is typically developed with 320 meters thickness in the central part, being gradually thinner east- and westward, and is divided into three members. The lower member composed mostly of sandstone contains many brackish molluscs such as *Corbicula* and *Ostrea*. The middle member consists of sandy siltstone and silty sandstone, and includes a number of marine fossils such as *Acila*, *Yoldia*, *Nemocardium* and *Mya*. The upper member consists largely of massive medium-grained sandstone which yields few molluscs. These three members are gradually coarser westward, with many intercalated beds of conglomerate.

The Shakubetsu formation, representing the uppermost of the Urahoro group, is well developed in the central part with maximum thickness of 300 meters, and is gradually thinner toward the margin of the basin. It consists mainly of alternation of siltstone and arkosic sandstone, with frequently interbedded white tuff and low-grade coal seams, or in part conglomerates. These coals have been sometimes worked at a few mines. Plant fossils are commonly found from dark gray siltstone throughout this formation, but most of them are not well-preserved. Brackish molluscs such as *Ostrea* and *Corbicula* are usually found in the uppermost levels.

ONBETSU GROUP

The Onbetsu group of marine origin overlies the Urahoro with angular disconformity, and is widely distributed only in the western and central parts of this field. This group consists largely of thick, argillaceous rocks excepting the basal part, and contains a number of marine molluscs and foraminifera thorughout. It shows more than 1000 meters thickness in central areas, and is divided into two formations: the lower is the Charo, and the upper is the Nuibetsu.

The Charo formation is subdivided into a basal member, the Omagari sandstone, and the main member, the Charo siltstone. The Omagari member consists largely of greenish-gray sandstone which frequently contains glauconite. It is from 30 to 80 meters in thickness at the west, but in east-central part is less than 10 meters. The Charo member gradually changes from the Omagri, and consists mostly of massive dark gray siltstone, 200 to 450 meters in thickness. Through this formation a number of marine molluscs and foraminifera are usually found, such as *Yoldia*, *Venericardia*, *Clinocardium*, *Mya*, *Turritella*, *Orectospira*, *Neptunea*, *Plectofrondicularia*, *Cyclammina* and others.

The Nuibetsu formation shows characteristic alternation of dark gray hard siltstone and blackish tuffaceous sandstone. The sandstone is sometimes thicker, and becomes basic tuff or tuff breccia. The formation is generally from 350 to 450 meters in thickness, and may reach more than 800 meters, with accompanying tuff breccia or andestic agglomerate. A number of marine molluscs and foraminifera are usually recorded.

3. YOUNGER TERTIARY SEDIMENTS

ATSUNAI GROUP

The Paleogene sediments are overlain with angular unconformity by the Atsunai group, which is distributed principally in the southern half of the field. This group is more than 1700 meters in thickness in the south-central and southwestern areas, but is about 500 meters at the northeast. It consists predominantly of tuffaceous rocks, and is divided into three formations, which shows a considerable lateral change in lithology. The lowest formation, the Chokubetsu, is composed mainly of hard shale, tuffaceous siltstone and sandstone, with intercalated conglomerate and tuff or tuff breccia. The middle part of the Chokubetsu yields many marine molluscs, most of which are typically of Late Miocene age. The middle formation, the Atsunai, consists mainly of alternation of tuffaceous sandstone and siltstone, interbedding tuff and conglomerate. The siltstone is frequently diatomaceous, and contains abundant marine diatoms and few molluscs. The uppermost formation, the Shiranuka, is composed mainly of tuffaceous, sandy siltstone, interbedding sometimes sandstone and pumiceous tuff.

TOKACHI (AKAN) GROUP

The Tokachi group is typically distributed at the western margin of the basin, and its correlative, the Akan group, is in the north-central areas. These groups cover the lower sediments with angular unconformity, and comprise predominantly pyroclastic rocks. The Tokachi group, more than 2000 meters thickness, is composed mainly of tuffaceous sandstone and siltstone in its lower part, of dacitic agglomerate in its middle, and of siltstone, sandstone, conglomerate and lignite in its upper part. The Akan group with 800 meters thickness is composed mainly of marine sandy siltstone and sandstone in the lower part, and of tuff breccia, volcanic conglomerate and pumiceous tuff in the upper half. These two groups contain a number of marine molluscs in their lower levels, and are of Pliocene age.

III. THE HARUTORI FLORA

It has long been known that fossil plants occur in the Harutori formation at several localities in the Kushiro coal field, and especially at the Harutori coal mine. The Harutori flora has, however, been not yet studied in detail, excepting description of several plants and a preliminary floral list. The writer has collected many well-preserved plants in the Harutori coal mine during more than 15 years, a collection sufficient for consideration of the floristic composition and paleoecology of the Harutori forest. This flora provides the principal basis for discussion of the floral

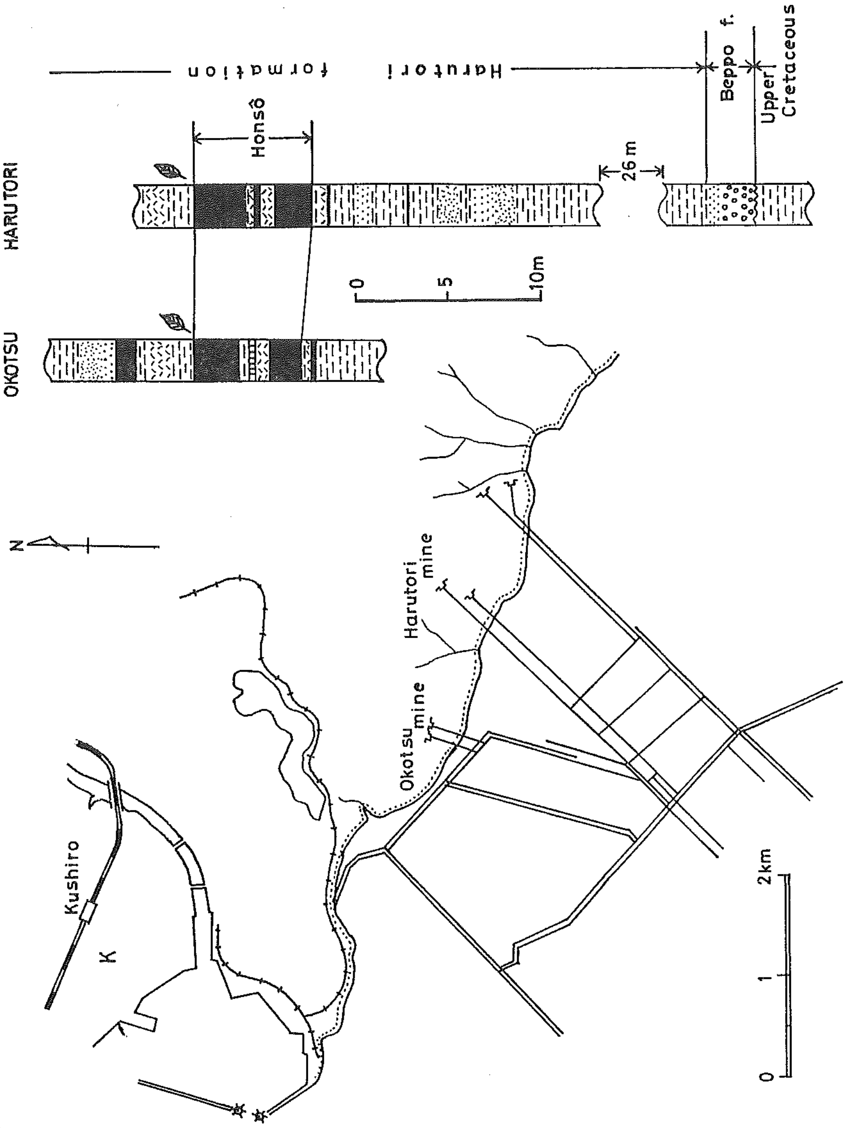

Fig. 2
The Okotsu and Harutori Localities (Pits), and their stratigraphic Relationships.

history of southeastern Hokkaido during Paleogene time.

1. GEOLOGIC OCCURRENCE

The Harutori formation is exposed along the sea-cliff to the west of Harutori, Kushiro City, with a northwest trend and gentle dip (about 10°), and is widely distributed under the sea off the coast. It contains six coal seams in this area, of which the two in the middle part are now mined: the " Harutori-Honso " (Main seam) and the " Kasô " (Lower seam). Plant fossils commonly occur in siltstones immediately above the coal seams, and are especially abundant from the " Honso ".

All of the fossil plants under consideration were obtained from waste rocks at two pits of the Harutori coal mine, the Okotsu and Harutori. These two inclined pits extend about 2 kilometers southwestward in the undersea area from the Harutori coast, and the above-noted two seams are worked. In these pits the coal seams and plant-bearing rocks are shown stratigraphically in Text-figure 2. The plant-bearing shale is of dark gray or blackish gray colour, and may show thin intercalation of sandstone. The leaves were deposited along laminated planes, and are mostly carbonized.

2. COMPOSITION

The Harutori flora as now known is distributed in 38 families, 52 genera and 58 generically named species, of which 32 are described as new, and three as new combinations. There are five ferns and one *Equisetum*, three conifers, two monocotyledons, and the remainder are dicotyledons. One species of uncertain affinity is added to the species in the systematic list. The largest family is the Betulaceae with three genera and five species; next come the Polypodiaceae and the Ulmaceae with four genera and four species each, and the Hamamelidaceae with three genera and three species. The remaining families have one or two species: most of them are represented by only one. Except for *Alnus* with three, and *Acer* and *Viburnum* with two each, none of the genera have more than one species.

Like the Neogene floras, the Harutori flora are well represented by temperate families such as the Juglandaceae, Betulaceae, Ulmaceae and Aceraceae. There are many subtropical families such as the Rutaceae, Burseraceae, Euphorbiaceae, Sapindaceae, Myrsinaceae, Apocynaceae and Boraginaceae, most of which are absent or only meagerly represented in the Neogene floras of Hokkaido. The Harutori plants have no representation of the Lauraceae and Leguminosae, whose abundant occurrence is to be expected in older Tertiary floras. Ferns are well represented as in the case of most Paleogene floras of the northern hemisphere. Of 52 genera designated, several have been not previously recognized in the Tertiary of Japan such as *Cordia*, *Coriaria*, *Cupania*, *Glochidion*, *Gordonia*, *Maesa* and *Melodinus*. These newly-found genera are largely distributed in low latitudes at the present time.

Most of our fossils occur as leaf or leaflet impressions. Ferns are represented by sterile and fertile pinnules. *Equisetum* is represented by sheaths and stems. Fruits and seeds have been found for *Metasequoia*, *Pinus*, and *Acer*.

Following is the list of plants which make up the Harutori flora:

Table 2. Systematic List of Families and Species

- Equisetaceae
  - *Equisetum arcticum* HEER
- Osmundaceae
  - *Osmunda sachalinensis* KRYSHTOFOVICH
- Polypodiaceae
  - *Dennstaedtia nipponica* OISHI and HUZIOKA
  - *Lastrea kushiroensis* new species
  - *Onoclea hebraidica* (FORBES) GARDNER and ETTINGSHAUSEN
  - *Woodwardia sasae* OISHI and HUZIOKA
- Pinaceae
  - *Pinus* sp.
- Taxodiaceae
  - *Glyptostrobus europaeus* (BRONGNIART) HEER
  - *Metasequoia occidentalis* (NEWBERRY) CHANEY
- Liliaceae
  - *Smilax hokkaidoensis* new species
- Musaceae
  - *Musophyllum nipponicum* new species
- Juglandaceae
  - *Carya ezoensis* new species
  - *Platycarya hokkaidoana* new species
- Betulaceae
  - *Alnus ezoensis* new species
  - *Alnus hokkaidoensis* new species
  - *Alnus kushiroensis* new species
  - *Carpinus kushiroensis* new species
  - *Corylus ezoana* new species
- Fagaceae
  - *Quercus kushiroensis* new species
- Ulmaceae
  - *Planera ezoana* OISHI and HUZIOKA
  - *Trema asiatica* (BORSUK) new combination
  - *Ulmus harutoriensis* OISHI and HUZIOKA
  - *Zelkova kushiroensis* OISHI and HUZIOKA
- Moraceae
  - *Broussonetia* sp.
  - *Ficus* sp.
- Nymphaeaceae
  - *Nelumbo nipponica* ENDO
- Cercidiphyllaceae
  - *Cercidiphyllum eojaponicum* ENDO

Menispermaceae
- *Cocculus ezoensis* new species

Hamamelidaceae
- *Disanthus nipponicus* TANAI
- *Hamamelis kushiroensis* TANAI
- *Liquidambar miosinica* HU and CHANEY

Platanaceae
- *Platanus aceroides* GOEPPERT
- *Platanus guillelmae* GOEPPERT

Rosacceae
- *Spiraea kushiroensis* new species

Rutaceae
- *Zanthoxylum oblongatum* new species

Burseraceae
- *Canarium ezoanum* new species

Meliaceae
- *Cedrela kushiroensis* new species

Euphorbiaceae
- *Glochidion japonicum* new species
- *Mallotus hokkaidoensis* new species

Coriariaceae
- *Coriaria* sp.

Aquifoliaceae
- *Ilex obovata* new species

Aceraceae
- *Acer arcticum* Heer
- *Acer oishii* new species

Hippocastanaceae
- *Aesculus* sp.

Sapindaceae
- *Cupania japonica* new species

Rhamnaceae
- *Zizyphus harutoriensis* new species

Actinidiaceae
- *Actinidia harutoriensis* new species

Theaceae
- *Gordonia japonica* new species

Flacourtiaceae
- *Idesia kushiroensis* new species

Alangiaceae
- *Alangium basiobliquum* (OISHI and HUZIOKA) TANAI
- *Alangium basitruncatum* (OISHI and HUZIOKA) new combination

Araliaceae
- *Aralia ezoana* new species

- Myrsinaceae
  - *Maesa nipponica* new species
- Oleaceae
  - *Chionanthus nipponicus* new species
- Apocynaceae
  - *Melodinus japonicus* new species
- Boraginaceae
  - *Cordia japonica* new species
- Caprifoliaceae
  - *Viburnum ezoanum* new species
  - *Viburnum basiobliquum* new species
- Insertae Sedis
  - *Carpites japonicus* (ENDO) new combination

To this megafossil list may be added a preliminary list of microfossils based on the studies by OKAZAKI (1962). From the main seam (the " Honso ") which is now worked at the Taiheiyo coal mine, a number of spores and pollen belonging to many genera or families have been found, as shown in the following list. Starred genera and families are represented also by megafossils in the Harutori flora.

List of Microfossils

- Musci
  - Sphagnaceae
    - *Sphagnum*
- Articulatae
  - Equisetaceae
    - **Equisetum*°
- Filicinae
  - Osmundaceae
    - **Osmunda*°
  - Lygodiaceae
    - *Lygodium*
  - Gleicheniaceae
  - *Polypodiaceae°
- Gymnospermae
  - Podocarpaceae
    - *Podocarpus*°
  - *Pinaceae
    - *Abies*
    - *Larix*
    - *Picea*°
    - *Tsuga*
  - Taxodiaceae
    - **Metasequoia* or *Sequoia*
    - *Sciadopitys*
- Betulaceae
  - **Alnus*°
  - *Betula*°
  - **Carpinus*
  - **Corylus*
- Fagaceae
  - *Castanea*
  - *Fagus*°
  - *Nothofagus* (?)
  - **Quercus*°
- Ulmaceae
  - **Planera* (?)
  - **Ulmus*
  - **Zelkova*
- Hamamelidaceae
  - **Liquidambar*
- Platanaceae
  - **Platanus* (?)
- Aquifoliaceae
  - **Ilex*°
- Aceraceae
  - **Acer*
- Tiliaceae
  - *Tilia*

- Angiospermae
  - Palmae
  - Myricaceae
  - Juglandaceae
    - *_Carya_°
    - _Juglans_
    - _Pterocarya_°
  - Nyssaceae
    - _Nyssa_
  - Ericaceae°
  - Oleaceae
    - _Fraxinus_ (?)
    - _Olea_ (?)
  - Caprifoliaceae
    - _Lonicera_ (?)

° Genera or families showing common occurrence.

The microfossil record of the ferns shows fewer recognized genera, but adds *Lygodium* which is one of the most typical members of Paleogene floras in both Asia and North America. Actually the Polypodiaceous spores show differences which suggest the presence of three genera. It seems probable that pollen of the Taxodiaceae represents *Metasequoia* rather than *Sequoia*, though these genera are not readily distinguishable in the pollen record. The four genera of the Pinaceae not recognized as megafossils may be supposed to have been montane members of the forest whose winged pollen was readily transported to depositional sites below. A similar interpretation may be placed on the occurrence of pollen of *Pterocarya*, *Betula*, *Fagus* and the Ericaceae, none of which have so far been recorded as foliage. Thus the differences noted between the micro- and megafossil record seem explainable largely on the basis of the nature of the living plants, and upon differences in their topographic distribution. A comparison of leaf and pollen floras from the Tertiary sediments raises many important problems for reconstruction of Tertiary forest, as lately amplified by Gray (Martin and Gray, 1962; Gray, 1964). These will be further discussed later in another paper.

ASSUMED GROWTH AND ABCISSION HABITS

The growth habit of a plant may be an important factor in determining the number of its foliar and fruiting units which are available for scattering and deposition at a sedimentary site. Preceding our consideration of numerical representation of the Harutori species, the author is listing their probable growth habits as judged from the living plants most similar to them.

The data in Table 3 show that 26 trees make up 44.8 per cent of the taxa total, 20 small trees and eight herbs 13.8 per cent. Juding from these percentages, the Harutori flora was predominantly arboreal, and with the percentage of herbaceous

Table 3. Assumed Growth Habit of the Harutori Plants

Trees

Pinus sp.
Glyptostrobus europaeus
Metasequoia occidentalis
Carya ezoensis
Zelkova kushiroensis
Ficus sp.
Cercidiphyllum eojaponicum
Liquidambar miosinica

Platycarya hokkaidoana
Alnus ezoensis
Alnus hokkaidoensis
Alnus kushiroensis
Carpinus kushiroensis
Quercus kushiroensis
Planera ezoana
Trema asiatica
Ulmus harutoriensis
Platanus aceroides
Platanus guillelmae
Canarium ezoanum
Cedrela kushiroensis
Acer arctium
Acer oishii
Aesculus sp.
Idesia kushiroensis
Chionanthus nipponicus

Small trees or shrubs

Corylus ezoana
Broussonetia sp.
Disanthus nipponicus
Hamamelis kushiroensis
Spiraea kushiroensis
Zanthoxylum oblongatum
Glochidion japonicum
Mallotus hokkaidoensis
Coriaria sp.
Ilex obovata
Cupania japonica
Zizyphus harutoriensis
Gordonia japonica
Alangium basiobliquum
Alangium basitruncatum
Aralia ezoana
Maesa nipponica
Cordia japonica
Viburunm ezoanum
Viburnum basiobliquum

Vines

Smilax hokkaidoensis
Cocculus ezoensis
Actinidia harutoriensis
Melodinus japonicus

Terrestrial herbs

Equisetum arcticum
Osmunda sachalinensis
Dennstaedtia nipponica
Lastrea kushiroensis
Onoclea hebraidica
Woodwardia sasae
Musophyllum nipponicum

Aquatic herb

Nelumbo nipponica

plants (largely ferns) higher than those in the Neogene floras of Japan. But the ratio of trees to shrubs is lower than in most Japanese Neogene floras, and is similar to those of older Tertiary floras of North America.

Of three conifers, *Glyptostrobus europaeus* and *Metasequoia occidentalis* were deciduous. Referring to the abcission habit of the broad-leafed members of the flora, the eight herbs can be omitted from consideration, but we shall include several angiosperms which have not been assigned specific status, and whose leaf characters indicate whether they were evergreen or deciduous. In this group of 47 angiosperms, the following 11 taxa may be assumed to have had an evergreen habit as judged from the thick texture of their leaves, and from the abcission regime of their living equivalents.

Quercus kushiroensis
Ficus sp.
Cupania japonica
Gordonia japonica

Canarium ezoanum
Glochidion japonicum
Mallotus hokkaidoensis
Ilex obovata
Maesa nipponica
Melodinus japonicus
Viburnum ezoanum

Deciduous plants outnumbered these broad-leafed evergreens by a ratio of more than three to one.

NUMERICAL REPRESENTATION

Some insight into the composition of the Harutori forest can be obtained from a consideration of the number of specimens of each species collected. Table 4 shows their relative abundance as based on a count of 6299 identifiable specimens, which were collected at two localities. This count is not sufficiently large to preclude the possibility that certain species, especially the rare ones, may have been more numerous than is suggested by these figures. However, they represent the totals for each of many collections during the past eight years, and with respect to the dominant species their proportional representation has not greatly changed during these leaf counts in the field.

Table 4. Numerical Representation of Harutori Species

Species	Number of specimens at localities		Total	Per cent
	Okotsu	Harutori		
Metasequoia occidentalis	1,463	1,386	2,849	45.23
(foliage shoots)	(1,429)	(1,364)	(2,793)	
(cones)	(34)	(22)	(56)	
Alnus hokkaidoensis	130	451	581	9.22
Cercidiphyllum eojaponicum	109	150	259	4.11
Musophyllum nipponicum	71	149	220	3.49
Cocculus ezoensis	125	67	192	3.05
Planera ezoana	92	84	176	2.79
Dennstaedtia nipponica	143	33	176	2.79
Corylus ezoana	71	96	167	2.65
Zelkova kushiroensis	56	75	131	2.08
Equisetum arcticum	105	18	123	1.95
Platanus aceroides	53	64	117	1.86
Viburnum ezoanum	34	78	112	1.78
Osmunda sachalinensis	56	55	111	1.76
Cordia japonica	38	73	111	1.76
Glyptostrobus europaeus	35	41	76	1.20
Actinidia harutoriensis	24	51	75	1.19
Platanus guillelmae	31	40	71	1.12
Ulmus harutoriensis	32	38	70	1.11
Viburnum basiobliquum	28	40	68	1.08
Alangium basiobliquum	33	19	52	0.92

Table 4—(*Continued*)

Species	Number of Specimens at localities		Total	Per cent
	Okotsu	Harutori		
Alnus kushiroensis	29	22	51	0.81
Platycarya hokkaidoana	33	15	48	0.76
Idesia kushiroensis	12	36	48	0.76
Disanthus nipponicus	11	26	37	0.58
Acer oishii	16	21	37	0.58
(leaves)	(14)	(20)	(34)	
(fruits)	(2)	(1)	(3)	
Carya ezoensis	12	18	30	0.47
Woodwardia sasae	18	9	27	0.43
Alangium basitruncatum	8	19	27	0.43
Chionanthus nipponicus	15	12	27	0.43
Zanthoxylum oblongatum	15	8	23	0.36
Acer arcticum	8	15	23	0.36
Alnus ezoensis	12	9	21	0.33
Aralia ezoana	13	7	20	0.32
Smilax hokkaidoensis	5	6	11	0.17
Mallotus hokkaidoensis	4	6	10	0.16
Carpinus kushiroensis	8	2	10	0.16
Quercus kushiroensis	7	3	10	0.16
Cedrela kushiroensis	6	3	9	0.14
Trema asiatica	4	4	8	0.13
Glochidion japonicum	5	3	8	0.13
Hamamelis kushiroensis	5	3	8	0.13
Canarium ezoanum	5	3	8	0.13
Maesa nipponica	5	3	8	0.13
Nelumbo nipponica	4	3	7	0.11
Lastrea kushiroensis	4	2	6	0.09
Onoclea hebraidica	4	1	5	0.08
Zizyphus harutoriensis	3	2	5	0.08
Ilex obovata	3	2	5	0.08
Aesculus sp.	2	0	2	0.03
Broussonetia sp.	0	2	2	0.03
Ficus sp.	1	1	2	0.03
Coriaria sp.	2	0	2	0.03
Cupania japonica	0	2	2	0.03
Liquidambar miosinica	1	0	1	0.01
Spiraea kushiroensis	1	0	1	0.01
Pinus sp.	1	0	1	0.01
Melodinus japonicus	0	1	1	0.01
Gordonia japonica	0	1	1	0.01
Carpites japonicus	5	5	10	0.16
Totals	3,016	3,183	6,299	100.00

Note: Unless otherwise indicated, the organs recorded are leaves or leaflets.

Of the 58 Harutori plants, 19 make up more than one per cent each, and combine to constitute about 90 per cent of the total. All of these dominant plants, excluding only one species, *Viburnum ezoanum*, are deciduous. *Metasequoia occidentalis*, represented by foliage shoots and cones, is the predominant species, making up about 45 per cent of the specimens counted. It is followed by *Alnus hokkaidoensis*, *Cercidiphyllum eojaponicum*, *Musophyllum nipponicum* and *Cocculus ezoensis*, and these four species make up nearly 20 per cent of the total. The next four species, *Planera ezoana*, *Dennstaedtia nipponica*, *Corylus ezoana* and *Zelkova kushiroensis*, make up more than 10 per cent. Each of the remaining species comprises less than 2 per cent of the total; most of them are represented by less 0.5 per cent.

Twenty-six plants listed as trees in Table 3 represent 74.01 per cent of the total specimens, 20 shrubs and small trees represent 10.87 per cent, four vines 4.42 per cent, and eight herbs 10.7 per cent. In this connection it should be noted that there is more chance for leaves of trees to enter the fossil record than those of small trees and shrubs. However the following four shrubs, *Corylus ezoana*, *Viburnum ezoanum*, *Cordia japonica* and *Alangium basiobliquum*, show comparatively high scores with one per cent each, though they are represented by large leaves which would seem unsuited to survive transport for a long distances. Accordingly, these four shrubs must have been dominant or common members of the understory of the Harutori forest.

It is noteworthy that the Harutori flora is dominated (over 45 per cent) by *Metasequoia occidentalis*, represented by such comparatively heavy organs as leafy twigs and cones. As judged from the scoring of plant organs in modern pools of deposition by CHANEY (1959, p. 23–25), it was suggested that *M. occidentalis* was hydric in its requirements and was confined mainly to sites of deposition much like those of the modern *Taxodium* and *Glyptostrobus*. This interpretation agrees with the fact that *M. occidentalis* in the Harutori flora is associated with the water-loving species of *Alnus*, *Planera*, *Corylus*, *Platanus*, *Cordia*, *Glyptostrobus*, *Equisetum* and *Osmunda* that are generally known to have been confined to stream- or lake-border sites. All of these associated plants are numerous in the Harutori record. Today the living *Metaseqoia* is known to live in rather wet places along the valley, and even in the midst of rice-paddies in western Szechuan, China (CHANEY, 1948, a, b: CHU & COOPER, 1950). These relations shows that *M. occidentalis*, probably was confined principally to the margins of lakes during the Harutori time rather than to the bordering slope forests.

Herbaceous plants with fragile leaves represent high percentage in occurrence, especially as in the case of *Musophyllum nipponicum*, *Dennstaedtia nipponica*, *Equisetum arcticum* and *Osmunda sachalinensis*. They also appear to have lived near the sites of deposition. All of the broad-leafed evergreen trees, excluding only *Viburnum ezoanum*, are represented by meagre percentage. It should be noted that broad-leafed evergreen trees may be at a disadvantage so far as their record is concerned, since they shed their leaves in relatively small numbers at any one time, while deciduous leaves enter the fossil record in large quantities at the end of each growing season. Our figures show that specimens of the deciduous angiosperms and conifers make up 90.08 per cent of the total, while those of evergreen angiosperms and conifer total only 2.66 per cent.

It may be concluded that deciduous trees, notably *Metasequoia*, *Alnus*, *Corylus*, *Planera*, *Zelkova*, *Cercidiphyllum*, *Platanus*, *Alangium* and *Cordia*, were dominant members of the forest near the sites of deposition, together with such herbaceous plants as *Musophyllum*, *Equisetum* and several ferns.

3. PALEOECOLOGY

A comparison of the Harutori flora with similar living vegetation provides the basis for conclusions regarding its environment. In this comparison, consideration of the distribution of modern equivalent species is of primary importance, since it directs attention to existing forests whose physical settings are well known.

DISTRIBUTIONAL CONSIDERATIONS

The Harutori flora consists largely of temperate genera, most of which are now found growing luxuriantly at middle latitudes. Although several Harutori genera such as *Smilax*, *Trema*, *Broussonetia*, *Cocculus*, *Zanthoxylum*, *Mallotus*, *Ilex*, *Alangium* and *Viburnum* now live at low latitudes, they regularly extend into temperate latitudes and altitudes. *Zelkova*, *Quercus*, *Actinidia* and *Idesia* are common members of both temperate and subtropical forests in eastern Asia. *Nelumbo* and *Platanus* are now widely cultivated in the temperate regions of eastern Asia. Ten genera are typically tropical or subtropical: *Musa*, *Ficus*, *Canarium*, *Glochidion*, *Cupania*, *Zizyphys*, *Gordonia*, *Maesa*, *Melodinus* and *Cordia*. Two ferns, *Dennstaedtia* and *Woodwardia*, range up from the tropics into warm temperate regions.

Table 5 shows the modern distribution of the Harutori 52 genera in seven regions of abundance: in Hokkaido, the northernmost iland of Japan; in Japan from Honshu to Kyushu, including southern islands; in Korea; in China proper; in Formosa, including Ryukyu Islands; in North America east of the Rocky Mountains; and in North America westward to the Pacific Coast. The list includes 14 genera which no longer live in natural growth in Japan, but all except *Planera*, *Platanus* and *Cupania* now live in East Asia, especially in China. *Planera* is confined at present to southeastern North America. *Cupania* lives at low latitudes in America: Mexico, Central America and West Indies. *Platanus* is living in North America, and also from West Asia to southeastern Europe. Hokkaido, in the area including the Harutori fossil localities, has fewer surviving genera than other regions of East Asia. Representation of the Harutori genera in the living

Table 5. Present-day Distribution of the Harutori Genera

	East Asia					North America	
	Hokkaido	Japan*	Korea	Formosa	China	East	West
Equisetum	×	×	×	×	×	×	×
Osmunda	×	×	×	×	×	×	×
Dennstaedtia	×	×	×	×	×	×	...
Lastrea	×	×	×	×	×	×	×
Onoclea	×	×	×	×	×	×	...
Woodwardia	...	×	×	×	×	×	×
Pinus	×	×	×	×	×	×	×
Glyptostrobus	...	...	...	...	×	...	...
Metasequoia	...	...	...	...	×	...	...
Smilax	×	×	×	×	×	×	×
*Musa***	...	...	...	×	×	...	...
Carya	...	...	...	...	×	×	...
Platycarya	...	×	×	×	×	...	...
Alnus	×	×	×	×	×	×	×
Carpinus	×	×	×	×	×	×	×
Corylus	×	×	×	×	×	×	×
Quercus	×	×	×	×	×	×	×
Planera	...	...	...	...	...	×	...
Trema	...	×	...	×	×	×	...
Ulmus	×	×	×	×	×	×	...
Zelkova	...	×	×	×	×	...	...
Broussonetia	...	×	×	×	×	...	...
Ficus	...	×	×	×	×	×	...
Nelumbo	...	...	...	...	×	×	...
Cercidiphyllum	×	×	×	...	×	...	...
Cocculus	...	×	×	×	×	×	...
Disanthus	...	×	...	...	×	...	...
Hamamelis	×	×	×	...	×	×	...
Liquidambar	...	...	...	×	×	×	...
Platanus	...	...	...	...	...	×	×
Spiraea	×	×	×	×	×	×	×
Zanthoxylum	×	×	×	×	×	×	...
Canarium	...	...	...	...	×	...	...
Cedrela	...	...	...	...	×	...	...
Glochidion	...	×	...	×	×	...	...
Mallotus	...	×	...	×	×	...	...
Coriaria	×	×	...	×	×	...	...
Ilex	×	×	×	×	×	×	...

Table 5.—(*Continued*)

	East Asia					North America	
	Hokkaido	Japan*	Korea	Formosa	China	East	West
Acer	×	×	×	×	×	×	×
Aesculus	×	×	...	...	×	×	×
*Cupania***	...	...	...	...	...	...	...
Zizyphus	...	...	...	×	×	×	×
Actinidia	×	×	×	...	×	...	...
Gordonia	...	...	...	×	×	×	...
Idesia	...	×	...	×	×	...	...
Alangium	...	×	×	×	×	...	...
Aralia	×	×	×	×	×	×	×
Maesa	...	×	...	×	×	...	...
Chionanthus	...	×	×	×	×	×	...
Melodinus	...	...	...	×	×	...	...
Cordia	...	×	...	×	×	×	×
Viburnum	×	×	×	×	×	×	×
Totals	23	38	29	38	49	33	17
Per cent	44	73	56	73	94	63	33

* Honshu, Shikoku and Kyushu.
** Confined to low American latitudes.

forest of eastern North America is lower than in East Asia; and it is lower in western than in eastern America, as is also the case with the Neogene floras of Japan. Twenty-six genera, one conifer and 25 angiosperms, are common between East Asia and North America; they include five genera, *Carya*, *Hamamelis*, *Liquidambar*, *Gordonia* and *Chionanthus*, which are a part of the so-called East Asian-American alliance in phytogeographical relationships. Thus, the Harutori flora is composed mainly of temperate or warm-temperate plants, which are now most common in forest of middle latitudes.

Table 6* shows that the Harutori flora is composed mostly of the East Asian and the East American Elements, and that the living species most similar to the Harutori plants occur (a) in China, (b) in Japan, (c) in Taiwan, and (d) in the eastern United States and adjacent Canada, where broad-leafed deciduous forests with many broad-leafed evergreens grow luxuriantly. In addition, there are a few species in such genera as *Ficus*, *Mallotus*, *Nelumbo* and *Platanus*, which resemble plants now living in the warmer regions of southwestern Asia. There are no fossil

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* Excluded from consideration are the widely distributed herbaceous plants, *Dennstaedia*, *Equisetum*, *Osmunda* and *Lastrea*.

Table 6. Distribution of Living Species Representing Harutori Floristic Elements

Harutori species	Similar living Species*			
	East Asian			Eastern N. America
	Japan	Taiwan	China	
Onoclea hebraidica	*O. sensibilis*	——	*O. sensibilis*	*O. sensibilis*
Woodwardia sasae	*W. orientalis*	(*W. orientalis* var. *formosana*)	*W. orientalis*	——
Pinus sp.	*P. densiflora*	(*P. massoniana*)	(*P. massoniana*)	(*P. echinata*)
Glyptostrobus europaeus	——	——	*G. pensilis*	——
Metasequoia occidentalis	——	——	*M. glyptostroboides*	——
Smilax hokkaidoensis	*S. china*; *trinervula*	*S. china*	*S. china*	(*S. rotundifolia*)
Musophyllum nipponicum	——	(*M. formosana*)	*Musa uranoscopos*	——
Carya ezoensis	——	——	*C. cathayensis*	*C. ovata*; *tomentosa*
Platycarya hokkaidoana	*P. strobilacea*	*P. strobilacea*	*P. strobilacea*	——
Alnus ezoensis	*A. japonica*	*A. japonica*	*A. japonica*	(*A. maritima*)
Alnus hokkaidoensis	——	——	——	*A. rugosa*
Alnus kushiroensis	——	——	——	*A. serrulata*
Carpinus kushiroensis	*C. cordata*	(*C. rankanensis*)	*C. cordata*	(*C. caroliniana*)
Corylus ezoana	*C. sieboldiana*	——	*C. chinensis*	(*C. americana*)
Quercus kushiroensis	*Q. myrsinaefolia*	(*Q. longinux*)	*Q. myrsinaefolia*	——
Planera ezoana	——	——	——	*P. aquatica*
Trema asiatica	*T. cannabina*	*T. cannabina*	*T. cannabina*	——
Ulmus harutoriensis	*U. davidiana* var.	(*U. uematsui*)	*U. davidiana*	*U. fulva*
Zelkova kushiroensis	*Z. serrata*	*Z. serrata*	*Z. serrata* var.	——
Broussonetia sp.	*B. papyrifera*; *kazinoki*	*B. papyrifera*	*B. papyrifera*; *kazinoki*	——
Ficus sp.	(*F. wightiana*)	*F. vasculosa*; *caspidatocaudata*	*F. lacor*; *vasculosa*	(*F. brevifolia*)
Nelumbo nipponica	——	——	*N. nucifera*	——
Cercidiphyllum eojaponicum	*C. japonicum*	——	*C. japonicum* var.	(*C. carolinus*)
Cocculus ezoensis	*C. trilobus*	*C. trilobus*	*C. trilobus*	——
Disanthus nipponicus	*D. cercidifolius*	——	*D. cercidifolius*	——
Hamamelis kushiroensis	*H. japonica*	——	*H. mollis*	*H. virginiana*
Liquidambar miosinica	——	*L. formosana*	*L. formosana*	(*L. styraciflua*)
Platanus aceroides	——	——	——	*P. occidentalis*
Platanuss guillelmae	——	——	——	——
Spiraea kushiroensis	*S. betulifolia*; *nervosa*	(*S. morrisonicula*)	(*S. blumei*)	(*S. corymbosa*)
Zanthoxylum oblongatum	*Z. planispinum*	*Z. planispinum*	*Z. planispinum*	(*Z. clava-herculis*)
Canarium ezoanum	——	——	*C. album*	——

Table 6.—(*Continued*)

Harutori species	Similar living Species*			
	East Asian			Eastern N. America
	Japan	Taiwan	China	
Cedrela kushiroensis	——	——	*C. sinensis*	——
Glochidion japonicum	(*G. obovatum*)	*G. philippicum*	*G. philippicum*	——
Mallotus hokkaidoensis	(*M. japonicus*)	*M. philippensis*	*M. philippensis*	——
Coriaria sp.	(*C. japonica*)	*C. intermedia*	(*C. sinica*)	——
Ilex obovata	——	*I. kanehirai*; *kusanoi*	*I. triflora* var. *kanehirai*	——
Acer arcticum	——	——	——	(*A. spicatum*)
Acer oishii	*A. pycnanthum*	——	——	*A. rubum*
Aesculus sp.	(*A. turbinata*)	——	(*A. wilsonii*)	(*A. octandra*)
Zizyphus harutoriensis	——	——	*Z. jujuba*	——
Actinidia harutoriensis	(*A. rufa*)	*A. chinnsis*	*A. chinensis*	——
Gordonia japonica	——	*G. axillaris*	*G. axillaris*	(*G. lasianthus*)
Idesia kushiroensis	*I. polycarpa*	*I. polycarpa*	*I. polycarpa*	——
Alangium basiobliquum	(*A. premnifolium*)	*A. chinense*	*A. chinense*	——
Alangium basitruncatum	*A. platanifolium*	*A. platanifolium*	*A. platanifolium*	——
Aralia ezoana	(*A. elata*)	*A. bipinnata*	*A. chinensis*	*A. spinosa*
Maesa nipponica	*M. japonica*	*M. japonica*	*M. japonica*	——
Chionanthus nipponicus	*C. retusa*	*C. retusa* var.	*C. retusa*	(*C. virginicus*)
Melodinus japonicus	——	——	*M. monogynus*	——
Cordia japonica	——	*C. dichotoma*	*C. dichotoma*	(*C. sebestena*)
Viburnum ezoanum	*V. japonicum*	*V. japonicum*	(*V. ichangense*)	——
Viburnum basiobliquum	*V. tomentosum*	(*V. cordifolium*)	*V. tomentosum*	(*V. dentatum*)

* Species in parenthese are more distantly related to the fossil plants.

species whose similar living equivalents are confined to western North America.

The East Asian Element

Most of the living equivalents of the Harutori plants fall in the East Asian Element, with 47 species making up 81 per cent of the total species and about 80 percent of the specimens recorded. These proportions become larger if the excluded herbs are included. We find most of the East Asian modern qeuivalents in the living forests of China.

Related Modern Forests of Chinese Mainland

Abundance of *Metasequoia occidentalis* in the fossil record turns our attention to the mixed deciduous hardwood forest of central China, where *Metasequoia* survives in western Hupeh and eastern Szechuan. As discussed in preceding pages, although *Metasequoia* specimens comprise about 45 per cent of the total collection, their abundance seems due chiefly to restriction of the source trees to lake margins: *M. occidentalis* probably did not have a prominent place in the adjacent slope forest. The actual representation of plants on nearby slopes and better-drained flats was probably much higher than we might suppose from the counts of species frequency (Table 4). Thus, in order to evaluate the physical conditions at the Harutori site, the deciduous broad-leafed forest of central China is considered first, and thereafter other communities in the regions to the north and the south that contain species similar to those in the Harutori flora.

The Mixed Mesophytic Forest Formation of central China is distributed in hilly country along the Yangtze Valley over an east-west range of more than 2000 kilometers. It is composed of many species, most of which are broad-leafed deciduous trees. Many of the families represented include monotypic and relict plants, as pointed out by WANG in his valuable discussion of the Forests of China (1961, Chapter 5). His treatment divides this forest formation into two subdivisions, the Lower and the Upper Yangtze Valley, with Regional Treatizes listing the important trees recorded at six localities (p. 119, fig. 48).

The Mixed Mesophytic Forest of the Lower Yangtze occurs in the hilly country of southern Kiangsu, Anhwei, northern Chekiang and Kiangsi. It generally begins at the elevation about 500 meters or higher, and extends to more than 1500 meters in Hwang-Shan. The lower part of these forests, especially on the alluvial plains, has long been affected by human influences, and little of the natural vegetation remains. WANG describes (op. cit. pp. 103–108) natural forests are well preserved on the following mountains: Tienmu-shan (500–1200 meters at altitudes) in northern Chekiang (CHANG, T. P., 1936; TSOONG, P. C., 1936); Huang-Shang (450–1500 meters) (CHIEN, S. S., 1927) and Chiuhu-shan (500–650 meters) (FAN, C. S., 1935) in southern Anhwei; Lu-shan (800–1500 meters) in northern Kiangsi (CHEN, H. C., 1936). These are mainly composed of temperate trees including *Acanthopanax*, *Acer*, *Alniphyllum*, *Alnus*, *Carpinus*, *Celtis*, *Fraxinus*, *Ilex*, *Illicium*, *Juglans*, *Kalopanax*, *Maackia*, *Magnolia*, *Mallotus*, *Meliosma*, *Photonia*, *Pistacia*, *Platycarya*, *Populus*, *Pterocarya*, *Quercus*, *Rhus*, *Tilia*, *Ulmus*, *Zelkova* and others; there are many endemic or relict plants whose Tertiary equivalents were widely distributed in the northern hemisphere. Conifers are common, such as *Cephalotaxus*, *Cryptomeria*, *Cunninghamia*, *Pseudolarix* and *Torreya*. The Harutori plants find many of their closely similar living equivalents in these forests, as shown in Table 7.

The Mixed Mesophytic Forest extends upstream into the watersheds of the Upper Yangtze Valley, with somewhat increasing broad-leafed evergreen trees. This area includes Szechuan, Kweichow, Hupeh and adjacent part of Hunan, at altitudes generally more than 1500 meters; the deciduous hardwood trees are usually mixed with the evergreen broad-leafed trees at the lower altitudes. The forests are

Table 7. Plants of the Mixed Mesophytic Forest of the Yangtze Valley of Central China and Harutori Equivalents

Harutori flora	Lower Yangtze	Upper Yangtze
Pinus sp.	**P. massoniana*	**P. massoniana*
Tsuga-pollen	——	*T. yunnanensis*
Metasequoia occidentalis	——	*M. glyptostroboides*
Carya ezoensis	*C. cathayensis*	*C. cathayensis*
Juglans-pollen	**J. cathayensis*	**J. cathayensis*
Platycarya hokkaidoana	*P. strobilacea*	*P. strobilacea*
Pterocarya-pollen	**P. paliurus*	**P. paliurus*
Alnus ezoensis	**A. trabeculosa*	**A. cremastogyne*
Betula-pollen	**B. luminifera*	**B. luminifera*
Carpinus kushiroensis	*C. cordata*	*C. cordata*
Corylus ezoana	——	*C. chinensis*
Castanea-pollen	*C. mollissima*	*C. mollissima*
Fagus-pollen	**F. longipetiolata*	**F. longipetiolata*
Quercus kushiroensis	*Q. myrsinaefolia*	*Q. myrsinaefolia*
Trema asiatica	**T. dielsiana*	——
Ulmus harutoriensis	*U. davidiana*	——
Zelkova kushiroensis	*Q. sinica*	*Z. sinica*
Broussonetia sp.	——	*B. papyrifera*
Cercidiphyllum eojaponicum	——	*C. japonicum* var.
Liquidambar miosinica	*L. formosana*	*L. formosana*
Cedrela kushiroensis	*C. sinensis*	*C. sinensis*
Glochidion japonicum	**G. fortunei*	**G. wilsonii*
Coriaria sp.	——	*C. sinica*
Ilex obovata	**I. henryi*	**I. henryi*
Aesculus sp.	**A. chinensis*	**A. wilsonii*
Actinidia harutoriensis	——	*A. chinensis*
Idesia kushiroensis	*I. polycarpa*	*I. polycarpa*
Alangium basiobliquum	*A. chinense*	*A. chinense*
Alangium basitruncatmu	*A. platanifolium*	*A. platanifolium*
Nyssa-pollen	——	*N. sinensis*
Chionanthus nipponicus	*C. retusa*	*C. retusa*
Viburnum ezoanum	——	**V. ichangense*

* Somewhat similar though not the nearest living equivalent species.

extensively altered, but several natural remnants preserved in the following mountains, as pointed out by WANG (1961, p. 108–119): Shui-hsa-pa* (1000–1100 meters at altitudes) in western Hupeh (CHU, K. L. & COOPER, 1950; CHANEY, 1948, 1952), Chenkou-Pingho area (1600–2400 meters) in eastern Szechuan (CHENG,

W. C., 1939); Omei-Shan and Opienn district (1300–2500 meters) in western Szechuan (CHENG, W. C. et al., 1938; HSU, Y. C., 1939; others); Fanching-shan (1700–1850 meters) in eastern Kweichow (TSOONG, P. C., 1941). The Mixed Mesophytic Forest of these regions is similar to that of the Lower Yangtze, but is even richer in composition, with species of *Acanthopanax*, *Acer*, *Betula*, *Carpinus*, *Castanea*, *Castanopsis*, *Celtis*, *Cinnamomum*, *Cornus*, *Evodia*, *Fagus*, *Fraxinus*, *Hydrangea*, *Ilex*, *Lonicera*, *Machilus*, *Magnolia*, *Michelia*, *Morus*, *Pasania*, *Populus*, *Prunus*, *Sorbus*, *Spiraea*, *Tilia*, *Ulmus* and *Viburnum*. Conifers are also common. As in the Lower Yangtze, there are a number of endemic and relict plants in such genera as *Cunninghamia*, *Ginkgo*, *Keteleeria*, *Taiwania*, *Metasequoia*, *Bretschneidera*, *Catalpa*, *Cedrela*, *Chionanthus*, *Cudrania*, *Davidia*, *Engelhardtia*, *Euptelea*, *Liquidambar*, *Nyssa*, *Pteroceltis*, *Sassafras*, *Spondias*, *Tetracentron* and *Zelkova*. The Harutori flora contains more species similar to living plants in this forest than in the forest of the Lower Yangtze, as shown in Table 7. Relationships from the microfossil record are added to the list.

Of 32 plants listed, 12 species are dominant or common members of the Harutori flora, with high-score leaf counts (more than 0.4 per cent). In addition, there are many other living equivalents of the Harutori species which inhabit the secondary forests in the Yangtze Valley and somewhat southward: they are *Aralia chinensis* (*A. ezoana*), *Cocculus trilobus* (*C. ezoensis*), *Hamamelis mollis* (*H. kushiroensis*), *Maesa japonica* (*M. nipponica*), *Mallotus philippensis* (*M. hokkaidoensis*), *Spiraea blumei* (*S. kushiroensis*), *Zanthoxylum planispinum* (*Z. oblongatum*) and *Zizyphus jujuba* (*Z. harutoriensis*). When these eight species are added to Table 7, the resemblance between the Harutori flora and the Mixed Mesophytic Forest of the Yangtze Valley is further emphasized. A number of evergreen broad-leafed trees are scattered in the Mixed Mesophytic Forest, especially in the Upper Yangtze. They are increasingly more evident toward lower elevations and toward southern regions, where the evergreen forest is growing luxuriantly. These trees include members of the Fagaceae, Lauraceae, Theaceae and Magnoliaceae. The Harutori flora includes only one such evergreen, *Quercus kushiroensis;* it is a minor constituent with the representation of only 0.16 per cent.

Northward from the Yangtze Valley, the deciduous broad-leafed forest designated as the Mixed Northern Hardwood Forest (WANG, op. cit., p. 72), is widely distributed with a transitional zone. It is composed mainly of *Acer*, *Betula*, *Fraxinus*, *Juglans*, *Maackia*, *Phellodendron*, *Quercus* (deciduous), *Ulmus* and *Pinus koraiensis*. Furthermore, though less important constituents in this forest, there are many genera of deciduous broad-leafed trees, especially to the south, which are also represented in the Mixed Mesophytic Forest. It is noteworthy that the Haru-

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* On the valley bottom and slopes of this region *Metasequoia* is a constituent of the natural forest, and is reproducing actively.

tori flora contains no deciduous oaks which are so common in the Northern Hardwood Forest. The Harutori plants includes 18 living equivalent trees in the southern part of this forest: they are *Actinidia chinensis*, *Aesculus wilsonii*, *Alnus japonica*, *Aralia chinensis*, *Carpinus cordata*, *Cercidiphyllum japonicum*, *Cocculus trilobus*, *Coriaria sinica*, *Corylus chinensis*, *Hamamelis mollis*, *Idesia polycarpa*, *Smilax china*, *Spiraea blumei*, *Ulmus davidiana*, *Viburnum tomentosum*, *Zanthoxylum planispinum*, *Zelkova serrata* and *Zizyphus jujuba*. However, of these 18 plants there are few trees restricted to this Northern Hardwood Forest; many are common is the Mixed Mesophytic Forest, and some of them range into southern China.

When we turn our attention southward, we find the Evergreen Broad-leafed Forest Formation widely distributed in southern China. This forest is divided into three major distinctive types: (1) evergreen sclerophyllous broad-leafed forest, (2) rain forest, and (3) littoral forest (WANG, op. cit., p. 129).

The evergreen sclerophyllus broad-leafed forest is typically developed in Hainan, Kwangtung, Fokien, Kwangsi and southern Hunan, excluding coastal areas of these regions. It extends northward into the southern Yangtze region, and also southward into montane regions of Yunnan, Vietnam, Burma and Thailand. This forest is composed mainly of cupliferous trees (*Castanopsis*, *Pasania* and *Quercus*) with accessory constituents of Theaceae (*Ternstroemia*, *Gordonia*), Magnoliaceae (*Michelia*, *Magnolia*, *Manglietia*, *Illicium*), Hamamelidaceae (*Eustigma*, *Distylium* and *Bucklandia*) and others. Fossil species similar to such characteristic evergreens are not contained in the Harutori flora, with a exception of *Quercus kushiroensis* (*Q. myrsinaefolia*). However, most of the Harutori broad-leafed evergreens trees find their most similar living species in this sclerophyllous forest, especially of Fukien and Kwangtung. The following list shows the resemblance between the Harutori flora and the sclerophyllous forest of these regions.

Harutori flora	Evergeen sclerophyllous broad-leafed forest of southern China
Podocarpus-pollen	**P. nagi*
Glyptostrobus europaeus	*G. pensilis*
Pinus sp.	*P. massoniana*; *kwangtungensis*
Smilax china	*S. china*
Platycarya hokkaidoana	*P. strobilacea*
°*Quercus kushiroensis*	*Q. myrsinaefolia*
Trema asiatica	**T. orientalis*
°*Ficus* sp.	*F. vasculosa*
Cocculus ezoana	*C. trilobus*
Liquidambar miosinica	*L. formosana*
Spiraea kushiroensis	**S. blumei*
Zanthoxylum oblongatum	*Z. planispinum*
Cedrela kushiroensis	*C. sinensis*

°*Glochidion japonicum*	**G. fortueni*
°*Mallotus hokkaidoensis*	*M. philippensis*
Coriaria sp.	*C. sinica*
°*Ilex obovata*	*I. kaneharai*
°*Zizyphus harutoriensis*	*Z. jujuba*
°*Gordonia japonica*	*G. axillaris*
Idesia kushiroensis	*I. polycarpa*
°*Melodinus japonicus*	*M. monogynus*

° Evergreen broad-leafed trees.
* Most similar species found here.

Most of these living plants are among the less important constituents in the evergreen sclerophyllous forest, while their analogous Harutori plants also shows small representation in the leaf count, excepting *Cocculus ezoensis*, *Idesia kushiroensis*, *Platycarya hokkaidoana* and *Glyptostrobus eruopaeus*. Of these four exceptions the former three plants appear to have lived under more temperate conditions, because their modern equivalents are rather common members in the Mixed Mesophytic Forest of the Yangtze. *Glyptostrobus pensilis* is a deciduous conifer which is endemic to the rain forest region of southern China; it has been reported in the evergreen sclerophyllous forest of higher elevation, for instance, on Taiyun-Shan (1400 meters elevation) of southern Fukien and on Taming-Shan (1000–1700 meters) in southern Kwangsi, but these records are subject to confirmation. The high representation (1.2 per cent) of *G. europaeus* suggests that its habitat was at lower altitudes near the sites of Harutori deposition.

The rain forest on the Chinese Mainland extends to about 26° North latitudes along the coast, and characterizes the lower elevations of Hainan, Fukien, Kwangtung, and partly of Kwangsi and Yunnan. It is composed almost entirely of evergreen broad-leafed trees, palms, tree ferns, epiphytes and lianes, with a rare admixture of deciduous trees and shrubs. There are not many similar living equivalents of the Harutori plants in this forest, but they include such characteristic ones such as *Canarium album* (*C. ezoanum*), *Cordia dichotoma* (*C. japonica*), *Glyptostrobus pensilis* (*G. europaeus*), *Melodinus monogynus* (*M. japonicus*) and *Musa uranoscopos* (*Musophyllum nipponicum*). *Musa*, along with tree ferns, bamboo and palms, make up the understory of this living forest, and is especially abundant near forest margins and along stream banks. *Glyptostrobus pensilis* grows dominantly in swampy lowlands, and along streams in hilly areas of southern Kwangtung, Kwangsi and Hainan Island. *Cordia dichotoma* is common in the coastal areas of Fukien, Kwangtung and Hainan. Although characteristic of the littoral forest, it also grows commonly in the rain forest of Yunnan. *Canarium album* inhabits the lowlands and nearshore areas in southern Yunnan and Hainan. Of these four genera, *Cordia*, *Musophyllum* and *Glyptostrobus* show high scores (more than one per cent each) in our Harutori leaf-count, and they appear to have occupied habitats similar to those of their living equivalents. In addition, *Cedrela sinensis* (*C. kushiroensis*), *Ficus* spp. (*Ficus* sp.), *Coriaria sinica* (*Coriaria* sp.) and *Gordonia axillaris* (*G. japnoica*) are members of the rain-forest which are closely similar to Harutori plants. *Nelumbo nucifera* (*N. nipponica*), a fresh-water herb, is a native of southern China, extending into Malaysia and India, though it is now widely cultivated in temperate regions. Common occurrence of these several members of southern lowland forests indicates that the Harutori forest represents at least in part the vegetation of hilly lowlands along the coast.

In summary, the Harutori forest is closely similar to the Mixed Mesophytic Forest along the Yangtze River at middle altitudes (700–1500 meters). A minority of the Harutori species have contain their living analogues in the evergreen sclerophyllous and rain forests of southern China at lower elevations along the coast. The Harutori flora includes no trees similar to those in the montane conifer forest above the mesophytic forest. Pollen of *Abies*, *Larix*, *Picea* and *Tsuga* constitute the only record of these genera.

Related Modern Forests of Taiwan

Twenty-four plants living in Taiwan are assigned to the East Asian Element in Table 6, and an additional eight show relationships though they are not the nearest equivalents. Because of its favorable climate, the vegetation of Taiwan is exceedingly rich in species, and resembles that of southern China. Most of the resemblances noted in Table 6 involve subtropical trees.

The subtropical forest of Taiwan is made up dominantly of broad-leafed evergreen trees, with many deciduous members at higher levels. It covers the slopes from 500 to 1500 meters in altitude at the north, and from 800 to 1800 meters at the south. Among the most abundant families are the Lauraceae, Fagaceae, Magnoliaceae and Theaceae. Though the Harutori flora shows only limited similarity to most of the predominant evergreens, it contains other similar living species, as shown in Table 8. However, most of the plants there listed, excluding *Actinidia*, *Alangium*, *Cocculus* and *Zelkova*, seem to have been minor members of the Harutori forest, as judged from their small representation in the leaf count. Accordingly, the relationship appears not to be close. Deciduous broad-leafed trees gradually increase in number above 800 meters elevation. Table 8 shows that the Harutori plants include more similar living species in this upper forest zone. Furthermore, several deciduous trees extend up into the temperate (mixed conifer-hardwood) forest; they are *Actinidia chinensis*, *Alnus japonica*, *Coriaria intermedia*, *Juglans cathayensis*, *Liquidambar formosana*, *Ulmus uematsui* and *Zelkova serrata*. This temperate mixed forest grows on mountain slopes from 1500 to 2100 meters elevation at the north, and from 1800 to 2400 meters at the south. Additionally, two Harutori equivalets, *Viburnum cordifolium* (*V. basiobliquum*) and *Spiraea morrisonicola* (*S. kushiroensis*), are found in this temperate forest.

Below the elevation of 500 meters, the tropical rain forest occupies the hilly

Table 8. Plants of the Subtropical Forest of Slopes of Taiwan and Harutori Equivalents

Harutori Flora	Subtropical Forest of Taiwan		
		Lower zone (500–800 m)	Upper zone (800–1,800 m)
Smilax hokkaidoensis	*S. china*	×	×
Juglans-pollen	**J. cathayensis*	×	×
Platycarya hokkaidoana	*P. strobilacea*	—	×
Alnus ezoensis	*A. japonica*	×	×
Carpinus kushiroensis	**C. rankanensis*	—	×
Fagus-pollen	*F. hayatae*	—	×
Quercus kushiroensis	**Q. longinux*	×	×
Ficus sp.	*F. vasculosa*	×	—
Trema asiatica	**T. orientalis*	×	—
Ulmus harutoriensis	*U. uematsui*	—	×
Zelkova kushiroensis	*Z. serrata*	×	×
Broussonetia sp.	*B. papyrifera*	×	—
Cocculus ezoensis	*C. trilobus*	×	—
Liquidambar miosinica	*L. formosana*	×	×
Zanthoxylum oblongatum	*Z. planispinum*	×	×
Coriaria sp.	**C. intermedia*	×	×
Ilex obovata	*I. kanehirai*	×	×
Mallotus hokkaidoensis	*M. philippensis*	×	—
Actinidia harutoriensis	*A. chinensis*	—	×
Idesia kushiroensis	*I. polycarpa*	—	×
Gordonia japonica	*G. axillaris*	×	×
Alangium basiobliquum	*A. chinense*	—	×
Alangium basitruncatum	*A. platanifolium*	—	×
Aralia ezoana	*A. bipinnata*	×	—
Maesa nipponica	*M. japonica*	×	×

* Similar species found here.

lowlands excepting coastal areas, but has been extensively destroyed and replaced by a secondary forest. Natural forests of this type are preserved at the northeast, and also in the Hengchung region to the south. Of the 25 species listed in Table 8, the following 10 trees also live in these forests on the hilly lowlands (200–500 meters): *Aralia bippinata*, *Broussonetia papyrifera*, *Cocculus trilobus*, *Coriaria intermedia*, *Ficus vasculosa*, *Gordonia axillaris*, *Liquidambar formosana*, *Maesa japonica*, *Zanthoxylum planispinum* and *Zelkova serrata*. In addition, the rain forest near the sea-coast contains several living species similar to the Harutori plants; they are *Chionanthus retusa* var., *Cordia dichotoma*, *Ficus vasulosa* and *Glochidion album*. To these lowland plant list, we can further add *Woodwardia orientalis* var. (*W. sasae*), which is a common fern in the undergrowth of the tropical rain forest.

Related Modern Forests of Japan

The temperate decidious hardwood forest of central and western Japan lies above the evergreen broad-leafed forest, which is growing on lower elevations (below 500 meters) along the Pacific. The upper half of this deciduous hardwood forest is designated as the *Fagus* zone, and the lower half is the Castanea zone by NAKANO (1942), HARA (1959) and others. The Castanea zone forest is closely similar in its composition to the Mixed Mesophytic Forest of China, and displays also a close relationship to the Harutori flora.

In the Castanea zone of central Honshu (600–700～1200–1300 meters at altitudes), *Castanea crenata*, *Fagus japonica* and *Quercus serrata* grow luxuriantly, accompanied by *Acer mayrii*, *Acer mono*, *Aesculus turbinata*, *Alnus hirsuta* var., *Carpinus laxiflora*, *Cercidiphyllum japonicum*, *Kalopanax septemlobus*, *Magnolia obovata*, *Pterocarya rhoifolia*, *Zelkova serrata* and others. The Harutori plants contain a number of living analogues in this zone, though chestnut, beech and deciduous oak are not represented in the macrofossil record. The natural vegetation on Mt. Ontake of central Honshu, as investigated by KOIDZUMI (1914), TAKAHASHI (1943) and lately by MAEDA (1958), shows well developed broad-leafed deciduous forests at altitudes of about 600 to 1800 meters; slope and valley forests at elevation of 600–1400 meters belong to the *Castanea* zone. The vegetation covering the wide Kwanto Plain around Tokyo and the adjacent hills is secondary forest belonging to the *Castanea* zone, though extensively cultivated. The Izu peninsula, southwest of Tokyo, is mostly covered by an evergreen broad-leafed forest, but the vegetation at higher elevation is the deciduous broad-leafed forest including *Fagus crenata*, associated with such conifers as *Abies firma*, *Torreya nucifera* and *Tsuga sieboldi*. The natural vegetation around Mt. Amagi (1405 meters) at elevations from 600 to 1000 meters is similar in composition to the *Castanea* zone, as investigated by HAYASHI (1952), though including several evergreen trees. The Harutori plants find many of their similar living species in these natural forests of the *Castanea* zone, as shown in Table 9.

When we turn our attention to the *Castanea* zone forest in western Japan, we also find living vegetation similar to the Harutori flora. In the Chugoku mountain range, deciduous hardwood trees such as *Acer*, *Aesculus*, *Betula*, *Capinus*, *Castanea*, *Cercidiphyllum*, *Platycarya*, *Pterocarya*, *Quercus* (deciduous), *Stewartia* and *Zelkova* make up the *Castanea* zone forest. The natural forest of this zone is well preserved on valley slopes and alluvial fans (500 to 900 meters elevation) in the Sandankyo Gorge and the Yawata Highland, southeastern Hiroshima Prefecture (HORIKAWA et al., 1959; TATEWAKI et al., 1956). We find many similar living species of the Harutori plants in this forest, as shown also in Table 9.

Of the Harutori plants listed in Table 9, ten species of *Actinidia*, *Cercidiphyllum*, *Cocculus*, *Corylus*, *Disanthus*, *Idesia*, *Platycarya*, *Ulmus*, *Viburnum* and *Zelkova*

Table 9. Plants of the Castanea Zone Forest of Central and Western Honshu and Harutori Equivalents

Harutori Flora	Slope forest Mt. Amagi (300-600 m)	Slope forest Mt. Ontake (600-1,200 m)	Sandankyo ravine forest, Hiroshima Pref. (500-900 m)
Pinus sp.	*P. densiflora*	——	*P. densiflora*
Smilax hokkaidoensis	*S. china*	*S. china*	*S. china*
Platycarya hokkaidoana	*P. strobilacea*	——	*P. strobilacea*
Carpinus kushiroensis	*C. cordata*	*C. cordata*	*C. cordata*
Betula-pollen	**B. grossa*	**B. grossa*	**B. grossa*
Corylus ezoana	*C. sieboldiana*	*C. sieboldiana*	*C. sieboldiana*
Quercus kushiroensis	*Q. myrsinaefolia*	——	——
Castanea-pollen	*C. crenata*	*C. crenata*	*C. crenata*
Zelkova kushiroensis	*Z. serrata*	*Z. serrata*	*Z. serrata*
Broussonetia sp.	*B. kazinoki*	——	——
Ficus sp.	**F. erecta*	——	——
Cercidiphyllum eojaponicum	*C. japonicum*	*C. japonicum*	*C. japonicum*
Cocculus ezoensis	*C. trilobus*	——	**C. thunbergi*
Disanthus nipponicus	——	*D. cercidifolius*	*D. cercidifolius*
Hamamelis kushiroensis	*H. japonica*	*H. japonica*	*H. japonica*
Zanthoxylum oblongatum	*Z. ailanthoides*	——	——
Mallotus hokkaidoensis	**M. japonicus*	——	——
Coriaria sp.	*C. japonica*	——	——
Acer oishii	——	*A. pycnanthum*	——
Aesculus sp.	*A. turbinata*	*A. turbinata*	*A. turbinata*
Actinidia harutoriensis	**A. polygama*	**A. polygama*	**A. polygama*
Idesia kushiroensis	*I. polycarpa*	——	——
Alangium basitruncatum	*A. platanifolium*	*A. platanifolium*	*A. platanifolium*
Aralia ezoana	**A. elata*	*A. elata*	*A. elata*
Maesa nipponica	*M. japonica*	——	——
Chionanthus nipponicus	——	*C. retusa*	——
Viburnum basiobliquum	*V. tomentosum*	*V. tomentosum*	*V. tomentosum*

* Somewhat similar though not the nearest equivalent species.

are common or abundant members in the Harutori forest, each with representation of more than 0.76 per cent in our leaf count. All of the living species listed, with the exception of *Chionanthus retusa*, *Disanthus cercidifolius* and *Platycarya strobilacea*, are widely distributed in the temperate deciduous forest of Japan; most of them extend into northern Honshu, and even into southwestern Hokkaido where there is a cool-temperate climate. The three exceptions above-noted have their principal occurrence southwestward from central Honshu; *D. cercidifolius* and *C. retusa* are living in central and western Honshu with disjunct distribution.

The *Castanea* zone forest ascends to somewhat higher altitudes southward; in Kyushu between 900 and 1200 meters, and on Kii peninsula and Shikoku at elevation of 800 to 1300 meters, forests with Harutori equivalents are also well developed, with evergreen broad-leafed trees at lower levels.

Below the deciduous hardwood forest, an evergreen broad-leafed forest is widely distributed along the sea-coast from central Honshu southward, with abundant species of evergreen oaks, *Machilus* and other lauraceous trees, *Ternstroemia*, and others. On the Pacific side of central Honshu, especially Kii, Izu and Boso peninsulas, in the Seto Inland Sea region, and on the island of Shikoku, these evergreen forests grow luxuriantly below an elevation of 500 meters. Most of them have been logged and are replaced by secondary forests, but remnants may be preserved around old shrines and temples. The Harutori flora includes Tertiary equivalents of the following evergreen species: *Ficus erecta* or *F. wightiana* (*Ficus* sp.), *Glochidion obovatum* (*G. japonicum*), *Maesa japonica* (*M. nipponica*), *Quercus myrsinaefolia* (*Q. kushiroensis*) and *Viburnum japonicum* (*V. ezoanum*). Deciduous trees with similar Harutori relationships are: *Actinida rufa* (*A. harutoriensis*), *Alangium platanifolium* (*A. basitruncatum*), *Alangum chinense* (*A. basiobliquum*), *Aralia elata* (*A. ezoana*), *Cocculus trilobus* (*C. ezoensis*), *Idesia polycarpa* (*I. kushiroensis*), *Mallotus japonicus* (*M. hokkaidoensis*), *Smilax china* (*S. hokkaidoensis*), *Trema cannabina* (*T. asiatica*) and *Zanthoxylum planispinum* (*Z. oblongatum*). Occurrence of *Pinus densiflora* (*Pinus* sp.) may also be noted. All of these trees except *Viburnum japonicum* and *Alangium chinense*, commonly occupy coastal and hilly regions along the Pacific, westward from Kwanto district; *Ficus wightiana* and *Glochidion obovatum* are restricted to the sea-coast. *Alngium chinense* is found only in the coastal forest on Osumi peninsula at the southern end of Kyushu, where cycads and tree ferns are native, with a number of other tropical or subtropical plants. *Viburnum japonicum* is found in the evergreen forests at the southwestern end of Honshu (western Yamaguchi Prefecture) and on Kyushu. The above-listed 16 plants include six trees, *Alangium* (two species), *Actinidia*, *Cocculus*, *Idesia* and *Viburnum*, which fossil species were dominant or fairly numerous are members of the Harutori forest. It shows that the Harutori forest has a marked relationship to the evergreen forest of lower elevation, though the forest contains a number of temperate deciduous hardwood trees. In addition, the Harutori dominant ferns find their close living analogues, *Woodwardia orientalis* and *Dennstaedtia scabra*, in the undergrowth of the evergreen forests along the Pacific coastal region of Japan.

From the discussion of distribution in East Asia of modern trees, shrubs and herbs which resemble the Harutori species, and which may be supposed to have occupied similar environments, it may be concluded that the Harutori forest appears to have grown on extensive hilly coastal plain and its bordering mountain slopes.

The North American Element

The trees assigned to the North American Element in Table 6 include only 9 dicotyledons, but it is noteworthy that the distinctively American species, in terms of their modern relationships, make up over 17 per cent of the fossil record. They include alders, sycamore and water elm with high frequency of fossil record, which fossil species cannot find their similar living plants in the modern forests of East Asia. In addition, there are 16 species which show suggestive relationsips to the Harutori plants. All of these living species except *Corylus* is not distributed in western North America, and they are confined to eastern North America, where the Mixed Mesophytic Forest is extensively developed.

The Mixed Mesophytic Forest of the eastern United States is coextensive with the unglaciated Appalachian Plateaus except at the north; it is typically developed in the Cumberland and Allegheny Mountains, and on their plateaus, as pointed out by BRAUN (1950). The natural forests in these regions are composed mainly of *Acer saccharum*, *Aesculus octandra*, *Fagus grandifolia*, *Liriodendron tulipifera*, *Quercus alba* and *Tsuga canadensis*. The following species are also locally abundant: *Acer rubrum*, *Betula lutea*, *Carya* spp, *Castanea dentata*, *Juglans nigra*, *Magnolia acuminata*, *Nyssa sylvatica* and *Prunus serotina*. A similar forest, though somewhat different in representation of dominant species, extends west and southwestward into the so-called Interior Low Plateau, which includes western Kentucky, western Tennessee and northern Mississippi. These forests designated as the Western Mesophytic Forest (BRAUN, 1950) contain many upland species similar to those of the Appalachian Plateaus, together with members of the swamp forests of the lower Green River and Wabash River basins. The Harutori plants find many of their living analogues in these Mesophytic forests, though Tertiary eqivalents of the white oak, beech and chestnut have been not recorded. Table 10 indicates relationships to the slope and valley forests of the Appalachian and Interior Low Plateaus. Most of these living plants are also widely distributed in the eastern United States, including eight common species of the Harutori forest, such as *Acer*, *Alnus* (two species), *Aralia*, *Carya*, *Cocculus*, *Corylus* and *Ulmus*. Two alder species, *A. serrulata* and *A. rugosa*, range from eastern Canada into the northeastern United States, and *A. serrulata* reaches northwest Florida. These alders usually grow near stream-banks and on swamp border. The large representation of the Harutori alders suggests that they had a similar habitat.

Below the deciduous hardwood forest, the forest on the coastal plain from southern Virginia to northern Florida, and extending into southeastern Texas, is designated as the Southeastern Evergreen Forest (BRAUN, 1950); it is chracterized by abundant evergreen broad-leafed trees and long-leaf pines. In addition, many deciduous hardwood trees of the Mesophytic forest descend to lower elevations,

Table 10. Plants of the Mesophytic Forest of Appalachian Slopes and Harutori Equivalents

Harutori plants	Similar Species
Pinus sp.	*P. echinata*
Smilax hokkaidoensis	*S. rotundifolia*
Carya ezoensis	*C. ovata*
Alnus hokkaidoensis	*A. rugosa*
Alnus kushiroensis	*A. serrulata*
Betula-pollen	*B. lutea*
Carpinus kushiroensis	*C. caroliniana*
Corylus ezoana	*C. americana*
Castanea-pollen	*C. dentata*
Cocculus ezoensis	*C. calorinus*
Ulmus harutoriensis	**U. fulva*
Hamamelis kushiroensis	*H. virginiana*
Liquidambar miosinica	*L. styraciflua*
Platanus aceroides	*P. occidentalis*
Spiraea kushiroensis	**S. corymbosa*
Acer arcticum	*A. spicatum*
Acer oishii	*A. rubrum*
Aesculus sp.	*A. octandra*
Aralia ezoana	*A. spinosa*
Nyssa-pollen	*N. sylvatica*
Viburnum basiobliquum	*V. dentatum*

* Somewhat similar though not the nearest equivalent species.

and mingle with the evergreens on hilly slopes and ravines. The Harutori plants includes a number of their living analogues in these forests of the Atlantic and Gulf Coastal Plains, and of their adjacent slopes, as shown in Table 11. Some of similar species listed are characteristic members of the swamp cypress forest and its borders, a forest well developed on the Mississippi bottomland and along the streams in the low flat Coastal Plain border. They include *Chionanthus virginicus*, *Gordonia lasianthus*, *Ilex decidua*, *Liquidambar styraciflua* and *Planera aquatica;* absent from the Harutori record are the remains of *Taxodium* and lobed oaks. *Glyptostrobus europaeus*, an abundant fossil species, must have held a similar position to the swamp cypress, judging from the occurrence of the living *G. pensilis* on the Canton Delta. Lobed oaks appear to have been rare or absent in most Tertiary floras of Asia, including those of Neogene age at which time they became abundant in North America. *Liquidambar*, *Gordonia* and *Zanthoxylum* extend southward into the subtropical forest of Florida, where two additional Harutori equivalents, *Ficus brevifolia* (*Ficus* sp.) and *Cordia sebestena* (*C. japonica*), grow near

Table 11. Plants of the Deciduous Hardwood Forest on Gulf and Atlantic Coastal Plains and the Harutori Equivalents

Harutori plants	Similar Species	1	2	3	4	5
Pinus sp.	*P. echinata*		×		×	
Smilax hokkaidoensis	*S. rotundifolia*	×	×	×		×
Carya ezoensis	*C. ovata*	×	×	×	×	×
Alnus ezoensis	*A. maritima*			×		
Alnus hokkaidoensis	*A. rugosa*		×	×	×	
Alnus kushiroensis	*A. serrulata*	×	×	×	×	×
Carpinus kushiroensis	*C. caroliniana*	×	×	×	×	×
Planera ezoana	*P. aquatica*	×		×	×	×
Ulmus harutoriensis	*U. americana*	×	×	×	×	
Cocculus ezoensis	*C. caroliniana*	×	×	×	×	×
Hamamelis kushiroensis	*H. virginiana*		×	×	×	
Liquidambar miosinica	*L. styraciflua*	×	×	×	×	×
Platanus aceroides	*P. occidentalis*	×	×	×	×	×
Zanthoxylum oblongatum	**Z. clava-Herculis*	×		×		×
Ilex obovata	**I. decidua*	×	×		×	×
Acer oishii	*A. rubrum*	×	×	×	×	×
Aesculus sp.	*A. octandra*		×			
Gordonia japonica	*G. lasianthus*	×		×		×
Aralia ezoana	*A. spinosa*	×	×	×	×	×
Nyssa-pollen	*N. sylvatica*	×	×	×	×	×
Chionanthus nipponicus	*C. virginicus*	×		×	×	
Cordia japonica	*C. sebestena*					×
Viburnum basiobliquum	*V. dentatum*	×		×	×	×

* The most similar species found here.
1. Gulf Coastal Plain
2. Gulf lower Slopes
3. Atlantic Coastal Plain
4. Atlantic lowers Slope
5. Bottomland forest

the sea-coast.

Comparison of the Harutori flora with the modern forests of eastern North America appears to indicate that it is more similar to the vegetation of the lowlands of the southern Atlantic and Gulf Coastal Plains than to that of the Appalachian Mountain slope.

GEOLOGIC SETTING

Following deposition of the Beppo formation consisting mainly of conglomerate, the plant-bearing Harutori formation was deposited with thick coal seams. The extensive distribution of these coal seams suggests that they accumulated in large, deep swamps, perhaps as a part of deltaic areas within the Harutori basin. Recent sedimentary studies (IIJIMA, 1964 a, b; OKAZAKI, 1966; others) indicate that the sites of Harutori deposition were in an inland basin having a probable southwestward connection with sea, as illustrated in Text-fig. 3. In the absence of marine fossils, the deposits seem to be largely of fresh-water origin. The Harutori formation consists mainly of siltstone and sandstone, and contains almost no conglomerates. Predominance of fine-grained rocks suggests that the immediate area was of low relief with low stream gradients. It was either a broad river valley or a flat piedmont bordering a hilly or mountainous region. In any case the physical environment was characterized by low relief and a lack of topographic diversity.

From the above geologic consideration, we could suppose that the Harutori depositional basin was surrounded by hills or low mountains at some distance. According to sedimentary-petrological studies of IIJIMA (1964 b), the Harutori sediments seem to have been derived from terrains to the north and east. This conclusion is supported by the fact that most of the cross-lamination in the Harutori formation shows directions of east to west (SATO et al., 1967). There is no evidence

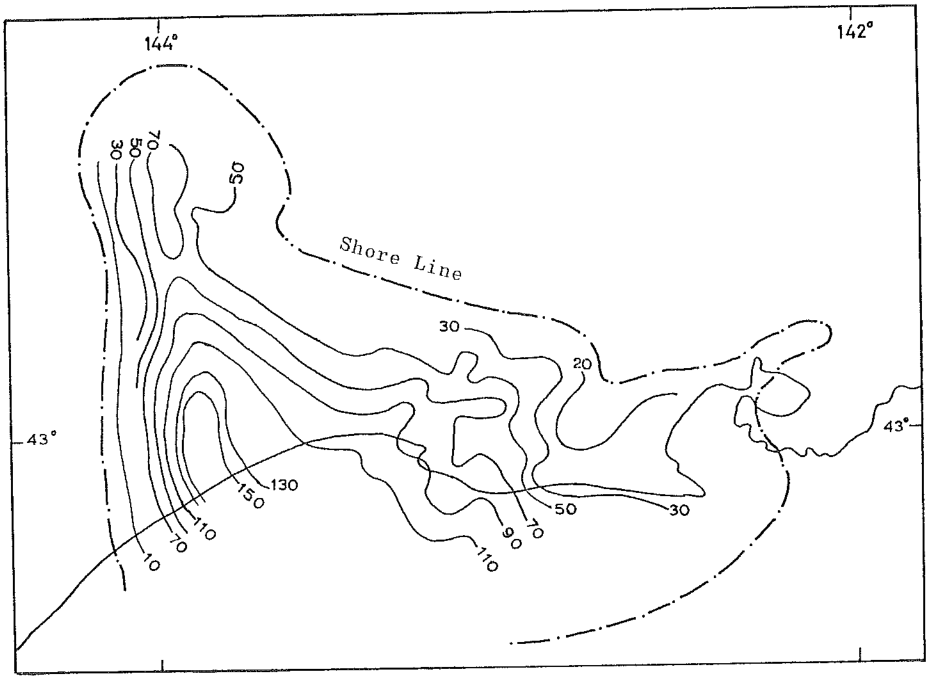

Fig. 3

Isopach Map of the Harutori Formation and probable Sites of Harutori Deposition (partly revised after OKAZAKI, 1966).
The thickness is shown in meters.

that the sediments were supplied from western and southern terrains, even though there may have been areas at high altitudes there. The Harutori flora seems to represent the forests bordering the depositional basin on its adjacent northern or eastern slopes of low relief. The Harutori coals originated from the plant debris of these forests.

THE HARUTORI PLANT COMMUNITIES

The areas and environments described in the preceding pages are occupied by modern forests which show marked resemblance to the Harutori flora; most similar is the Mixed Mesophytic Forest of the Yangtze Valley and southward, in central China; the Castanea zone forest of central and western Japan also has much in common; resemblance to the swamp forest of the Atlantic and Gulf Coastal Plains in the eastern United States involves also many similar species. No one of these forests contains all the trees and shrubs that lived together in southeastern Hokkaido during Paleogene time, because the Paleogene forests were more diverse than those now living in the northern hemisphere. However, from the preceding discussion of geologic setting of the Harutori flora, the numerical representation of its fossil plants, and the ecologic occurrence of their related plants in modern forests as reviewed above, it is now feasible to set up the plant communities at the Harutori basin, and their distribution about the basin of deposition.

Table 12 shows the Harutori species grouped according to the communities which they probably formed. Some of species contributed to more than one community, as do similar plants today. Such interrelations are well illustrated by plants assigned to swamp vegetation and lake-border woodlands, or to lake-border woodlands and the valley forest.

Aquatic Vegetation

Only two species belong to this community, and their similar modern plants are confined to areas of shallow water. *Equisetum arcticum*, representing mainly by abscissing stems, shows high frequency of occurrence and probably lived in sites along the shore where its colonies were rapidly buried. This is also suggested by occurrence of the remains of roots and nodules. On the other hand, *Nelumbo nipponica* shows low representation (seven specimens, 0.11 per cent). It seems not due to its rarity in the area, but rather to its generally fragile tissues which would not favour easy preservation. Good preservation of the Harutori lotus-leaves suggests that they quietly entered the sediments. It is supported by the fact that the plant-bearing rocks are composed of finely laminated siltstone and fine-grained sandstone.

Table 12. Plant Communities Represented in the Harutori Flora

	Aquatic Vegetation	Swamp Vegetation	Lakeshore Woodland	Valley forest	Slope forest
Nelumbo nipponicum	×				
Equisetum arcticum	×	×	×		
Glyptostrobus europaeus		×	×		
Planera ezoana		×	×		
Acer oishii		×	×	×	
Alnus hokkaidoensis		×	×	×	
Alnus kushiroensis		×	×	×	
Chionanthus nipponicus		×	×	×	
Metasequoia occidentalis			×	×	
Musophyllum nippponicum			×		
Osmunda sachalinensis			×	×	
Woodwardia sasae			×	×	
Alangium basiobliquum			×	×	
**Canarium ezoanum*			×		
Cordia japonica			×		
**Cupania japonica*			×		
**Ficus* sp.			×		
**Glochidion japonicum*			×		
**Mallotus hokkaidoensis*			×		
**Melodinus japonicus*			×		
Platanus aceroides			×	×	
Platanus guillelmae			×	×	
Ulmus harutoriensis			×	×	
**Viburnum ezoanum*			×		
Dennstaedtia nipponica				×	×
Lastrea kushiroensis				×	
Onoclea hebraidica				×	
Smilax hokkaidoensis				×	×
Actinidia harutoriensis				×	×
Aesculus sp.				×	×
Alangium basitruncatum				×	×
Alnus ezoensis				×	×
Aralia ezoana				×	×
Broussonetia sp.				×	×
Carya ezoensis				×	×
Carpinus kushiroensis				×	×
Cedrela kushiroensis				×	
Cercidiphyllum eojaponicum				×	×

Table 12.—(*Continued*)

	Aquatic Vegetation	Swamp Vegetation	Lakeshore Woodland	Valley Forest	Slope Forest
Cocculus ezoensis				×	×
Coriaria sp.				×	×
Corylus ezoana				×	×
Disanthus nipponicus				×	×
Hamamelis kushiroensis				×	×
Idesia kushiroensis				×	×
Liquidambar miosinica				×	
Platycarya hokkaidoana				×	×
**Quercus kushiroensis*				×	×
Trema asiatica				×	×
Viburnum basiobliquum				×	×
Zanthoxylum oblongatum				×	×
Zelkova kushiroensis				×	×
Zizyphus harutoriensis				×	×
Acer arcticum					×
**Gordonia japonica*				×	
**Ilex obovata*				×	
**Maesa nipponica*				×	
Pinus sp.					×
Spiraea kushiroensis					×

* Evergreen trees or shrubs.

Swamp Vegetation

Though large, deep swamps in Harutori time are suggested by thick coal seams of a great lateral extent, as discussed in preceding pages (Geologic Setting), there are only seven species which can be included in this community. To judge from the habitats occupied by similar living plants, they seem to have lived behind the beach zone, chiefly in stagnant ponds and on poorly drained flats with permanently high water tables. These seven swamp members show high representation in the fossil record (Table 4) with a total of about 19 per cent, as might be expected if they lived near the sites of deposition. However, none of them need have been confined to these sites, for all of them could have been members of adjacent communities, chiefly lake-border woodlands and stream-margin sites in the valley forest. The wide development of thick coal seams in the Harutori formation seems to have had its source of supply not only from these swamp plants but from accumulations of drifted debris, from plants living on lake shores and the adjacent lower flood plains.

Lake-border and Riparian Woodlands

This community represented by 23 plants, seems to have formed dense woodlands and thickets along the lake shore, and probably also on the banks of streams along the delta. The sites were characterized by continuously high water tables, and must have been regularly subject to periods of flooding. Of these 23 plants, 16 are deciduous, and all of them shows high representation in the fossil record. The seven remaining plants, *Viburnum ezoanum*, *Melodinus japonicus*, *Mallotus hokkaidoensis*, *Glochidion japonicum*, *Canarium ezoanum*, *Ficus* sp. and *Cupania japonica*, are broad-leafed evergreens, and excepting of *V. ezoanum* they are represented by small scores (less than 10 specimens and 0.16 per cent each). Their low representation is interpreted to indicate that these evergreen plants were not numerous in the Harutori forest; most of them appear to have been small trees or vines, which would further reduce their representation in the fossil record. The abundance of *Metasequoia occidentalis* (45.23 per cent) and *Alnus hokkaidoensis* (9.22 per cent) indicates that dense stands of *Metasequoia* and alders lined the lake and stream margins, along with *Planera ezoana* (2.79 per cent), *Platanus aceroides* (1.88 per cent) and *Cordia japonica* (1.76 per cent). The evergreen shrub, *Viburnum ezoanum*, appears to have been an abundant member of the understory, judging from its high representation in the fossil record (1.78 per ent), and the habitat occupied by similar living plants. Thus, the lake-border forest were composed mainly of deciduous hardwood trees and *Metasequoia*, with several evergreen trees and shrubs and some herbaceous plants such as *Osmunda*, *Woodwardia* and *Musophyllum* making up the understory. The trees and shrubs of this community were not confined to the lake-shore, excepting swamp plants, but also occupied stream banks in the region. Most of them mingled with members of valley-slope forests which occupied the broad, well-watered flood-plain and valley flats flanking the stream.

Deciduous Hardwood Forest

Most of the Harutori species are included in this category which consists of two communities: (a) valley forest, and (b) slope forest. These forests are largely composed of deciduous hardwoods and ferns, and are mixed with a few evergreen broad-leafed trees (mostly shrubs) in the valley forest.

(a) Valley Forest: This forest of 42 species was made up of very mesic to near-hydric plants which were confined mainly to well-drained, moist, valley sites such as stream banks, damp swales, and moist flats. Some of more abundant species of the flora, such as *Alnus hokkaidoensis*, *Cercidiphyllum eojaponicum*, *Corylus ezoana*, *Zelkova kushiroensis*, *Platanus aceroides* and *Cocculus ezoensis*, probably found their most luxuriant growth in this community. On moister tracts such as valley bottom and stream border, *Acer oishii*, *Alnus* spp. (3 species), *Ulmus harutoriensis*, *Platanus* spp. (2 species), and *Disanthus nipponicus* were probably common, with *Woodwardia*, *Osmunda* and other ferns (except *Dennstaedtia*). From the stream border sites most of other members listed in Table 12 (column Valley forest) may have reached the well-drained, valley flats, hilly areas, and lower slopes. Especially, *Dennstaedtia*, *Zelkova*, *Platycarya*, *Quercus* and *Trema* may have been common on well-drained, somewhat sunnier flats. Several shrubs and vines may have formed the understory of the above trees, such as *Actinidia*, *Alnagium* (2 species), *Cocculus*, *Cordia*, *Corylus*, *Disanthus*, *Smilax* and *Viburnum*. Considering the habitat of the similar living species, *Liquidambar miosinica* might be expected to have been common; but its representation by only a fruit shows that sweet gum was not a common member.

(b) Slope Forest: This forest of 27 species has most of its members in the valley forest; it is composed of all the deciduous hardwoods, excluding *Quercus kushiroensis*, and especially *Cercidiphyllum*, *Alangium*, *Zelkova*, *Disanthus*, *Idesia* and *Zanthoxylum* are common members in this forest. No conifers, exluding pine, seem assignable to this community. Judging from the pollen record, some conifers such as *Podocarpus* and *Sciadopitys* may have been mixed with the hardwoods. Though they may be recorded as megafossils because of evergreen nature, it is evident that they appear not to have been common in this community. In short, this community may represent the forest of lower slopes with no high altitudes nearly. Pine represented only by a single winged seed suggests an adjacent slope. *Spiraea kushiroensis* and *Acer arcticum* probably lived only on slopes, judging from their low representation in the fossil record, and the habitat of their living similar species.

No megafossil records of montane or higher slope forest are found in the Harutori flora. Trees considered as montane members are known only by pollen such as *Abies*, *Larix*, *Picea* and *Tsuga*, which might be transported for some distance by wind into depositional sites. Accordingly, we may suppose that the Harutori flora represents mainly forests which lived from the lake borders to lower slopes. It may be concluded that the topography around the depositional sites was a broad, well-developed flood-plain and its adjacent hilly slopes around a lake, and that montane areas were at some distance from the sites of Harutori deposition. This topographic consideration is also consistent with the fact that the plant-bearing Harutori formation is largely composed of siltstone and sandstone, and contains no coarser sediments.

CLIMATE

To reconstruct the climate under which the Harutori forest lived, we may draw inferences from the conditions under which similar forests are living today on hilly lowlands and lower slopes. However, there is no modern forest of any one region covering the Harutori flora, which is more diverse in components and composition. This is due to the fact that the distribution and composition of present-day forests have been altered through differentiation and segregation during the long history of the Tetiary. The Paleogene Harutori flora is more diverse in components than those of Neogene floras, which the author has frequently investigated in Japan. As discussed in preceding pages, the Harutori forest is composed mainly of members of the Mixed Mesophytic Forest of East Asia, which has a counterpart in eastern North America. It contains also members of the Evergreen Sclero-

Table 13. Climatic Data for Several Localities in Japan, China and the Eastern United States

	Altitude	Latitude	Mean Ann. precip.	Mean Ann. temp.	Warmth Index	Coldness Index
Central China						
Chung-King, Szechuan	217	29.3	1,054	18.7	163.1	0
Hankow, Hupeh	36	30.3	1,160	16.9	144.1	−1.1
Chang-sha, Hunan	90	28.1	1,282	17.7	153.5	−1.0
Shanghai, Kiangsu	3	31.2	1,134	15.7	130.2	−1.8
Southern China						
Minhow, Fukien	20	25.6	1,401	19.5	174.5	0
Hongkong	33	22.2	2,163	22.3	207.3	0
Nan-ning, Kwangsi	80	22.4	1,350	22.2	205.9	0
Kweilin, Hunan	200	25.1	—	17.6*	162.4*	0
Kiungchow, Hainan	3	20.0	1,434	24.4	232.4	0
Central Honshu, Japan						
Katsuura, Chiba	12	35.1	2,036	15.0	119.9	0
Mishima, Shizuoka	20	35.1	1,832	14.6	116.1	−3.1
Iida, Nagano	482	35.3	1,553	11.9	94.8	−12.6
Western Honshu, Japan						
Wakayama, Wakayama	14	34.1	1,386	15.3	124.5	−0.5
Hiroshima, Hiroshima	29	34.2	1,527	14.6	117.5	−2.1
Shimonoseki, Yamaguchi	46	33.6	1,631	15.2	122.5	0
The United States						
Knoxville, Tenn.	290	35.5	1,156	15.2	122.4	−0.3
Atlanta, Virg.	297	33.4	1,249	16.8	141.4	0
Cape Hatteras, N. Carol.	1	35.1	1,391	17.3	147.2	0
Charleston, S. Carol.	3	32.5	1,168	19.2	170.8	0

Latitude to nearest degrees; altitude in meters; precipitotion in mm.; temperature in degrees Centigrade.

* As monthly temperatures were recorded only 1936 excepting December, these two data show only approximate value.

phyllous and Rain forests of East Asia. Table 13 gives climatic records at localities situated near the regions where these modern forests occur.

Precipitation and Temperature

The Harutori forest is closely similar to the Mixed Mesophytic Forest along the Yangtze Valley of central China, especially to that of the Upper Yangtze Valley; here the mean annual precipitation is 1054 mm.; the mean annual temperature is 18.7°C at Chung-king (Szechuan); mean monthly temperatures during the summer season (June to August) are 25° to 29.4°C, and 7.3° to 10.2°C during the winter. The Harutori sites under consideration may have been a hilly coastal plain with more precipitation than in an interior basin such as Chung-king. There is an increase in precipitation toward the Middle Yangtze region, with a reduction in mean annual temperature. For instance, mean annual precipitation is 1160 mm. at Hankow (Hupeh) and 1280 mm. at Chang-sha (Hunan).

The Harutori plants find many of their modern analogues in the evergreen sclerophyllous broad-leafed forest, which is widely distributed south of the Yangtze River in southeastern Asia. This is interpreted to indicate that the climate was warmer in winter than at the above-described locations in the Yangtze Valley. At Minhow (Fukien) and Kwei-lin (North Kwangsi) the mean monthly temperatures in winter are from 10° to 13.5°C and 6.1° to 10°C respectively, though summer temperatures are much the same. Mean annual precipitation is 1300 to 1400 mm. in these regions. Warmer winter climate is also supported by occurrence of rain forest members such as *Cordia*, *Musa* (*Musophyllum*), *Melodinus*, *Canarium*, *Glyptostrobus* and others; climtic records at Hong-kong, Nang-ning (South Kwangsi) and Kiung-chou (Hainan) show a subtropical aspect with warmer winter, as shown in Table 13. The Paleogene occurrence of the Rain forest genera seems mainly due to summer-wet and winter-warm condition during Harutori time, and partly to poorly-drained condition around the sites of Harutori deposition. However, as members of these evergreen sclerophyllous broad-leafed and rain forests are not predominant, the Harutori climate was probably more similar to that in the northern part of the evergreen forest region, where there is no reliable climatic record unfortunately.

The Harutori forest shows a close similarity to the *Castanea* zone forest with associated evergreen broad-leafed trees, which is distributed on lower slopes along the Pacific in central Honshu, and also to those along the Seto Inland Sea of western Honshu. Records from several localities of these regions (for instance, Katsuura, Mishima, Hiroshima and Shimonoseki) are shown in Table 13; mean annual precipitation is 1500 to 1800 mm. due to sea influence, and is somewhat higher than that of the Yangtze Valley region. On the other hand, mean annual temperature is somewhat less, from 14° to 16°C: mean monthly temperatures during summer are

20° to 26.7°C, and are 3.7° to 9°C during winter. In the Pacific coastal region of Japan, where their mixed evergreen forest is now growing, mean annual precipitation is still higher than that of the above-noted areas, with about 2500 mm., while mean annual temperature is somewhat higher. It may be suggested that under a climatic condition showing more than a certain annual mean temperature the higher precipitation is useful for growing of evergreen trees which analogues are found in the Harutori flora.

Table 13 includes climatic records from several localities in the southeastern Unites States, where a living deciduous forest with associated evergreens is closely similar to the Harutori flora. These records are not greatly different from those of the Yangtze Valley region and areas somewhat southward. Summer-wet and winter-warm climate is characteristic of the Gulf Coast and Atlantic Coast regions (for instance, at Atlanta, Charleston, and Cape Hatteras), where there are found several evergreen and other subtropical plants similar to the Harutori species. The climate on Appalachian slopes (for instance, at Knoxville) where the living forest is typically mesophytic, seems generally similar to that of central and western Honshu, though there is somewhat less precipitation.

The preceding analysis of the modern distribution and habitat of the Harutori equivalents in eastern Asia and North America, and the quantitative significance of the fossil record, suggest that the Harutori forest occupied mainly lowlands and adjacent slopes. Our discussion of the climatic setting of these environments on the basis of their similar forests makes possible the following conclusions; the climate had a mean annual temperature from 16° to 20°C., with winter mean monthly temperature showing 8° to 12°C; winter temperature seems usually not to have fallen below freezing; mean annual precipitation was from 1200 to 1500 mm., with summer the rainiest season.

Warmth and Coldness Indices

Various attempts of inference of past climate indicated by a fossil flora have been done by many workers; especially KIRA (1954) has discussed the general problem for the Late Cenozoic flora, and AXELROD (1966) has lately provided a method for determining the altitudes of Tertiary floras, in connection with past climatic condition. The author considers additionally the Harutori climate on the basis of an means of climatic analysis provided by KIRA (1948, 1949). Though climatic condition consists of various factors, we may consider mainly two factors of temperature and precipitation when forest composition in broad region shall be discussed. Especially, temperature is most important for distribution of forest components in East Asia, with a few exception in drier region. Gradual northward replacement from evergreen broad-leafed to boreal conifer forests in East Asia is seen similarly as in the altitudinal zonation of their forests from sea level to higher altitudes. General arrangement as to altitudinal and latitudinal forest distribution seems due largely to climatic difference, especially to temperature.

Regarding relationships between temperature and plant growth, it has been pointed out that " Total Effective Temperature " is intimately related to distribution of trees and crops. The total effective temperature is usually calculated from mean daily temperature. Simplifying this calculation, Kira (1948, 1949) proposed the " Warmth and Coldness Indices " by using monthly mean temperature. Warmth Index (WI) is shown by the total degrees of difference between mean monthly temperature of more than 5°C and 5°C in a year. On the one hand, Coldness Index (CI) is represented by the total degrees of difference between 5°C and mean monthly temperature of less than 5°C. For instance, at Tokyo they are calculated as follows:

Month	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Mean Monthly Tem. (C)	3.2	3.9	7.0	12.8	17.2	20.8	25.1	26.4	22.6	16.4	11.0	5.7
Warm. Index			2.0	+7.8	+12.2	+15.8	+20.1	+21.4	+17.6	+11.4	+6.1	0.7=115
Cold. Index	1.8	+1.1										=−2.9

The distribution of Warmth Index in East Asia is illustrated as shown in Text-fig. 4*, based on climatic records at various loclities. The two indices play a important role for limited distribution of modern forests; WI represents a positive action for plant life, while CI represents a negative one. Kira (1949) well explained the modern forest zones of Japan as to their distribution and components, using these two indices.

As shown in Fig. 5, the Yangtze Valley region shows 140° to 160° of WI and 0° to —1.1° of CI. On the one hand, the evergreen sclerophyllous broad-leafed and rain forests in southern China require generally 180° to 230° of WI, and zero of CI. Most of the Harutori analogues in these forests sometimes extend northward, where WI is about 170°. These Harutori sclerophyllous members seem to have been able to live under the condition of CI zero. However, members of the rain forest such as *Musa*, *Melodinus*, *Canarium*, *Cordia* and *Glyptostrobus*, are generally confined to the regions of more than WI 180°. The fact that the warmth indices required by the Harutori analogues are discontinuous, may apt to show the fossil record brought together from the communities lived at different altitudes. But, as discussed in preceding analysis of plant community, the Harutori forest represents from lowlands to adjacent lower slopes. Thus, the rain forest members appears to have lived under the condition of higher precipitation and CI zero (winter-warm), although WI was less than 180°.

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* Kira (1949) illustrated only on Japan, but other regions are added in this figure by the author.

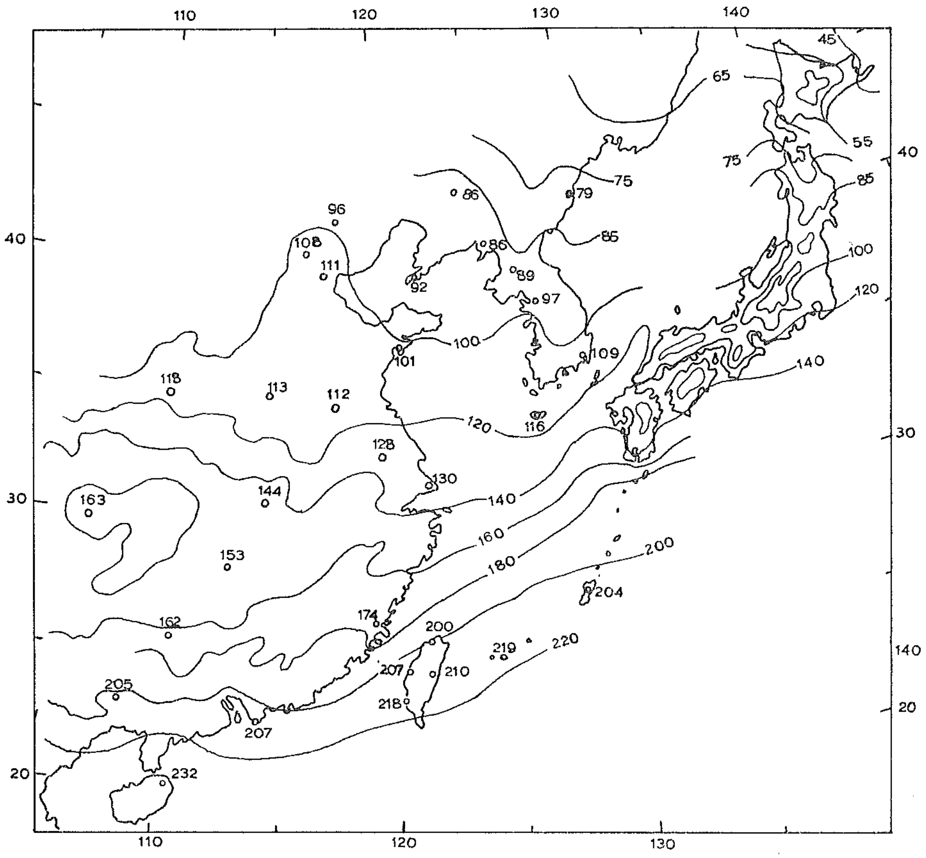

Fig. 4
The Distribution of Warmth Index in East Asia.

The Castanea zone forest along the Pacific in central and western Honshu of Japan is growing under 110° to 120° of WI, while from —1° to —5° of CI. These indices are also similar to those of Appalachian slopes (at Knoxville) in the eastern United States. These forests do not include nearly so many of the evergreen broad-leafed trees which are similar to the Harutori species. In the Gulf Coastal and Atlantic Coastal Plains where the modern forests are most closely similar to the Harutori, WI is from 140° to 170°, and CI is zero. From all of the above consideration, the Harutori climate is concluded to have shown 140° to 160° of WI and zero of CI, having a higher precipitation. This inference is consistent with the conclusion of preceding paragraph.

IV. OTHER OLIGOCENE FLORAS FROM THE KUSHIRO COAL FIELD

From upper members of the Urahoro group a number of well-preserved plant fossils have been frequently found in coal-bearing sediments of the Tenneru, Yubetsu, and Shakubetsu formation. Collections from them are too poor in number of specimens to make clear their paleoecology, but they seem sufficient to compare with the Harutori flora for stratigraphic relationships and floral changes. Accordingly, these three floras will be described as to their composition, and thereafter the floral changes during the whole of Oligocene time in southeastern Hokkaido will be briefly discussed.

1. THE TENNERU FLORA

Plant fossils have occasionally been found in the Tenneru formation, but they are mostly ill-preserved. This is partly due to the fact that this formation is largely composed of coarse sediments such as conglomerate and sandstone. About 15 years ago, the author found many plant fossils on the upper course of the Tokomuro River in the western Kushiro field (Text-fig. 5). Here along the river the Tenneru formation is typically exposed with about 300 meters thickness, and it contains two or three thin coal seams in the middle part. A number of fossil leaves were collected from the dark-gray siltstone immediately above these coal seams. Since the plant-bearing rocks are somewhat sandy, the fossil leaves are not always well-preserved.

There are 22 species represented in about a hundred specimens collected as follows:

Euqisetaceae
    Equisetum arcticum HEER
Osmudaceae
    Osmunda sachalinensis KRYSHTOFOVICH

Polypodiaceae
    Lastrea kushiroensis new species

Taxodiaceae
    Glyptostrobus europaeus (BRONGNIART) HEER
    Metasequoia occidentalis (NEWBERRY) CHANEY

Betulaceae
    Alnus ezoensis new species

Ulmaceae
    Planera ezoana OISHI and HUZIOKA
    Trema asiatica (Borsuk) new combination

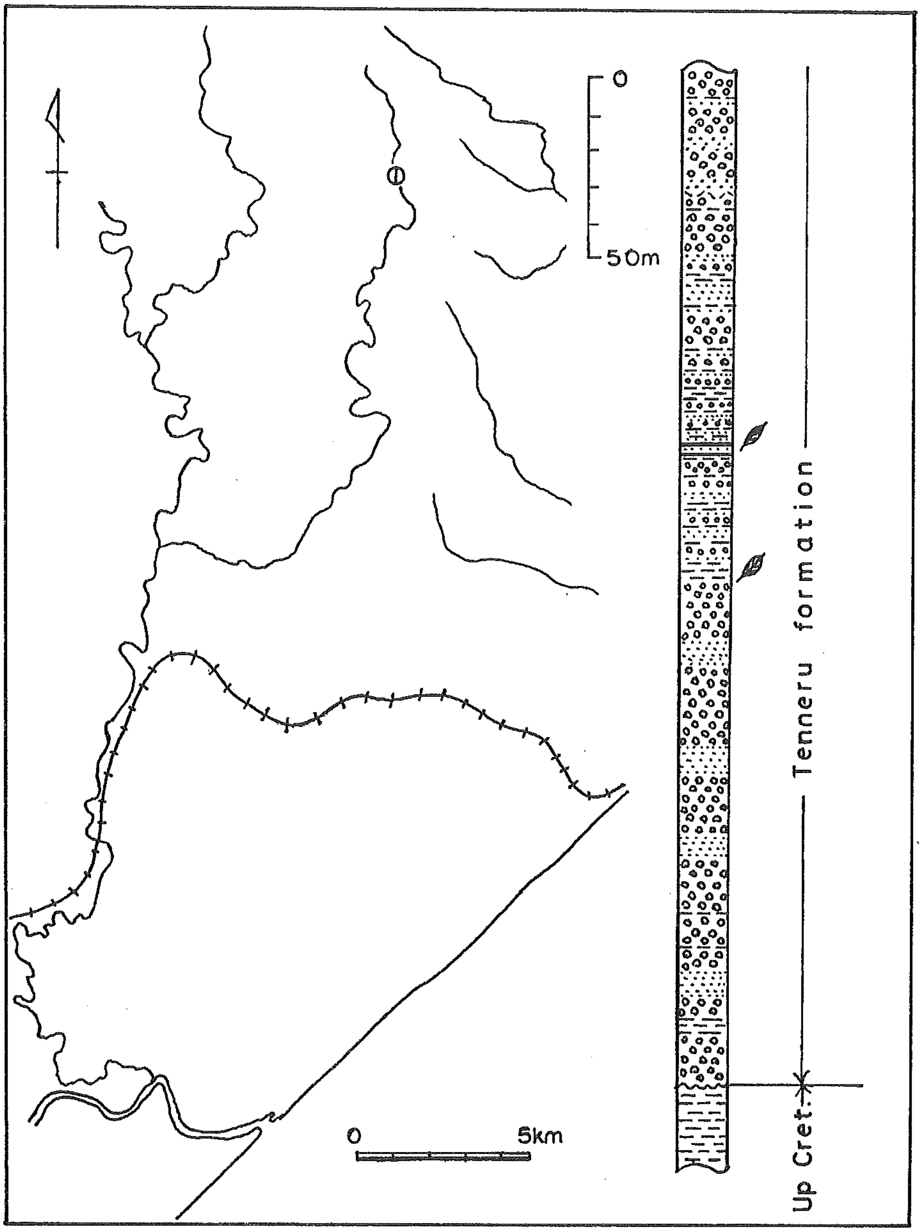

Fig. 5
The Localities of the Tenneru Plants and their Stratigraphic Position.

- *Ulmus harutoriensis* OISHI and HUZIOKA
- *Zelkova kushiroensis* OISHI and HUZIOKA

Cercidiphyllaceae
- *Cercidiphyllum eojaponicum* ENDO

Platanaceae
- *Platanus aceroides* GOEPPERT
- *Platanus guillelmae* GOEPPERT

Aceraceae
- *Acer arcticum* HEER

Sapidaceae
- *Cupania japonica* new species

Actinidiaceae
- *Actinidia harutoriensis* new species

Flacourtiaceae
- *Idesia kushiroensis* new species

Alangiaceae
- *Alangium basiobliquum* (OISHI and HUZIOKA) TANAI
- *Alangium basitruncatum* (OISHI and HUZIOKA) new combination

Araliaceae
- *Aralia ezoana* new species

Myrsinaceae
- *Maesa nipponica* new species

Boraginaceae
- *Cordia japonica* new species

These plants are distributed in 16 families and 20 genera; there are two pteridophytes, one *Equisetum* and two conifers, and the remainder are dicotyledons. Of these *Lasterea kushiroensis*, *Metasequoia occidentalis*, *Platanus aceroides* and *Alangium basitruncatum* are most abundant, and these four comprises nearly half of all specimens collected. Most of the remainder are represented by less than five specimens.

All of the Tenneru plants listed above are included also in the Harutori flora. Among the 19 dominant species of the Harutori flora showing more than one percent representation, two-thirds are also represented in the Tenneru flora. It is, however, noteworthy that the Tenneru flora contains no *Woodwardia* and no *Dennstaedtia*, though some ferns such as *Lastrea* and *Osmunda* are common.

2. THE YUBETSU FLORA

The Yubetsu formation is one of the coal-bearing sediments containing well-

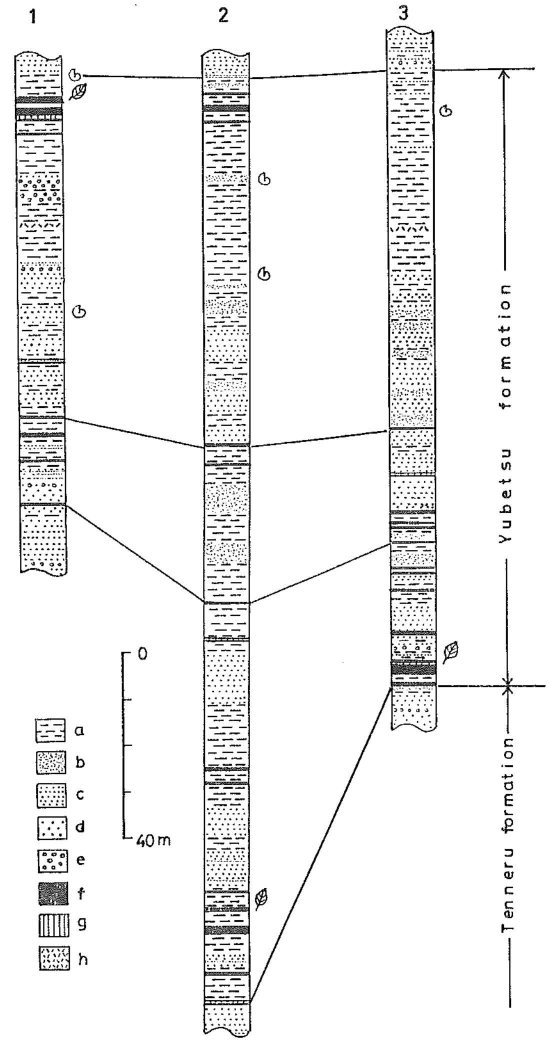

Fig. 6

Stratigraphic Relationships among the Localities of the Yubetsu Plants.

1 : Shakubetsu mine 2 : Yubetsu mine 3 : Ponki mine
a : Silitstone b : Fine Sandstone 3 : Medium Sandstone
d : Coarse Sandstone e : Conglomerate f : Coal
g : Coaly shale h : Tuff

preserved plant fossils in the Kushiro field. It consists mainly of thin alternation of sandstone and siltstone; plant fossils are frequently accumulated in the banded siltstone or very fine-grained sandstone. At the uppermost and lower part of this formation several thick coal seams are intercalated; they are mined at the Yubetsu and the Ponki mines in the east, and at the Shakubetsu mine in the west of this field. The author has collected a number of plant fossils from the banded siltstone of the roof strata of the coal seams near or in these mines. Fossil localities are as follows:

1) Nakanosawa, near the Yubetsu coal mine, Yubetsu, Akan-machi.
2) Ponki coal mine, Shoro, Shiranuka-machi.
3) Shakubetsu coal mine, Shakubetsu, Onbetsu-mura.

The coal seams mined at the Yubetsu are generally correlated with those of the Ponki mine; these seams are intercalated in the lower part of this formation. On the other hand, the coal seams worked at the Shakubetsu mine are interbedded in the uppermost shale member. Thus, the plant-bearing rocks at these three localities are at somewhat different horizons; their stratigraphic relationships are shown in Text-fig. 6. However, including together these plants from three localities, they are, as a whole, called here as " the Yubetsu flora ". Among these three localities, the plants from the Yubetsu mine are most abundant, and they are, in general, well-preserved with carbonized materials.

The Yubetsu flora, as now known, is distributed in 20 families, 26 genera and 30 species, of which 17 have been described as new. There are one *Equisetum*, three pteridophytes, two conifers, one monocotyledon, and the remainder dicotyledons. The largest family is the Betulaceae with three genera and five species; next is the Ulmaceae with three genera and three species. The remaining familes are represented by one species, except the Osmundaceae, the Taxodiaceae and the Juglandaceae with two species. To these plants we can add two species based on fruit-like fossils, which modern relationships are unknown. Following are the plants from three localities:

Systematic List of the Yubetsu Flora

	1	2	3
Equisetaceae			
Equisetum arcticum HEER	×	×	×
Osmundaceae			
Osmunda lignitum (GIEBEL) STUR	×		×
Osmunda sachalinensis KRYSHTOFOVICH	×	×	×
Polypodiaceae			
Onoclea hebraidica (FORBES) GARD. and ETTING.	×		

(*Continued*)	1	2	3
Taxodiaceae			
Glyptostrobus europaeus (Brong.) Heer	×	×	
Metasequoia occidentalis (Newb.) Chaney	×	×	×
Musaceae			
Musophyllum nipponicum new species	×		
Myricaceae			
Comptonia kushiroensis new species	×		
Juglandaceae			
Carya ezoensis new species	×	×	
Platycarya hokkaidoensis new species	×		
Betulaceae			
Alnus ezoensis new species	×	×	×
Alnus hokkaidoensis new species	×	×	
Alnus kushiroensis new species		×	
Carpinus kushiroensis new species	×	×	×
Corylus ezoana new species	×	×	×
Fagaceae			
Quercus kushiroensis new species	×		×
Ulmaceae			
Planera ezoana Oishi and Huzioka	×		
Ulmus harutoriensis Oishi and Huzioka	×		
Zelkova kushiroensis Oishi and Huzioka	×	×	×
Cercidiphyllaceae			
Cercidiphyllum eojaponicum Endo	×	×	×
Menispermaceae			
Cocculus ezoensis new species	×		
Hamamelidaceae			
Liquidambar miosinica Hu and Chaney	×		
Platanaceae			
Platanus aceroides Goeppert	×		×
Rutaceae			
Zanthoxylum oblongatum new species	×		
Aceraceae			
Acer kushiroanum new species	×		
Acer oishii new species	×		×
Sapindaceae			
Cupania japonica new species	×		
Flacourtiaceae			
Idesia kushiroensis new species	×		×

(*Continued*)	1	2	3
Alangiaceae			
Alangium basiobliquum (OISHI & HUZIOKA) TANAI	×	×	
Araliaceae			
Aralia ezoana new species	×		
Insertae Sedis			
Carpites japonicus (ENDO) new Comb.		×	
Nordenskioldia borealis HEER	×		

Localities: 1. Nakanosawa, near the Yubetsu coal mine. 2. Ponki coal mine, Shoro. 3. Shakubetsu coal mine, Shakubetsu.

Of these 31 species listed, *Osmunda sachalinensis*, *Metasequoia occidentalis*, *Platycarya hokkaidoensis*, *Alnus ezoensis*, *Carpinus kushiroensis*, *Corylus ezona*, *Cercidiphyllum eojaponicum* and *Zelkova kushiroensis* are abundant in number of specimens, and all of these eight species, excluding *Carpinus*, are found at all three localities. These eight species make up about 60 per cent of the total specimens (about 150) collected. Following them, *Quercus kushiroensis*, *Osmunda lignitum*, *Equisetum arcticum*, *Carya ezoensis*, *Plantanus aceroides* and *Alangium basiobliquum* are rather common. The remaining species are represented by less than three specimens each.

With the exception of *Osmunda lignitum*, *Comptonia kushiroensis* and *Nordenskioldia borealis*, all of the Yubetsu plants are also represented in the Harutori flora. *O. lignitum* is found at the Yubetsu and Shakubetsu mines, and is closely similar to the modern evergreen fern, *O. banksiaefolia* (PRESL.) KUHN, which is distributed from southern Japan to tropical Southeast Asia. *O. lignitum* described from the Eocene and the Oligocene of Europe, has also been reported from the Late Eocene Takashima flora of Kyushu. *Comptonia* leaves, though of different species, are generally common in the Neogene of Japan, but they are also rarely found in the Oligocene of Honshu. Compared with the Harutori, the Yubetsu flora does not show any marked difference in composition; it consists mainly of the Taxodiaceae, the Juglandaceae, the Betulaceae, the Ulmaceae and the Cercidiphyllaceae, and seems to indicate a somewhat more temperate aspect. It is, however, noteworthy that several subtropical plants such as *Osmunda lignitum*, *Musophyllum*, *Cupania*, and an evergreen oak (*Quercus kushiroensis*) are included, though not common. These Paleotropical-Tertiary elements in the Yubetsu flora are less numerous both in species and specimens.

3. THE SHAKUBETSU FLORA

The Shakubetsu formation contains about 30 coal seams showing various thickness and considerable splitting. From siltstone of the roof strata of these seams or

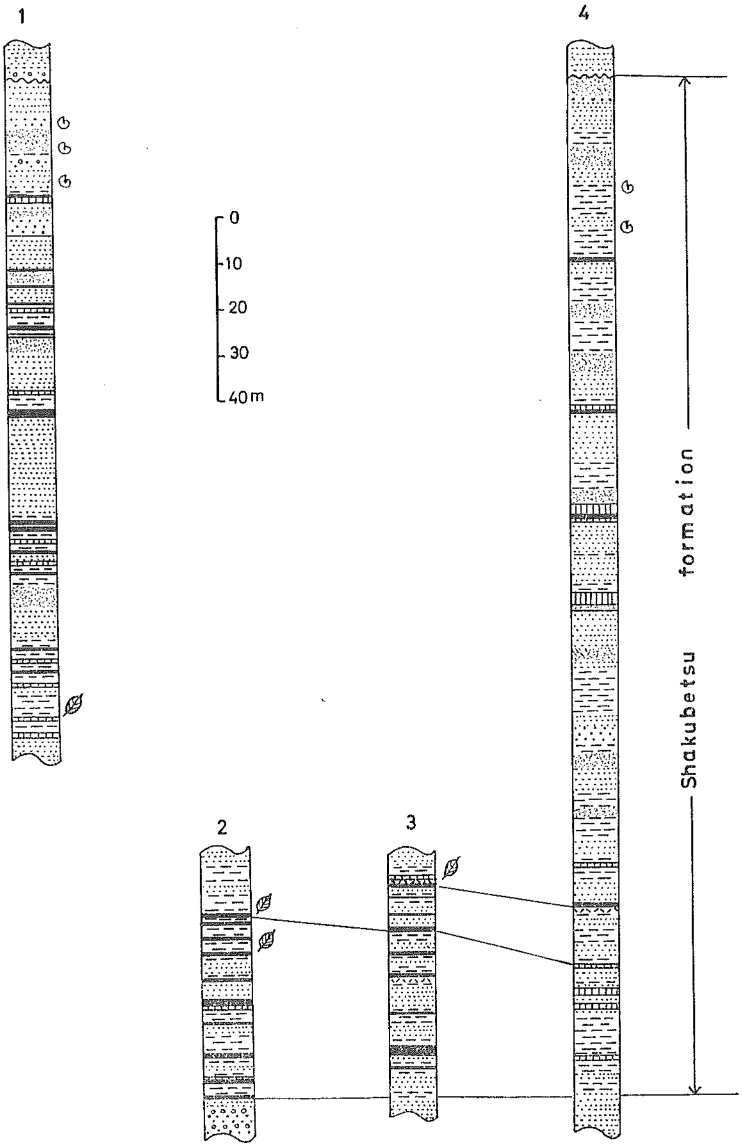

Fig. 7
Stratigraphic Relationships among the Localities of the Shakubetsu Plants.
1 : Kami-onbetsu mine 2 : Shinshiranuka mine 3 : Chinomizawa
4 : Along the Shitakara River, near Yubetsu mine

from marlstone interbedded in this formation, plant fossils are frequently found throughout the Kushiro field. Generally the rocks of the Shakubetsu formation are less hard and compact than those of the underlying formation, and their plant fossils are too fragile to be readily collected. The author collected many plant fossils at various localities of this field, largely at the following:

1) Cliff along the Shitakara river, near the Yubetsu coal mine, Akan-machi.
2) Chinomi-zawa, east of the Shoro coal mine, Shoro, Shiranuka-machi.
3) Shin-Shiranuka coal mine (abandoned at present), Shiranuka-machi.
4) Kami-onbestu coal mine, Kami-onbetsu-mura.

The plant-bearing rocks at these four localities are at somewhat different horizons as shown in Text-figure 7, but all the material collected may be assigned to the Shakubetsu flora.

The Shakubetsu flora is distributed in 16 families, 20 genera and 24 species, of which 12 are hereafter described as new. There are one *Equisetum*, one pteridophyte, one conifer, and the remainder dicotyledons. To these plants we can add two species based on reproductive organs, whose relationships with modern plants is at present unknown. The larger families are the Betulaceae with three genera and four species, and the Ulmaceae with three genera and three species. The remaining families are represented by single genera and no more than two species each. Following are the plants as now known from the four localities:

Systematic List of the Shakubetsu Flora

	1	2	3	4
Equisetaceae				
Equisetum arcticum Heer	×	×	×	×
Osmundaceae				
Osmunda sachalinensis Kryshtofovich	×	×	×	×
Taxodiaceae				
Metasequoia occidentalis (Newb.) Chaney	×	×	×	×
Juglandaceae				
Carya ezoensis new species	×	×	×	×
Betulaceae				
Alnus ezoensis new species	×		×	×
Alnus hokkaidoensis new species	×	×		×
Carpinus kushiroensis new species	×	×	×	×
Corylus ezoana new species	×		×	×
Fagaceae				
Quercus kushiroensis new species	×	×		
Ulmaceae				
Planera ezoana Oishi and Huzioka	×	×	×	×
Ulmus harutoriensis Oishi and Huzioka	×	×		×
Zelkova kushiroensis Oishi and Huzioka	×	×	×	×

(Continued)	1	1	3	4
Cercidiphyllaceae				
Cercidiphyllum eojaponicum ENDO	×	×	×	×
Platanaceae				
Platanus aceroides GOEPPERT	×	×	×	×
Platanus guillelmae GOEPPERT			×	×
Rosaceae				
Spiraea kushiroensis new species		×		
Aceraceae				
Acer arcticum HEER			×	
Acer oishii new species	×			
Sapindaceae				
Cupania japonica new species	×			
Actinidicaceae				
Actinidia harutoriensis new species	×	×	×	
Alangiaceae				
Alangium basiobliquum (OISHI & HUZ.)	×		×	×
Alangium basitruncatum (OISHI & HUZ.) n. comb.	×	×		
Araliaceae				
Aralia ezoana new species	×			
Caprifoliaceae				
Viburnum ezoanum new species	×			
Insertae Sedis				
Antholites cruciatus new species	×			
Carpites japonicus (ENDO) new comb.	×			

1. Shitakara River cliff, Yubetsu.
2. Chinomi-zawa, Shoro.
3. Shin-Shiranuka mine.
4. Kami-Onbetsu mine.

Of these 26 species, *Osmunda sachalinensis*, *Metasequoia occidentalis*, *Alnus ezoensis*, *Carpinus kushiroensis*, *Zelkova kushiroensis*, *Planera ezoana* and *Cercidiphyllum eojaponicum* are abundant in number of specimens, and these seven species make up about 70 per cent of the total specimens (about 150) collected. Following them, *Carya ezoensis*, *Platanus aceroides* and *Equisetum arcticum* are also common. These 10 species, excluding the alders, are found at all of our localities. The remaining species are represented by less than five specimens each.

Of the Shakubetsu plants listed above, all are represented also in the Harutori flora, excluding *Antholites cruciatus*. As in the case of the Yubetsu flora, the Shakubetsu flora consists mainly of temperate plants such as the Juglandaceae, the Betulaceae, the Ulmaceae, the Cercidiphyllaceae and the Aceraceae; it includes fewer subtropical or warm-temperate species, *Cupania japonica*, *Quercus kushi-*

roensis and *Viburnum ezoana*. As far as known at present, the Shakubetsu flora is more temperate in aspect than the Yubetsu flora. Thus it may be suggested that the forests which lived from Harutori to Shakubetsu time seem to have become gradually more temperate.

V. GEOLOGIC AGE

It is apparent that the basis for age evaluation of these fossil flora includes an analysis of the geologic evidence, relations, and climatic implications. The Harutori flora along with the other three minor floras under consideration, is situated near the northeastern extreme of North Japan. As described in an early chapter, these Paleogene floras are quite different in composition and components from the modern forests living there or elsewhere in Japan. This is, of course, due to floral changes during the long history since the Early Tertiary. A number of extensive investigations have told us that Tertiary forests of the northern hemisphere generally shifted southward and differentiated into more limited distribution, corresponding with climatic deterioration from Eocene to Pliocene time. It is one of the current trends in Tertiary paleobotany to analyse the latitudinal and altitudinal distribution of successive flora units. The geologic age of a fossil flora cannot be properly evaluated unless we consider its latitudinal and altitudinal situation during the past.

The Urahoro group comprising these four floras has been discussed in terms of age evaluation by various authors, mainly on the basis of invertebrate fossils which occur in its marine intercalations, and in overlying marine formations. The author has previously discussed the geologic age and correlation (TANAI, 1952, 1957), based on a floral list tentatively determined. Now that the composition and paleoecology of the Harutori flora have been fully considered, further consideration will be given to the evidence which is the basis for age evaluation.

1. PREVIOUS ASSIGNMENTS

Paleontologic evidence that suggests the age of the Urahoro group is provided both by fossil animals and plants included, and also by fossil animals found in the overlying Onbetsu group. Most previous age assignments have been based largely on the fossil molluscs and foraminifera, especially those from the Onbetsu group. This has been due to the fact that their overlying group is wholly of marine origin, with abundant marine fossils throughout. By contrast, the Urahoro group is mostly of terrestrial and shallow water origin, and contains fewer marine intercalations. Furthermore, most of this previous consideration has been limited to the Ishikari coal fied, where terrestrial and marine sediments are more completely developed, and with greater thickness. It seems unnecessary to give here a complete review of previous discussions, but some of the current opinions are here presented.

Paleogene molluscan faunas of Hokkaido have been investigated by a number of workers, and have been comprehensively described by NAGAO (1933), TAKEDA (1953), OYAMA et al. (1960), and MIZUNO (1964). The earlier age assignments were based mainly on the fact that the Onbetsu fauna, along with the Poronai fauna of the Ishikari field, is most closely similar to that of the Lower Blakely formation of Washington in the western United States, which is considered as of Late Oligocene age. Accordingly, the Urahoro group overlain unconformably by the Onbetsu group, has been assigned an age older than Late Oligocene, i.c. Early Oligocene or Late Eocene.

Lately MIZUNO (1964) has summarized the Paleogene molluscan faunas of North Japan, considering the stratigraphic conclusions of many workers; he differentiated the following four faunas: the Lower Ishikarian, the Middle Ishikarian, the Upper Ishikarian, and the Poronaian faunas in the asecnding order. According to his brief discussion, the first is of Eocene age, having some warmer species similar to those of the Gulf Coast Eocene of North America; while the latter three, showing temperate aspect, are of Oligocene age. The Urahoro group contains marine sediments in its upper-middle part (the Shitakara formation), and to some extent in its lower part (the Tenneru formation). These marine molluscan faunas are assigned to the Upper Ishikarian. The molluscan fauna from the Onbetsu group is assigned to the Poronaian, as already pointed out by various workers. Thus from the standpoint of molluscs, the Urahoro group is considered to be probably of Early to Middle Oligocene age.

Paleogene foraminiferal faunas of Hokkaido have been extensively investigated. ASANO (1958, 1962) set up the following zones in the Poronai group: *Plectfrondicularia packardi* zone, *Bulmina ezoensis* zone, *Cornuspiroides oinomikadoi* zone and *Nonion sorachiense—Ammobaculites akabiraensis* zone in descending order. The *Bulmina* and *Plectofrondicularia* zones are also developed in the Onbetsu group in the Kushiro field. Some of these four zones are found in marine sediments of the Ishikari and Urahoro group: for instance, the *Nonion—Ammobaculites* zone is found in the Middle of the Ishikari group (the Wakanabe formation); the *Cornuspiroides* zone is found in marine intercalations of the Urahoro group (the Shitakara formation). These occurrences are the main basis for ASANO's conclusion that the marine Poronai group changed laterally into the Ishikari group which is made up largely of terrestrial and brackish sediments, and is equivalent to the upper half of the Ishikari as suggested by YABE (1951). However, his theoretical conclusion is quite inconsistent with the stratigraphic relations between these two groups, which have been established in detail by many workers. Furthermore, it has been never accepted by most coal geologists of Hokkaido, though there were a few who agree. It should be added that ASANO's foraminiferal zones have been not accepted by some other micropaleontologists (UCHIO, 1961; UJIIE et al., 1960), who have also investigated the Paleogene of Hokkaido.

Regarding his age evaluations based on foraminifera, ASANO first assigned an Oligocene date (1952, 1954); later he indicated that the Poronai, the Onbetsu, the Urahoro, and the Upper Ishikari group are of Late Eocene age (Priabonian), and the Middle and Lower Ishikari groups are Middle Eocene (Lutetian) in age (1962). However, UJIIE et al. (1960) have pointed out that the Poronai benthic foraminiferal fauna is closely similar to that of the Narizian (Late Eocene) in California, but it contains also several species ranging up to Oligocene or even to Middle Miocene. The marine Paleogene of Hokkaido contains no world-wide planktonic foraminifera, excepting *Globorotaloides suteri* (Late Eocene to Middle Oligocene) and *Globigerina* cf. *linaperta* (Eocene) occurring in the Poronai group (UJIIE et al., 1960). These two plantonic foraminifera largely afforded the basis for ASANO's age evaluation.

The above-noted dating by fossil animals has been supported partly by the fact that the fossil flora from the Upper Ishikari group (the Ikushunbetsu formation*) was once referred to the Upper Eocene by ENDO (ENDO, 1931; YABE and ENDO, 1939). ENDO's age evaluation was based on the fact that the Ikushunbetsu flora is closely similar to the so-called " Eocene " floras of Arctic region (HEER, 1868–1883) and the Kenai flora of Alaska (HOLLICK, 1936). It is true that most of the temperate plants of the Ikushunbetsu and Harutori floras find close specific relationships in the Tertiary of northern regions. But this is also the case when we turn to the Early and Middle Miocene floras of Japan (TANAI, 1961). Tertiary floras in Arctic regions described by HEER range in age from Paleocene to Miocene, even involving the Cretaceous. This was long ago pointed out by OISHI and HUZIOKA (1943), and has recently been discussed in detail by CHANEY (1967). Recent studies by WOLFE (WOLFE, 1966, 1969; HOPKINS, WOLFE et al., 1966) stated that the Tertiary floras of Alaska range in age from Late Cretaceous to Miocene, and that the Kenai flora is dated as the Lower Miocene; it may be noted that this latter dating is not fully supported by the evidence presented. In any case, ENDO's age evaluation has now lost its basis for floral comparison, and must be re-investigated.

2. STRATIGRAPHIC EVIDENCE

The Onbetsu group, unconformably overlying the Urahoro, is properly correlated with the Poronai group of the Ishikari field by its monotonous, argillaceous lithology. This correlation is supported by the similarity of their molluscan and foraminiferal faunas as already described, although there is an objection. The Harutori formation is correlated to the Upper Ishikari, especially to the Ikushun-

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* The Ikushunbetsu flora has been called the " *Woodwardia* sand-stone flora ", due to predominant occurrence of *Woodwardia*, and is correlated with the Harutori flora. The author will describe this flora in detail in his next paper.

betsu formation, by the fact that both are coal-bearing, and contain closely similar floras. The floral similarity from these two formations has been pointed out by many authors, and is clearly evident in Table 15. In the Kushiro coal ffeld the Urahoro group directly overlies the Upper Cretaceous, lacking the equivalents of the Lower and Middle Ishikari groups. The similar stratigraphic relation is observed in the Kabato coal filed, west of the Ishikari field, as already discussed by the author (TANAI, 1956; TANAI and IIJIMA, 1958): the Kabato coal-bearing formation, the equivalent of Ikushunbetsu, rests on Mesozoic sediments. To the north of the Ishikari field lies the Rumoe coal field, where the equivalent sediments from the Middle Ishikari to the Poronai groups overlie the Upper Cretaceous; in the Uryu group, the basal part (the Shiraki formation) contains marine molluscan fauna similar to the Middle Ishikarian, and the middle part (the Daikoku formation) yields abundant *Woodwardia*.

Table 14. Stratigraphic Correlation of the Paleogene in Hokkaido

Area / Stage	RUMOE COAL FIELD	ISHIKARI COAL FIELD		KUSHIRO COAL FIELD
		Sorachi	Yubari	
Poronaian	Tappu gr.	Poronai gr.	Poronai gr.	Onbetsu gr.
Upper Ishikarian	Réuke f. Takasago f. Daikoku f.	Ashibetsu f. Hiragishi f. Ikushunbetsu f.	Ikushunbetsu f.	Shakubetsu f. Shitakara f. Yubetsu f. Tenneru f. Harutori f. Beppo f.
Middle Ishikarian	Tachibetsu f. Uryū f. Shiraki f.	Akabira f. Bibai f. Wakanabe f.		
Lower Ishikarian		Yubari f. Horokabetsu f. Noborikawa f.	Yubari f. Horokabetsu f. Noborikawa f.	
Late Cretaceous	Hakobuchi and Ezo groups			Nemuro gr.

gr : group f : formation

Table 14 shows the stratigraphic correlation of the Paleogene sediments in Hokkaido, which has been accepted by various authors. Considering the sedimentary history of the Paleogene in Hokkaido, the depositional basins seem to have changed with enlargment four times. The first Paleogene depositional sites situated only in the Ishikari district during the Lower Ishikarian stage, seem to have extended northward into the Rumoe-Uryu district at the Middle Ishikarian stage, and then to have further extended into eastern Hokkaido at the Upper Ishikarian. The sediments during these three stages are represented largely by fluvio-lacustrine lithology, partly by marine intercalations. Finally, these sites were covered by marine invasion represented by the Poronaian. This sedimentary history of the Paleogene has been well discussed by IIJIMA (1964) on the basis of lithology and sedimentary-petrological studies; his maps is here reproduced, as shown in

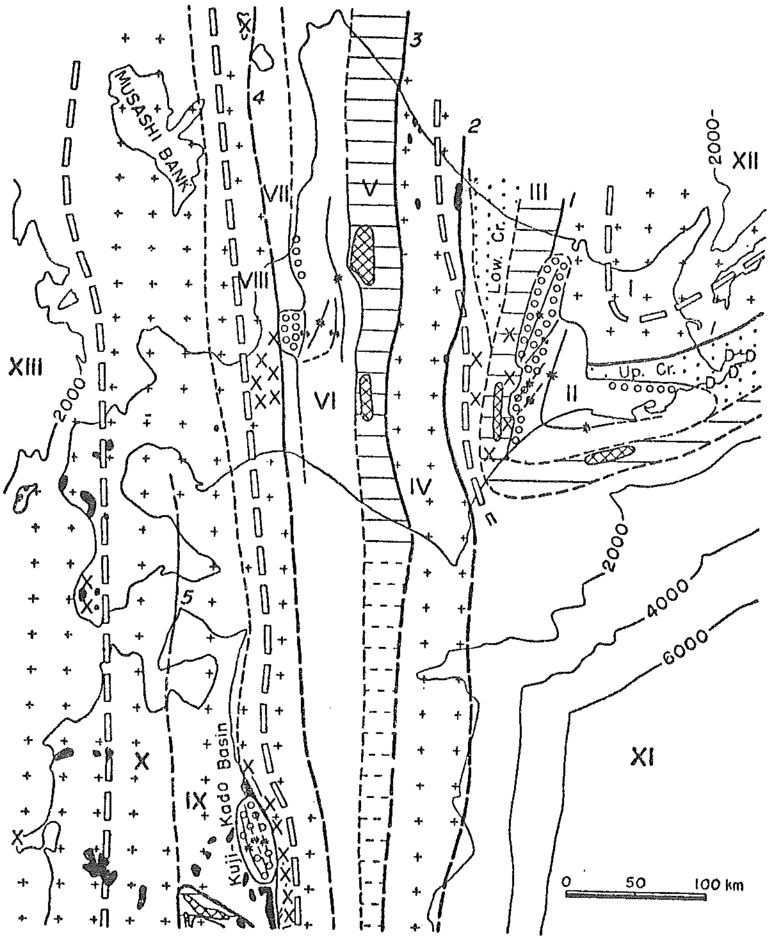

Fig. 8

Paleogene Paleogeographic Map of Hokkaido and its Environs. (After Iijima, 1964)

I. Circum-Okhotsk granitic belt. II. East Hokkaido Upper Cretaceo-Paleogene depression. III. Circum-Okhotsk ultrabasic intrusion belt. IV. Hidaka-Kitami tectonic belt. V. Kamuikotan tectonic belt. VI. Central Hokkaido-West Sakhalin Cretaceo-Paleogene depression. VII. Kabato Massif. VIII. Sanriku-Betsukaridake volcanic belt. IX. Outer Northeast Honshu belt. X. Inner Northeast Honshu belt. XI. Japan and Kamchatka-Kuril trenches and Pacific Ocean basin. XII. Okhotsk deep-sea basin. XIII. Deep-hollow of the Japan Sea.

1. Circum-Okhotsk Median Line. 2. Okoppe-Shirataki-Biro tectonic line. 3. Hokkaido Median Line. 4. Betsukaridake tectonic line. 5. Hakodate-Morioka tectonic line.

Cross: granitic terrain, Bar: ultrabasic and metamorphic terrain, Mesh: serpentinite terrain, Dotted: Cretaceous deposits, Circle: Paleogene conglomeratic facies, Solid: Pre-Tertiary granites, X: Cretaceous to Paleogene volcanic terrain.

Text-figure 8. The Urahoro group resulted from the third stage of Paleogene deposition.

3. PALEOBOTANICAL EVIDENCE

No Paleogene floras comparable to the Harutori have been fully described or well-dated in East Asia, though there have been many reports with preliminary lists in which the taxonomic evidence and illustrations were not presented. The Paleogene floras of the Urahoro group are closely similar to the Ikushunbetsu flora of the Ishikari coal ffeld (ENDO, 1968; TANAI, unpublished), to the Fushun floras of Manchuria (ENDO, 1943), and also the the Lower Dué flora of South Saghalien (BORSUK, 1956). Table 15 show these comparison. Actually, the Harutori flora is most closely similar to the Ikushunbetsu and Fushun floras, which are situated at nearly the same latitude. Fossil plants of Saghalien have been investigated by many authors (KRYSHTOFOVICH, 1936; YABE and ENDO, 1939); they seem to represent floras of several ages, from Paleogene to Miocene. Recently BORSUK (1956) revised these floras with critical taxonomic descriptions. The Lower Dué flora, situated about 800 km. north of Kushiro, is similar to the Harutori flora, but contains fewer of the warmer plants.

It is difficult to reach any final conclusion regarding the age relationships of a flora from a table showing the number of species in common. The author must present other evidence for age evaluation by the following methods: the first is climatic implication of the Harutori and other three minor floras; the second is the comparison with the floras which were well dated in other continents, especially at similar latitudes in western North America.

CLIMATIC IMPLICATIONS

The Harutori flora consists mostly of the Arcto-Tertiary temperate plants, but it also contains many warm-temperate or subtropical plants belonging to the Paleotropical-Tertiary Geoflora. As shown in Table 15, these warmer plants gradually decreased from the Harutori upward to the Shakubetsu flora in the Urahoro group. This illustrates the nature of climatic change following the Harutori stage—from a warm-temperate to a temperate forest. The fact that the Harutori flora represents a temperate to warm-temperate rather than a subtropical forest suggests its probable Oligocene age; most Oligocene floras at middle latitudes in the northern hemisphere were temperate to warm-temperate in aspect. On the other hand, most Eocene floras at these latitudes and corresponding low altitudes represent subtropical to tropical forests, as frequently discussed by many authors (CHANEY, 1947; DORF, 1964; others).

In the Ishikari coal field, the Bibai formation (the Middle Ishikari group) underlying the Ikushunbetsu formation contains a number of palms, lauraceous

Table 15. Plant Fossils from the Urahoro Group, and their Occurrence from Several Paleogene Floras in East Asia.

	Ht	Tn	Yb	Sb	Ik	Fu	Du
Equisetum arcticum	…………	…………	…………	…………	×		
Osmunda lignitum			…………			×	
Osmunda sachalinensis	…………	…………	…………	…………	×		×
Dennstaedtia nipponica	…………				×		
Lastrea kushiroensis	…………	…………					
Onoclea hebraidica	…………				×		
Woodwardia sasae	…………				○		
Pinus sp.	…………						
Glyptostrobus europaeus	…………	…………	…………		×	×	×
Metasequoia occidentalis	…………	…………	…………	…………	×	×	×
Smilax hokkaidoensis	…………				×	○	
Musophyllum nipponicum	…………		…………		×		
Comptonia kushiroensis			…………			○	○
Carya ezoensis	…………		…………	…………	×		×
Platycarya hokkaidoana	…………		…………		×		
Alnus ezoensis	…………	…………	…………	…………	×		
Alnus hokkaidoensis	…………		…………	…………	×	○	○
Alnus kushiroensis	…………		…………				
Carpinus kushiroensis	…………		…………	…………	×	○	
Corylus ezoana	…………	…………	…………	…………	×	○	×
Quercus kushiroensis	…………		…………	…………	×	○	○
Planera ezoana	…………	…………	…………	…………	×		
Trema asiatica	…………	…………					×
Ulmus harutoriensis	…………	…………	…………	…………	×		○
Zelkova kushiroensis	…………	…………	…………	…………	×	×	
Broussonetia sp.	…………						
Ficus sp.	…………				○	○	
Nelumbo nipponica	…………				×	×	
Cercidiphyllum eojaponicum	…………	…………	…………	…………	×	×	○
Cocculus ezoensis	…………		…………		×	×	
Disanthus nipponicus	…………				×		
Hamamelis kushiroensis	…………		…………		×		
Liquidambar miosinica	…………		…………		×		×
Platanus aceroides	…………	…………	…………	…………	×	×	×
Platanus guillelmae	…………	…………		…………	×		×
Spiraea kushiroensis	…………			…………			
Zanthoxylum oblongatum	…………		…………		×		

Table 15.—(*Continued*)

	Ht	Tn	Yb	Sb	Ik	Fu	Du
Canarium ezoanum	…………						
Cedrela kushiroensis	…………						
Mallotus hokkaidoensis	…………				×		
Coriaria sp.	…………						
Ilex obovata	…………						
Acer arcticum	…………	…………		…………	×	×	
Acer kushiroanum			…………		×		
Acer oishii	…………		…………	…………			
Cupania japonica	…………	…………	…………	…………	×		
Zizyphus harutoriensis	…………						○
Actinidia kushiroensis	…………	…………		…………	×		
Gordonia japonica	…………						
Idesia kushiroensis	…………	…………	…………		×		
Tilia harutoriensis	…………						
Alangium basiobliquum	…………	…………	…………	…………	×		×
Alangium basitrucatum	…………	…………		…………	×		
Aralia ezoana	…………	…………	…………	…………	×		
Maesa nipponica	…………	…………			×		
Chionanthus nipponicus	…………				×		
Melodinus japonicus	…………						
Cordia japonica	…………	…………			×		
Viburnum ezoanum	…………	…………		…………	×	○	○
Viburnum basiobliquum	…………						
Antholites cruciatus				…………			
Carpites japonicus	…………		…………	…………	×	×	
Nordenskioldia borealis			…………		×		
Identical species	58	23	31	25	42	10	10
Closely similar species					2	8	7

Abbreviation Ht: Harutori flora; Tn: Tenneru flora; Yb: Yubetsu flora; Sb: Shakubetsu flora; Ik: Ikushunbetsu flora; Fu: Fushun Flora; Du: Lower Dué flora

leaves, and evergreen oaks, associated with deciduous hardwood leaves; the Bibai flora shows rather subtropical aspect. Furthermore, the flora of the Lower Ishikari group, especially of the Yubari formation, is again less subtropical than the Bibai (HUZIOKA et al., 1961). Thus we can infer the climatic trend through the Paleogene floras of the Ishikari-Urahoro groups: subtropical climate as its warmest peak is represented by the Bibai flora; then the climate seems to have gradually changed to warm-temperate during the Ikushunbetsu-Harutori stage, and further to temperate as shown by the Yubetsu and Shakubetsu floras. Such climatic changes from subtropical to temperate conditions during the Paleogene of Hokkaido are fairly consistent with those during Eocene to Oligocene time in western North America (DORF, 1964; WOLFE and HOPKINS, 1967).

The Paleogene floral sequence in Europe has been not yet comprehensively summarized, though a number of leaf and seed floras have been described. This incompleteness may be due to the fact that floras in Europe are dispersed too widely to set up a floral sequence. Lately KRUTZSCH (1967) has summarized the Paleogene floral sequence in central Europe on the basis of spore-pollen investigations. His illustrations of floral change and climatic history are quite similar to those of western North America; the Paleotropical-Tertiary Geoflora suddenly decreased since the Early Oligocene, due to climatic deterioration, while the Arcto-Tertiary temperate Elements considerably increased. We have no geologic evidence that the climatic history in East Asia was significantly different from those of Europe and western North America. Accordingly, the above-noted climatic records in Hokkaido seem to suggest that the Harutori and Ikushunbetsu floras are Early Oligocene in age, and that the Bibai flora is probably of Late Eocene age.

COMPARISON WITH PALEOGENE FLORAS OF WESTERN NORTH AMERICA

Tertiary floras in North America have been extensively investigated by various workers since the end of last century, and their evolutionary history has been summarized by CHANEY (1940, 1947) and others. Furthermore, many of these plant-bearing rocks were lately evaluated their radiometric age by potassium-argon dating (EVERNDEN and JAMES, 1964). On the basis of this radiometric evidence and floral composition, AXELROD (1966 a, b) has rearranged stratigraphically the Paleogene floras of the western United States, and has emphasized the necessity for altitudinal consideration of age assignments. Comparison with these Paleogene floras of the region bordering the eastern side of the Pacific gives fruitful information for our age evaluation of Japanese Tertiary floras. We must here compare our floras with Eocene and Oligocene lowland forests of western North America, because the Harutori and the other three associated floras represent forests at low altitudes as stated in an earlier chapter.

In the western United States, Early and Middle Eocene floras at low altitudes represent typically subtropical forests, as represented by the Steels Crossing (WEAVER, 1944), the Wilcox (BERRY, 1919) and the Chalk Bluff floras (MACGINITIE, 1941). Those of middle to high altitudes are less subtropical, and are rather warm-temperate to temperate in aspect, as represented by the Lower Cedarville*, the Salmon*

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* These floras were once assigned to Miocene age, based on paleobotanical evidence, but recent K/Ar dating of the plant-bearing rocks indicates to be of Middle Eocene age (40–45 million years old).

(Brown, 1935, 1937) and the Copper Basin floras (Axelrod, 1966). These non-subtropical floras of middle altitudes are somewhat similar to the Harutori flora in the predominance of temperate plants of the Arcto-Tertiary Geoflora. However, it is evident that such similarity is due not to their being of the same age, but rather to altitudinal differences.

We can readily find many floras similar to the Harutori among those of Late Eocene and Early Oligocene age in the western United States: the Clarno (Knowlton, 1902; Chaney, 1940; MacGinitie, 1941), the Comstock (Sanborn, 1935) and the Montgomery Creek floras (MacGinitie, 1937), the Florissant (MacGinitie, 1957), the Bridge Creek (Chaney, 1927), and the Ruby Basin floras (Becker, 1961) of Early and Middle Oligocene. The three Late Eocene floras represent the subtropical forests of low altitudes, according to altitudinal analysis by Axelrod (1966 b). Though they are similar to the Harutori, they show warmer climate than that of the Harutori since they contain many subtropical genera such as *Dioon*, *Sabalites*, *Cinnamomum*, *Litsea*, *Machilus*, *Persea*, *Lonchocarpus*, *Lucuma*, *Anona* and *Pterosperumum*, which are not represented in the Harutori flora. These three floras are rather closely similar to the Bibai flora of the Ishikari coal field.

The Harutori plants find many of their closely similar speies in the Weaverville and the Florissant floras of Early Oligocene as follows:

Harutori Species	Florissant Species	Weaverville Species
Equisetum arcticum	*E. florissantense*	———
Pinus sp.	*Pinus* spp.	———
Smilax hokkaidoensis	*S. labidurommae*	*S. lamarensis*
Carya ezoensis	*C. libbeyi*	———
Carpinus kushiroensis	*C. fraterna*	———
Quercus kushiroensis	*Q. scudderi*	*Q. pregrahami*
Ulmus harutoriensis	*U. tenuinervis*	———
Zelkova kushiroensis	*Z. drymeja*	———
Ficus sp.	———	*F. plinerva*
Platanus aceroides	*P. florissanti*	*P. dissecta*
Cedrela kushiroensis	*C. lancifolia*	———
Acer oishii	*A. florissanti*	———
Zizyphus sp.	*Z. florissanti*	———
Actinidia harutoriensis	———	*A. ovata*
Idesia kushiroensis	———	*I. cordata*
Tilia harutoriensis	*T. populifolia*	*T. inaequalis*

However, the Harutori flora contains almost no leaves of evergreen oaks, the Rosaceae, the Leguminosae, and the Anacardiaceae, which are represented by a number of species and specimens in the Florissant and Weaverville. On the other hand, these two American floras do not contain such lowland plants as *Musophyllum*, *Trema*, *Maesa*, *Gordonia*, *Canarium*, *Cordia* and *Melodinus*, which are included in the Harutori. It seems due to the altitudinal differences which determine what plant organs entered the depositional sites. The Harutori flora represents the lowland to lower slope vegetation, while the Florissant and the Weaverville represent the vegetation at moderate elevations, not exceeding 1000 meters.

Our final comparison reveals that the Harutori flora is most closely similar to the Bridge Creek and the Ruby Basin floras in the predominance of temperate plants. This resemblance is shown in the following table:

Harutori Species	Bridge Creek Species	Ruby Basin Species
Equisetum arcticum	————	*Equisetum* sp.
Osmunda sachalinensis	————	*O. occidentalis*
Dennstaedtia nipponica	————	*D. adamantea*
Pinus sp.	*P. knowltoni*	*P. monticolensis*
Glyptostrobus europaeus	————	*G. oregonenis*
Metasequoia occidentalis	*M. occidentalis*	*M. occidentalis*
Smilax hokkaidoensis	————	*S. rubyensis*
*Comptonia kushiroensis**	*C. diforme*	————
Carya ezoensis	*Carya* (?) sp.	————
Alnus hokkaidoensis	*A. carpinoides*	*A. carpinoides*
Alnus ezoensis	————	*A. relatus*
Carpinus kushiroensis	*C. payettensis*	*C. lanceolata*
Corylus ezoana	*C. macquarrii*	————
Quercus kushiroensis	*Q. consimilis*	*Q. consimilis*
Ulmus harutoriensis	*U. speciosa*	*U. speciosa*
Zelkova kushiroensis	*Z. oregoniana*	*Z. oregoniana*
Cercidiphyllum eojaponicum	*C. crenatum*	*C. elongatum*
Liquidambar miosinica	*L. europaeum*	————
Spiraea kushiroensis	————	*S. clavidens*
Cedrela kushiroensis	*C. merrilli*	*C. lancifolia*
Acer oishii	*A. bendirei*	*A. florissanti*
Tilia harutoriensis	*Tilia* sp.	————

The similarity of these three floras is shown largely by their Arcto-Tetiary members; the Bridge Creek and the Ruby Basin floras contain no Asiatic, subtropical genera, represented in the Harutori by *Musophyllum*, *Trema*, *Canarium*, *Glochidion*, *Mallotus*, *Zizyphus*, *Gordonia*, *Maesa*, *Alangium*, *Melodinus*, and *Cordia*. But some these genera are contained sometimes rather in Lower Oligocene and Eocene floras, such as in the Florissant, the Comstock, the Clarno and the Chalk Bluff. Accordingly, the Harutori flora seems to be somewhat older than the Bridge Creek and the Ruby Basin floras, though it is closely similar. In the sense of involving only a few warmer plants, the Yubetsu and Shakubetsu floras are rather similar to the Bridge Creek and the Ruby Basin.

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* *Comptonia* is found only from the Yubetsu flora.

From the above-described comparison with Eocene and Oligocene floras of western North America, it may be concluded that the Harutori flora is younger than the Clarno and Comstock floras of Late Eocene age, and is somewhat older than the Bridge Creek and the Ruby Basin floras. On the basis of paleobotanical evidence, the Bridge Creek flora was once dated as Late Oligocene age (CHANEY, 1927), while the Ruby Basin flora was considered to be somewhat older, probably of early Late Oligocene age (BECKER, 1961). Lately the Bridge Creek flora was assigned to be of early Middle Oligocene age (K/Ar dating=31 million years) by EVERNDEN et al. (1964). Thus the Harutori flora is suggested to be Early Oligocene in age.

In summary, the climatic implications indicated by the four floras and comparison with Paleogene floras of western North America reveal that the Harutori flora is dated as Early Oligocene age, and the Yubetsu and Shakubetsu floras are Middle to Late Oligocene, probably Middle Oligocene in age. Considering its stratigraphic relation to the Harutori, the Tenneru flora is probably of late Early Oligocene age. These age evaluations are consistent with the dating of the molluscan faunas, which are included in the Urahoro group and the overlying Onbetsu group. But, as already described, the geologic age based on foraminiferal faunas is somewhat older. It will be desirable to employ radiometric dating on several tuffs intercalated in the Urahoro group.

VI. CONCLUSION

The one major and three minor floras collected from the Oligocene Urahoro group of southeastern Hokkaido are described here in detail as to their geologic occurrence, composition, paleoecology and age.

The cyclic nature shown in the lithology of the Urahoro group represents an intermittent subsidence of an Oligocene depositional basin; then the coal basin was widely covered by the Late Oligocene sea, which resulted in deposition of the Onbetsu group. Such sedimentary history during Oligocene time is common in other regions of Hokkaido and on the Pacific side of northern Honshu, and also extended into Saghalien. Oligocene plants occurring in the Urahoro group have a great similarity to those of the Upper Ishikari group west of the Kushiro field, to those of the Kuji and Joban coal fields of northern Honshu, the Fushun coal field of Manchuria, and even to those of Dué district of Sahgalien. Thus the floral changes shown by the four floras, from the Harutori to the Shakubetsu, appear to be representative of Oligocene forest history at the low altitudes not only in North Japan but in East Asia.

The lowlands of southeastern Hokkaido during Oligocene age were occupied by a forest in which *Metasequoia* and deciduous hardwood trees were dominant trees. This forest, typically represented by the Harutori flora, widely covered the lowlands and lower slopes, which consisted mainly of the Upper Cretaceous sediments. Considering a number of thick coal seams, swampy areas must have been widely distributed on the lowlands along the coastal region; the swamp forest is not well represented in our collection. Most of the coal in the Kushiro field originated from plant debris supplied from the Lake-border and Riparian Woodlands, which are abundantly represented in our collection. The Early Oligocene forest represented by the Harutori consisted largely of temperate Arcto-Tertiary members. Toward the close of the Oligocene, subtropical and warm-temperate plants were gradually eliminated, as shown by the Yubetsu and Shakubetsu floras. This illustrates the trends in the forest history of southeastern Hokkaido from a warm-temperate to a temperate forest, due to climatic deterioration toward Late Oligocene time. The southward migration of the Arcto-Tertiary Geoflora to middle latitudes during Oligocene time is also recorded in western North America and central Europe.

SYSTEMATIC DESCRIPTION

Recently the Neogene plants have been considerably promoted their description and restudying, while the Paleogene plants have been little described until today, though their abundant occurrence have been known in Japan. It was due partly to their worse preservation, compared with Neogene plants, and was also to the difficulty of their definite taxonomic identification. The author has devoted much time for many years to collect well-preserved specimens and to identify cautiously them. Most of our fossils have close relationships to fossil species of Europe, North America, and elswhere in Asia. Furthermore they are closely similar to the modern plants of East Asia and eastern North America.

Most of the materials under studying here represent foliage, while the reproductive organs such as seeds and fruits are lesser. Only by morphologic features of foliage, even by comparative investigation of epidermis, fossil plants are usually difficult to refer to the modern species, although they are closely matched with foliage of the modern plants. Tertiary plants, especially in Europe, have been frequently referred to the modern species. On the one hand, it has long been the practice in Tertiary paleobotany to distinguish fossils from the modern plants by referring them to different species. The author continues this practice here, though some Japanese paleobotanists use sometimes modern specific names for the Paleogene plants.

In the following systematic descriptions, the specimen type numbers refer to those in the Museum of Paleontology, Hokkaido University, Sapporo (the abbreviation: H.U.M.P.). The localities and the plant-bearing rocks are explained in the preceding pages.

Family EQUISETACEAE

Equisetum arcticum HEER

Pl. 3, figs. 1, 2

Equisetum arcticum HEER, K. SVENSK. vet. akad. Ofvers. Förh. vol. 23, no. 6, p. 150, 1866.

HEER, Flora fossilis arctica, vol. 1, p. 156, pl. 29, figs. 8a-8d, 9e, f, 1868.

Equisetum ezoenze ENDO. Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 418, pl. 2, figs. 1–6, 1968.

Remarks: A number of remains of *Equisetum* from all localities of the Kushiro coal field are represented by fragments of separated sheaths, and grooved and ridged stems with sheaths or nodes. These various specimens are referred to *E. arcticum* widely distributed in the northern hemisphere during the Lower and Middle Tertiary. *E. ezoense* lately established from the Ikushunbetsu formation of the Ishikari coal filed (Endo, 1968) is inseparable from *E. arcticum.* As these fossils are fragmentary, they are difficult to compare with the living species of *Equisetum*; however *E. arcticum* is similar to the modern *E. hyemale* LINNE widely distributed in the northern hemisphere.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shiranuka mine; Ponki; Pon-Shitaka, Yubetsu; Shoro, Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25871, 25872.

Family OSMUNDACEAE

Osmunda lignitum (GIEBEL) STUR

Pl. 3, fig. 11; p.. 4, fig. 9

Osmunda lignitum (GIEBEL) STUR, Jahrb. Geol. Reichsanstalt, vol. 20, p. 5, 1870.

Osmunda grutschreiberi STUR, ibid., p. 9, p1. 2, figs. 1–8.

Pecopteris lignitum GIEBEL, Zeitschrift für gesam. Naturwiss., vol. 10, p. 303, pl. 2, fig. 2, 1857.

Osmunda lignitum (GIEBEL) GARDNER and ETTINGSHAUSEN, Monogr. Brit. Eocene Flora, vol. 1, p. 49, pl. 4, figs. 1–3; pl. 13, figs. 1–4, 1879.

Plenasium lignitum (GIEBEL) SQUINABOL, MATSUO, Ann. Sci. Kanazawa Univ., vol. 4, p. 40, pl. 1, figs. 2, 3, 5, 8; pl. 3, fig. 1. 1967.

Remarks: These characteristic ferns from the Yubetsu formation, though fragmentary, are referred to *Osmunda lignitum* in their shape and venation, which was frequently described from the Paleogene of Europe. Recently, this species was reported from the Eocene Takashima flora of Kyushu by MATSUO (1967). The specimens described as *Plenasium lignitum* from the Middle Miocene of Noto peninsula by MATSUO (1959, 1963) are different in venation from *O. lignitum* (synonymous to *P. lignitum*). These Miocene specimens are more closely similar to the living *O. banksiaefolia* (PRESL.) KUHN than *O. lignitum*, and they must be rather referred to other species, *O. bromeliaefolioides* MATSUO, which was first proposed by MATSUO (1953).

O. lignitum is closely similar to *Hemitelia pinnata* MACGINITIE from a Eocene flora of California (MACGINITIE, 1941) in their general appearance, but the pinnules of American fern are more deeply pinnatifid. It is also somewhat similar to some ferns described under various names such as *Lastraea dalmatica*, *Cyclosorus stiriacus* and *Goniopteris stiriaca** from the Tertiary of Europe, but differs in lateral venation of pinnules.

Occurrence: Nakanosawa, Yubetsu; Shakubetsu mine.

Collection: H.U.M.P., hypotype no. 25876; no. 25877.

Osmunda sachalinensis KRYSHTOFOVICH

Pl. 3, figs. 5–7

Osmunda Sachalinensis KRYSHTOFOVICH, Materials for Tertiary Lower Due flora of Saghalien, p. 708, pl. 1, figs. 4–6; text-gigs. 1, 2, 1936.
BORSUK, Paleogene flora of Saghalien, pl. 1, figs. 1–3, 1956.
Osmunda japonica THUNB. fossilis subsp. OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 6, p. 179, pl. 39, figs. 1–4, 4a, 5–8, 1941.
OISHI, Illust. Cat. East Asiatic Fos. Plants, p. 43, pl. 11, fig. 4, 1950.
Osmunda regalis L. var. ? ENDO, Trans. Proc. Palaeont. Soc. Jap., no. 44, p. 159, pl. 24, fig. 1, 1961.
Osmunda regalis L., ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 416, pl. 1, fig. 4, 1968.

Supplementary description: Sterile pinna trigonally ovate, more than 5 cm. long, with slender rachis; pinnules opposite to subopposite, obliquely arranging to the rachis; lateral pinnules lanceolate to broadly lanceolate, obliquely truncate or rounded at the base, acute to obtuse at the apex, 2 to 5 cm. long and 0.8 to 1.7 cm. wide, widest in proximal part; ultimate segments lanceolate to elliptical, acute or obtuse at the apex, cuneate at the base; midvein stout, nearly straight to the tip; secondary veins distinct, densely crowded, nearly parallel, or twice dichotomously branching, craspedodrome, reaching the marginal sinus; areolation indistinct; margin finely serrate, with nearly equal-sized and obtuse teeth; texture firm.

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* These fossils was recently referred to *Abacopteris* by WALTHER (1967).

Remarks: This species is represented by several incomplete sterile pinna and a number of detached pinnules from all localities. These specimens, though no sporangia, are referred to *Osmunda*, and are referred to *O. sachalinensis* in their shape and venation character, which was originally described from the Paleogene Lower Dué formation of Saghalien (KRYSHTOFOVICH, 1936). *O. sachalinensis* is closely similar to pinnules of the modern *O. japonica* THUNB. widely distributed in East Asia and Himalaya region. The fossil leaves of *O. japonica* subsp. described from the Paleogene flora of the Ishikari coal field, Hokkaido (OISHI and HUZIOKA, 1941) are identical with *O. sachalinensis* in all characters. A sterile pinna described as *O. regalis* var. from the Ikushunbetsu formation of Yubari distict, Hokkaido (ENDO, 1961) is also inseparable from *O. sachalinensis*. *O. tsunemoriensis* MATSUO from a Middle Miocene flora of north-central Honshu (MATSUO, 1953) resembles *O. sachalinensis* in general appearance, but differs in secondary venation and marginal character. Another allied species is *O. doroschiana* GOEPPERT described from the Paleogene floras of Europe and North America (GEOPPERT, 1861; HOLLICK, 1937; ILJINSKAYA, 1956).

O. sachalinensis is found through the Urahoro group of the Kushiro coal field, and also is commonly or abundantly found through the Ishikari group of central Hokkaido.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shakubetsu mine; Ponki; Pon-Shitakara, Yubetsu; Shoro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25873–25875.

Family POLYPODIACEAE

Dennstaedtia nipponica OISHI and HUZIOKA

Pl. 3, figs. 3, 4, 8, 9; pl. 4, figs. 5–7

Dennstaedtia nipponica OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 6, p. 179, figs. 10–14; pl. 40, figs. 1–5, 5a, 7, 8, 1941.

Remarks: A number of sterile and fertile pinna from the Harutori formation are referred to *D. nipponica* originally described from the Ikushunbetsu formation, though their pinnules are somewhat stronger and larger than the Ishikari specimens. Our specimens are closely similar to those of the modern *D. scabra* (WALL.) MOORE living in warm-temperate and tropical regions of East Asia.

D. nipponica closely resembles *D. americana* KNOWLTON described from the Paleocene to the Oligocene of North America (KNOLWTON, 1910; BROWN, 1962; WOLFE, 1966), and is sometimes difficult to be separted from the American species. Other allied species are *D. tschuktschorum* KRYSHTOFOVICH from a Cretaceous flora of the Anadyrya basin, eastern U.S.S.R. (KRYSHTOFOVICH, 1958), and *D. blomstandi*

(HEER) HOLLICK from the Paleocene and the Eocene of Alaska (HOLLICK, 1936; BELL, 1949), but these two species are distinguishable in venation character of pinnules from our species.

Occurrence: Harutori mine.

Collection: H.U.M.P., hypotypes nos. 25877–25882.

Lastrea kushiroensis new species

Pl. 4, figs. 3, 4

Lastraea japonica KRYSHTOFOVICH, Jour. Geol. Tokyo, vol. 25, p. 26, pl. 15, figs. 1, 1a, 1918.

Description: Outline of frond unknown; pinnae linear-lanceolate, 10 to 15 cm. long (estimated), 1.8 to 2.4 cm. wide at the middle part, deeply pinnatifid, dissected toward the rachis, cut into subalternate pinnules; pinna axis stout, gently arcuate; pinnules oblong, somewhat inequilateral, 0.8 to 1.2 cm. long and 0.4 to 0.6 cm. wide at the middle portion, obtuse to rounded at the apex; venation of pinnules consisting of a stout midrib and 10 to 12 lateral veins; lateral veins thin, diverging at angles 30 to 35 degrees, nearly straight toward the margin; margin entire or sometimes undulate; texture thin.

Remarks: Several incomplete ferns from the Harutori and Tenneru formations are closely similar to the pinnae of certain species of the Polypodiaceae, particularly to those of *Lastrea japonica* (BAKER) COPEL. and *L. tottae* (SCHLTDL.) OHWI, which are widely distributed in East Asia. A fern described as *L. japonica* KRYSHT. (not COPELAND) from the Eocene Takashima flora of Kyushu (KRYSHTOFOVICH, 1918), is closely similar to our specimens, and is conspecific. As this specific name, *L. japonica*, was, however, given for the living fern by COPELAND, the author gives a new specific name for our specimens.

L. kushiroenis is closely similar to *Dryopteris dalmatica* (HEER) DEPAPE from the Oligocene Cervera flora of France (DEPAPE, 1950) and *Lastreae* cf. *oeningensis* (A. BR.) HEER from a Oligocene flora of Hungary (ANDREANSZKY, 1966).

Occurrence: Harutori mine; Tokomuro.

Collection: H.U.M.P., holotype no. 25883; hypotype no. 25884.

Onoclea hebraidica (FORBES) GARDNER and ETTINGSHAUSEN

Pl. 3, fig. 10

Onoclea hebraidica (FORBES) GARDNER and ETTINGSHAUSEN, British Eocene flora, vol. 1, p. 68, pl. 13, figs. 5, 5a, 6, 6b, 1882.

BELL, Canada Geol. Surv. Bull., no. 13, p. 40, pl. 22, fig. 5; pl. 24, figs. 3, 5; pl. 25, fig. 2, 1949.

Filicites ? hebraidicus FORBES, Quart. Jour. Geol. Soc. London, vol. 7, p. 103, pl. 2, figs. 2a, b, 1851.

Onoclea sensibilis fossilis NEWBERRY, U.S. Geol. Surv. Mon. no. 35, p. 8, pl. 23, fig. 3; pl. 24, figs. 1–5, 1890.

OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vols. 6, p. 184, pl. 41, figs. 1, 1a, 2, 2a, 3, 4, 1941.

Remarks: Several fragmentary pinnules from the Harutori formation are surely identical with *Onoclea* in their characteristic venation. They are closely similar to those of the modern *O. sensibilis* LINN., which is a monotypic species of this genus, and is confined to East Asia and eastern North America. However, the fossil *Onoclea* has been widely recorded in the northern hemisphere since the Cretaceous to the Miocene, in particular abundantly from the Paleocene to the Oligocene. These fossils have been described under various specific names; but most of them were referred to the modern species, and were named as *O. sensibilis* fossilis. The earliest description of the fossil fern like *Onoclea* was given by FORBES (1851) on the basis of fragmentary pinna from the Eocene of the Isle of Mull, Scotland, though their specimens were originally described as *Filicites? hebraidicus.* Thirty years later, GARDNER and ETTINGSHAUSEN (1882) emended this fern to *Onoclea hebraidica.* Current practice does not favour the fossil reference to the modern specific name, though many of authors have referred this fern to *O. sensibilis* fossilis. Accordingly, the author refers the Harutori specimens to *O. hebraidica.* Recently, BROWN (1962) established a new species, *O. hesperia,* on the basis of sterile foliage from the Paleocene of North America, and referred all of American Paleocene specimens of *Onoclea* to it. However, its American species seems rather difficult to separate from *O. hebraidica.*

The living equivalent species, *O. sensibilis,* is distributed in the moist region from southern Saghalien to Kyushu, extending into Korea, Manchuria and eastern Siberia, and also is in eastern North America.

Occurrence: Harutori mine; Nakanosawa, Yubetsu.

Collection: H.U.M.P., hypotype no. 25885; no. 25886.

Woodwardia sasae OISHI and HUZIOKA

Pl. 4, figs. 1, 2, 8

Woodwardia sasae OISHI and HUZIOKA, Jour. Geol. Soc. Jap. vol. 49, p. 320, pl. 13, figs. 1–7, 1942.

Supplementary description: Outline of frond is unknown. Pinnae linear-lanceolate, 8 to 10 cm. long, 2 to 3 cm. wide at the middle, gradually narrowed towards basal and distal ends; pinna axis stout, with a longitudinal median groove on the upper side; pinnules oblong or oblong-triangular, sometimes slightly falcate, obtuse at apex, connected each other in the basal part, finely serrate with acute teeth in margin; a pair of deltoid to oblong lobes existing in basal part of each pinna; midvein of pinnules thin, slender, somewhat wavy, with a series of 5 to 6 oblong areoles on each side; secondary veins giving off from the areoles, thin, simple or once forking; sori linear or oblong, about 5 in number on each side of midvein.

Remarks: A number of fertile and sterile pinnae from the Harutori coal mine are referred to *W. sasae* described already from its mine by OISHI and HUZIOKA (1942), though pinnules were described to be entire in margin on the basis of incomplete specimens. All of our specimens are distinctly finely serrate margined, while the original specimens are also incompletely toothed in margin.

Among the fossils of Woodwardia *W. sasae* is closely similar to *W. endoana* OISHI and HUZIOKA from the Ikushunbetsu formation of the Ishikari coal field (OISHI and HUZIOKA, 1941), but pinnules of *W. endoana* are usually narrower, obtuse in the apex, and nearly entire or coarsely serrate in the margin. Another close species is *W. arctica* (HEER) BROWN from the Paleocene Fort Union flora of Wyoming, the western United States (BROWN, 1962). *W. sasae* is closely similar to the modern *W. japonica* (LINN. fil.) SMITH, which is distributed in western Honshu, Shikoku and Kyushu, Japan, and is in Quelpart island, Formosa, southern China and Indo-China. The common occurrence of this fern seems to show warm or subtropical climate during the Harutori time.

Occurrence: Harutori mine.

Collection: H.U.M.P., hypotypes nos. 25887, 25888; nos. 25889, 25890.

Family PINACEAE

Pinus sp.

Pl. 5, fig. 2

Description: Winged seed oblong, more than 1 cm. long; wing lacking upper part, 5 mm. wide; veins thin, numerous, parallel to margin of wing; seed ovate, 3.5 mm. long, 2 mm. wide.

Remarks: A single incomplete winged seed from the Okotsu pit is referable to *Pinus* in its shape, though it lacks upper part of wing. No fossil cone and leaves of *Pinus* have been found from the Kushiro coal field. But common occurrence of pine pollen from the Harutori coals was reported by OKAZAKI (1962).

Occurrence: Harutori mine.

Collection: H.U.M.P., no. 25891.

Family TAXODIACEAE

Glyptostrobus europaeus (BRONGNIART) HEER

Pl. 5, fig. 8

Glyptostrobus europaeus (BRONGNIART) HEER, Flora tertiaria Helvetia, vol. 1, p. 51, pl. 19; pl. 20 fig. 1, 1855.

ENDO and OKUTSU, Proc. Imp. Acad. Tokyo, vol. 12, p. 138, figs. 1–3. 1936.

Remarks: Many branchlets with slender leaves are identified as *G. europaeus*, one of the widely distributed species in the Tertiary of the northern hemisphere. This species is not common in the Kushiro field, and no cones have been found.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Ponki.

Collection: H.U.M.P., hypotype no. 25892.

Metasequoia occidentalis (NEWBERRY) CHANEY

Pl. 5, figs. 3, 4, 6, 7, 9; pl. 6, fig. 7

Metasequoia occidentalis (NEWBERRY) CHANEY, Trans. Amer. Philosoph. Soc. New Ser. vol. 40, pt. 3, p. 225, pl. 1, fig. 3; pl. 2, fig. 1–3; pl. 4, figs. 1, 2, 9; etc., 1951.

TANAI and ONOE, Bull. Geol. Surv. Japan, vol. 10, no. 4, p. 276, pl. 2, figs. 1–3; 1959.

TANAI, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 263, pl. 3, fig. 1–8, 12, 14 (see synonymy), 1961.

Sequoia chinensis ENDO, Jap. Jour. Geol. Geogr. vol. 6, p. 27, figs. 1–5, 1928.

Sequoia onukii ENDO, Proc. Imp. Acad. Tokyo, vol. 12, p. 173, text-fig. 6, 1936.

Sequoia rumoeenis ENDO, ibid. p. 173, text-fig. 4, 1936.

Sequoia cf. *chinensis* ENDO, Bull. Nat. Mus. Manch. no. 3, p. 39, pl. 16, fig. 2, 1942.

Metasequoia kimurae OISHI and HUZIOKA, Jour. Geol. Soc. Jap. vol. 49, p. 321, pl. 13, figs. 8–11, 1942.

Sequoia disticha HEER. ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 419, pl. 3, figs. 1–6, 1968.

Remarks: A number of deciduous branchlets with decussately attached needles and many of carbonized cones are referred to *M. occidentalis*, one of the most widely distributed conifers in the Tertiary floras of the northern hemisphere. *Metasequoia* is commonly found from all localities of the Kushiro coal field; especially it is most abundant in the Harutori flora, making about 45 per cent of the total specimens counted. Cones described as *M. kimurae* from the Harutori coal mine by OISHI and HUZIOKA (1942) are indistinguishable from those of *M. occidentalis*. Cones and branchlets of *Sequoia onukii*, *S. rumoeensis* and *S. chinensis* from the Paleogene of Hokkaido and Manchuria (ENDO, 1928, 1936, 1942) are closely similar to *M. occidentalis* in all characters, though they vary in size, and are included in it. All of foliaged shoots and cones described as *Sequoia disticha* from the Ikushunbetsu flora (ENDO, 1968) are referred to *Metasequoia*, and are included in our species. *Cephalotaxus yubariensis* established from the same flora by ENDO (1968) may represent a large foliage shoot of *M. occidentalis.*

M. occidentalis is closely similar to the modern *M. glyptostroboides* HU and CHENG survived only on the uplands of central China. The relative abundance of *M. occidentalis* from the shales immediately above thick coal seams of the Harutori mine, does not seem that this conifer had required the upland character in its habitat during the Paleogene time, similar as the modern species required.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shakubetsu mine; Ponki; Pon-Shitakara, Yubetsu; Shoro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25893–25898; no. 25899.

Family LILIACEAE

Smilax hokkaidoensis new species

Pl. 6, figs. 2, 8

Description: Leaves variable in shape, oval to compressed orbicular, 3.5 to 4 cm. long and 2.9 to 4 cm. wide; base rounded to broadly rounded, slightly decurrent; apex rounded; 3-plinerved, midvein medium, nearly straight; a pair of lateral primaries slender, originating from the very base, making angles of about 30 degrees with the midvein, arcuate, acrodrome; a pair of slender sub-primaries in outside of laterals originating from the base, arising up along the margin; secondary and tertiary veins indistinct; margin entire; texture subcoriaceous; petiole thick, more than 4 to 5 mm. long.

Remarks: These leaves are identified as *Smilax* by their acrodromous venation and entire margin, and are closely similar to those produced by the modern *S. china* LINN. and *S. trinervula* MIQ. *S. hokkaidoensis* closely resembles small leaves of *S. trinervis*, which is common in the Miocene of Japan, but it is more slender in primary venation. It is somewhat similar to *S. orbicularis* HEER from the Miocene of Switzerland (HEER, 1859) and *S. cyclophylla* NEWB. from the Paleogene of North America (NEWBERRY, 1863, 1898).

The similar modern species, *S. china*, is widely distributed in Japan, Formosa and China; *S. trinervula* is living in central Honshu, Japan.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25900; hypotype no. 25901.

Family MUSACEAE

Musophyllum nipponicum new species

Pl. 5, fig. 1

Musophyllum complicatum LESQUEREUX. ENDO, Cenozoic Plants, p. 9, text-fig. 6, 1931.

Description: Leaves incomplete but large, oblong, 18 to 20 cm. wide and more than 20 cm. long; apex and base missing; midrib very thick, 3 to 5 cm. thick in compressed specimens, with irregularly, longitudinal, thin veins; secondary veins thin, generally simple, very numerous, crowded with distance of 0.5 to 1 mm., diverging from the midrib at an acute angles, then abruptly opening with nearly right angles, nearly straight, near the margin abruptly curving upward, sometimes forking, craspedodrome; a few subsecondaries very thin, running parallel to the secondaries in intersecondary spaces; margin entire or irregularly undulate; texture subcoriaceous, but not firm.

Remarks: A number of fragmentary leaves from the Harutori coal mine are identical with *Musophyllum* in their very large size and characteristic venation. These leaves seem to have been splintery along the secondary veins, and so all of our specimens are fragmentary or splitted. *M. nipponicum* is closely similar to *M. complicatum* LESQUEREUX from the Eocene Green River flora of North America (LESQUREUX, 1878), but somewhat differs in secondary venation. A single leaf figured as *M. complicatum* from the Paleogene of the Kishima coal mine, northern Kyushu (ENDO, 1931) is inseparable from our new species. The occurrence of *Musophyllum* has been reported widely from the Paleogene coal-bearing forma tions of northern Kyushu, central Hokkaido and the Ube coal field, though not abundantly.

M. nipponicum resembles some of the genus *Musa*, which is widely distributed in tropical Asia, Australia, Africa and Oceania, and especially is similar to the modern *Musa uranoscopos* LOUR. of southern China in their size of leaves.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine.

Collection: H.U.M.P., holotype no. 25902; no. 25093.

Family MYRICACEAE

Comptonia kushiroensis new species

Pl. 5, fig. 5

Description: Leaf lanceolate, upper part of blade missing, 1.1 cm. wide, length unknown; base sharply cuneate; margin irregularly, shallowly lobed; midrib thick, arcuate; each lobe rounded or slightly pointed at apex, having 1 or 2 secondary veins; secondaries slender, diverging at angles of 70 to 90 degrees, bifurcating near the margin, its upper branch ending in the apex of lobes; 1 or 2 thinner sub-secondaries arising from midrib, nearly parallel to secondaries; tertiaries very thin, forming polygonal network; texture subfirm; petiole thick, 3 mm. long.

Remarks: A single leaf from the Yubetsu coal mine, though incomplete, is referred to *Comptonia* by its characteristic shape and venation, and is related to the modern *C. peregrina* (LINNE) COULT. living in eastern North America. Fossil leaves of *Comptonia* have been commonly found from the Upper Oligocene to the Pliocene in East Asia (TANAI, 1961; HUZIOKA, 1961; ENDO, 1954), and four species are known: *C. naumanni* (NATHORST) HUZIOKA, *C. kidoi* ENDO, *C. yanagisawae* HUZ. and SUZUKI, and *C. nipponica* ENDO. But they are different in their dissected leaves from our specimen. Our leaf is closely similar to some leaves figured as *Myrica vindobonensis* (ETT.) HEER from the Paleogene of Saghalien (BORSUK, 1956), but differs in narrower leaves and marginal character. Another similar leaves is those of *M. banksiaefolia curta* HOLLICK from the Paleogene of Alsaka (HOLLICK, 1936).

This characteristic leaves similar to our specimen have been widely reported from the Tertiary of the world under the various specific names of *Myrica* and *Comptonia*, and these fossils are somewhat confused in their taxonomy. Further detail discussion shall be retained until collecting more well-preserved specimens.

Occurrence: Nakanosawa, Yubetsu.

Collection: H.U.M.P., holotype no. 25094.

Family JUGLANDACEAE

Carya ezoensis new spesies

Pl. 6, figs. 1, 3, 4; pl. 15, fig. 7

Juglans nigella HEER. BORSUK, Paleogene flora of Saghalien, p. 25, pl. 3, fig. 8, 1956.
Juglans pictoroides HEER. BORSUK, ibid., p. 26, pl. 3, figs. 9, 10, 1956.

Description: Leaflets variable in shape and size, 10.5 to 15 cm. long (estimated) and 5.5 to 7 cm. wide; terminal leaflets oblanceolate, with asymmetrically cuneate base, and acute apex; lateral leaflets lanceolate to oblong, with acuminate apex, and with the base asymmetrical, rounded on one side, bluntly cuneate on the other; midrib stout, slightly curving; secondary veins rather thick, more than 15 subopposite pairs, diverging up, craspedodrome, or frequently forking near the margin, camptodrome with small branches; tertiaries thin but distinct, irregularly percurrent, trending nearly at right angles to the secondaries, near the margin ending in the teeth; nervilles thin, forming fine polygonal network; margin closely serrate with acute teeth; texture thin; petiolules missing.

Remarks: These leaflets apparently belong to the Juglandaceae and are referred to *Carya* in their shape, margin and secondary venation. The living species of *Carya* are abundant in North America, while only one species is living in China and Mexico respectively. *C. ezoensis* is more similar to American hickories rather than Chinese species, and closely resembles *C. ovata* (MILL.) K. KOCH. and *C. tementosa* NUTT. now living in the southeastern United States. The modern hickories generally bear large leaflets on moist bottom-lands near swamp and stream. Abundant occurrence of large leaflets from the Kushiro coal field suggests a similar condition near the site of deposition as indicated by the modern hickories.

Fossil leaflets reported as *Juglans nigella* and *J. pictoroides* from Paleogene floras of Saghalien (BORSUK, 1956) are included in *C. ezoensis*. *C. ezoensis* distinctly differs from *C. miocathayensis* HU and CHANEY in secondary venation, which is common in the Miocene of Japan (TANAI, 1961). It is closely similar to *C. cordioides* ILJINSKAYA and *C. tomentosifolia* ILJINSKAYA from the Oligocene Ashutus flora of Kazakhstan region, U.S.S.R. (ILJINSKAYA, in KYSHTOFOVICH, 1956). *C. ezoensis* is also closely similar to *C. libbeyi* (LESQ.) MACGINITIE from the Oligocene Florissant flora of Colorado (MACGINITIE, 1953) and *C. antiquora* from the Paleogene of Alaska (WOLFE, 1966).

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Ponki; Pon-Shitakara; Shoro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., holotype no. 25095; paratype no. 25096; hypotypes nos. 25907, 25908; no. 25909.

Platycarya hokkaidoana new species

Pl. 6, figs. 5, 6; pl. 7, fig. 6

Description: Leaflets lanceolate to oblong-lanceolate, 5.6 to 10.5 cm. (estimated) long, 2.7 to 3.6 cm. wide; apex acuminate; base asymmetrically rounded to cuneate; midrib strong, nearly straight, somewhat tapered at apical part; secondary veins rather stout, 15 to 20 paris, opposite to subopposite, diverging at angles of 50 to 60 degrees at the middle part of blade, nearly straight or gently curving up, forming near the blade, nearly straight or gently curving up, forming near the margin, usually craspedodrome, or sometimes forming irregularly small loops; tertiaries distinct, percurrent; nervilles finely reticulate; margin closely compound-serrate; texture thin; petiolule missing.

Remarks: These leaves commonly found from the Harutori formation belong surely to the Juglandaceae, and are referred to *Platycarya* in their secondary venation and marginal character. They closely resemble leaflets of the modern *P.*

strobilacea SIEB. and ZUCC. distributed in southern Japan, extending into central and southern China. *P. hokkaidoana* is closely similar to *P. miocenica* HU and CHANEY from the Middle Miocene of East Asia (HU and CHANEY, 1938; TANAI and N. SUZUKI, 1963), and are sometimes difficult to distinguish in venation character. It also resembles *Pterocarya ezoana* recently described from the Middle Miocene of southwestern Hokkaido (TANAI and N. SUZUKI 1963), but distinctly differs in prominent looping of secondary veins.

Occurrence: Harutori mine; Nakanosawa, Yubetsu.

Collection: H.U.M.P., holotype no. 25910; paratype no. 25911; hypotype no. 25912; no. 25913.

Family BETULACEAE

Alnus ezoensis new species

Pl. 7, figs. 1, 5, 7

Description: Leaves oblong to lanceolate, 6 to 8.2 cm. long and 2.7 to 3.5 cm. wide; apex acute; base cuneate to broadly cuneate; midrib stout, prominent on under surface, nearly straight; secondary veins 9 to 15 paris, subopposite to alternate, diverging at varying angles, from 40 to 65 degrees, nearly straight, near margin slightly curving, craspedodrome; tertiaries percurrent; nervilles thin, forming irregularly fine, polygonal network; margin doubly serrate, with widely spaced primary dentation at the extremities of secondaries, between them 3 to 5 small dentation existing; texture rather subfirm; petiole think, about 1 cm. long.

Remarks: A number of leaf impressions from the Harutori and Yubetsu coal mines are referred to *Alnus* in their venation and margin, and are closely similar to those of the modern *A. japonica* SIEB. and ZUCC. of Japan, China and Korea, and *A. pendula* MATSUMURA of Japan. *A. ezoensis* is closely similar to *A. miojaponica* TANAI commonly found from the Middle to the Upper Miocene of Japan (TANAI, 1955, 1961) and is probably the Early Tertiary progenitor of its Miocene alder species. There have been many alders closely similar to *A. japonica* from the Tertiary of the northern hemisphere; it closely resembles *A. operis* MACGINITIE from the Middle Eocene Chalk Bluff flora of central Sierra Nevada (MACGINITIE, 1941), *A. relata* (KNOWLTON) BROWN from the Oligocene to the Miocene of western North America (BROWN, 1937; CHANEY and AXELROD, 1959; BECKER, 1961), *A. gracilis* UNGER from the Miocene of Europe (UNGER, 1847), and *A. palaeojaponica* WEYLAND from an Oligocene flora of Germany (WEYLAND, 1943). *A. ezoensis* is identical to *A. palaeojaponica* recently established from the Ikushunbetsu flora (ENDO, 1968). But the specific name of *A. paleojaponica* has priority in taxonomic nomenclature for Oligocene alder of Germany.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine; Ponki; Pon-Shitakar, Yubetsu; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., holotype no. 24914; paratype no. 25915; hypotype no. 25916; no. 25917.

Alnus hokkaidoensis new species

Pl. 8, figs. 2, 7

Betula macrophylla HEER. BORSUK, Paleogene flora of Saghalien, p. 30, pl. 5, fig. 1, 1956.

Corylus japonica ENDO. Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 424, pl. 8, figs. 2,3, 1968.

Description: Leaves pentagonally oval to elongate-cordate, 7 to 10.5 cm. long and 5 to 8 cm. wide; base rounded, broadly cordate; apex abruptly narrowed, somewhat acuminate; midrib stout, nearly straight, slightly tapered in apex; secondary veins rather thin, 10 to 12 opposite to subopposite pairs, diverging at angles of 45 to 50 degrees at the middle portion of blade, lower at apical part, higher toward the base, one or two pairs of basal secondaries forming 90 degrees or more with midrib; all secondaries gently curving up, craspedodrome, near the margin branching off a few subsecondaries which end in marginal teeth; tertiary veins distinct, percurrent, enclosing coarse network; nervilles thin, making fine meshes; margin serrate, with rather obtuse teeth; texture thin; petiole stout, 1.2 to 1.8 cm. long.

Remarks: This new species of alder is represented by a number of well-preserved leaves from the Harutori mine. Two leaves described as *Corylus japonica* from the Ikushubetsu flora (ENDO, 1968) are referred to *Alnus* in their secondary venation character, and are identical with our new species. They may be emended as "*Alnus japonica* (ENDO) ", based on nomenclature priority, but this specific name has been already used for a living alder of Japan (*A. japonica* S. et Z.). *A. hokkaidoensis* is closely similar to *Alnus palibinii* GRUB. from the Oligocene flora of Kazakhstane, central Asia (GRUBOV, in KYSHTOFOVICH, 1956) in their shape, secondary venation and margin. Another allied species is *A. usyuensis* HUZIOKA from the Miocene floras of Hokkaido (TANAI, 1961; TANAI and SUZUKI, 1963), but differs in marginal serration. A single leaf reported as *Betula macrophylla* from the Paleogene of western coast of Saghalien (BORSUK, 1956) is inseparable from our new species in venation and marginal serration. *A. hokkaidoensis* is somewhat similar to *Betula macrophylla* HEER from the Tertiary of central Europe (HEER, 1855; REIMANN in KRAUSEL, 1917), but distinctly differs in venation character of basal secondaries.

No living alders in the world are definitely similar to *A. hokkaidoensis*, but it resembles *A. rugosa* SPRENGLEL of North America, *A. incana* WILD. of Europe and *A. hirsuta* TURCZ. of East Asia in its shape and secondary venation.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Ponki; Pon-Shitakara, Yubetsu; Shoro; Onbetsu mine.

Collection: H.U.M.P., holotype no. 25918, paratype no. 25919; no. 25920.

Alnus kushiroensis new species

Pl. 8, fig. 1; pl. 9, fig. 5

Description: Leaves elliptically ovate, 7 to 12 cm. (estimated) long and 4.2 to 9. 5cm. wide; base rounded to truncately rounded; apex abruptly narrowed; midrib rather slender, somewhat zigazg; secondary veins slender, 8 to 9 subalternate pairs, diverging at angles of 40 to 45 degrees in the middle and upper portion of blade, gradually higher toward base, a pair of basal secondaries diverging at right angles; most of secondaries gently curving up, craspedodrome, few lower pairs of secondaries curving up along the margin, forming loops with tertiaries; tertiary veins in intersecondary spaces distinct, irregularly percurrent, tertiaries near the margin branching off from secondaries, dichotomously branching, ending in marginal teeth; nervilles thin, finely reticulate; margin finely serrate, with nearly equal-sized teeth; texture thin; petiole missing.

Remarks: Several well-preserved impressions of incomplete leaves are referred to *Alnus* by their venation and marginal serration. They are closely similar to *A. schmalhausenii* GRUB. from the Oligocene Ashutus flora of Kazakhatane, Central Asia (GRUBOV, in KRISHTOFOVICH, 1956). The Russian species is variable in basal form, from broadly cuneate to truncately rounded; our leaves are difficult to distinguish some leaves of the Russian species. *A. kushiorensis* somewhat resembles the above-described *A. hokkidoensis* in general appearance, but distinctly differs in margin and venation. Another resembling species is *A. carpindoides* LESQ. from the Lower and Middle Tertiary floras of North America (LESQUEREUX, 1883; MACGINITIE, 1953; BROWN, 1937), but it somewhat differs in marginal serration. *A. rottensis* WILD. from an Oligocene flora of Germany (WEYLAND, 1943) is also somewhat similar to *A. kushiroensis*.

No modern leaves of alder in the world are definitely similar to this new species, but it is somewhat similar in shape, marginal serration and venation to the living *A. serrulata* WILD. of North America.

Occurrence: Harutori mine; Ponki.

Collection: H.U.M.P., holotype no. 25921; paratype no. 25922; no. 25923.

Carpinus kushiroensis new species

Pl. 9, figs. 2, 4, 6–8

Betula brongniarti ETTINGS. ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 423, pl. 7, figs. 1, 2, 1968.

Description: Leaves ovate, 3.7 to 7.6 cm. long and 2.4 to 4.7 cm. wide; apex acute to slightly acuminate; base rounded, slightly cordate; midrib stout, nearly straight or slightly arcuate at upper part; secondary veins strong, 9 to 12 paris, opposite to alternate, diverging at angles of 35 to 45 degrees in the middle part of blade, somewhat lower in the upper part and higher toward base, subparallel, nearly straight, ending in larger marginal teeth, one or two pairs of basal secondaries slender, extending at nearly right angles; a few subsecondary veins from secondaries branching abaxially near the margin, ending in smaller teeth; tertiaries distinct, irregularly percurrent; nervilles thin, finely reticulate; margin duplicately serrate, with acute teeth; texture thin, petiole missing.

Remarks: The leaves of this species are widely found from many localities of the Kushiro coal field, though they are not abundant. They are referred to *Carpinus* in their venation and margin, and resemble leaves of the modern *C. tschonoskii* MAXIM. and *C. cordata* BLUME of East Asia. However, this generic identification may be doubtful because of no fossil bract from the Kushiro fields. *C. kushiroensis* is closely similar to *C. grandis* UNGER, which has been widely reported from the Tertiary of the northern hemisphere (UNGER, 1845; REIMANN in KRAUSEL, 1917; HOLLICK, 1936). Another similar species is *C. subyedoensis* KONNO commonly found in the Neogene flora of East Asia (TANAI, 1961; TANAI and ONOE, 1961), but differs in basal pairs of secondaries. Two leaves described as *Betula brongniarti* from the Ikushunbetsu flora (ENDO, 1968) are identical with our new species.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine; Pon-Shitakara, Yubetsu; Shoro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., holotype no. 25924; paratype no. 25925; hypotypes nos. 25926–25928.

Corylus ezoana new species

Pl. 8, figs. 5, 6; pl. 9, figs. 1, 3; pl. 12, figs. 1

Corylus macquarrii FORBES. KRYSHTOFOVICH, Materials for Paleogene Lower Due Flora of Saghalien, p. 714, pl. 2, figs. 7, 8; text-fig. 7, c, d, 1936.

Corylus americana WALT. fossilis NEWBERRY. BORSUK, Paleogene flora of Saghalien, p. 28, pl. 4, figs. 8–10, 1956.

Description: Leaves ovate to oval, sometimes orbicular in shape, 2.3 to 13 cm. long and 1.7 to 8.5 cm. wide; base asymmetric, broadly to deeply cordate; apex abruptly narrowed, with acute tip; midrib stout, nearly straight; secondary veins rather stout, 8 to 13 paris, opposite to subopposite, diverging at angles of 40 to 50 degrees in one side, and at angles of 55 to 75 degrees in the other, gently curving up, craspedodrome; one or two pairs of basal secondaries diverging at right angles or more, craspedodrome, branching off 4 or 5 subsecondaries; several subsedondaries branching abaxially from secondaries, ending in smaller marginal teeth; tertiary veins distinct, percurrent; nervilles thin, forming fine network; margin duplicately serrate, with acute teeth; texture thin; petiole stout, more than 1 cm. long.

Remarks: This new species of hazel-nut is represented by a number of well-preserved impressions from all the localities of the Kushiro coal field. These leaves, though highly variable in shape and size, are referred to *Corylus* by characteristic venation and marginal serration; they are closely similar to those of the modern *C. sieboldiana* BLUME of Japan and Korea, and also are similar to those of the modern *C. chinensis* FRANCH. of central and southern China. Among the fossil hazel-nuts *C. ezoana* closely resembles *C. macquarrii* (FORBES) HEER which has been commonly described from the Tertiary of the northern hemisphere. This European species includes a number of various leaf forms showing somewhat different secondary venation, and has been frequently abused for a century. Therefore it may be better to assign our specimens to a new species.

Several leaves described as *C. americana* fossilis from the Paleogene of Saghalien (BORSUK, 1956) are closely similar to our new species, and are included in *C. ezoana*. Our new species is also closely similar to *C. insignis* HEER from the Paleocene of North America (BROWN, 1962), and also to *C. kenaiana* HOLLICK* from the Paleogene of Alaska (HOLLICK, 1936). Another similar species is *C. jaromlenkoi* GRUBOV from the Oligocene Ashutus flora of Kazakhstane, Central Asia (GRUBOV, in KRYSHTOFOVICH, 1956), but *C. jaromlenkoi* has usually 15 to 16 pairs of secondary veins.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Ponki; Pon-Shitakara, Yubetsu; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., holotype no. 25929; paratype no. 25930; hypotypes nos. 25931–25933.

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* Recently, leaves of *C. kenaiana* have been emended to *Alnus adumbrata* (HOLLICK) by WOLFE (1966).

Family FAGACEAE

Quercus kushiroensis new species

Pl. 10, figs. 9, 11; pl. 20, figs. 2

Description: Leaves lanceolate, 9.5 to 12 cm. long (estimated) and 2.5 to 2.8 cm. wide; apex acuminate; base somewhat asymmetrical, obtuse or broadly cuneate; midrib stout, opposite to subopposite, 10 to 13 paris, diverging at angles of 45 to 55 degrees in the middle and upper part of blade, at somewhat wider angles in the lower part, nearly straight or gently curving, craspedodrome; tertiary veins not prominent, percurrent; nervilles indistinct, but finely reticulate; margin simply serrate, with small acute teeth except entire lower part; texture coriaceous; petiole thick, more than 1 cm. long.

Remarks: These leaf impressions, though incomplete, are referred to *Quercus* in their shape, venation and marginal character, and closely resemble those of the modern *Q. myrsinaefolia* BLUME distributed in Japan and China. Among the fossil oaks, *Q. kushiroensis* is closely similar to *Q. scudderi* KNOWLTON from the Oligocene Florissant flora (MACGINITIE, 1953) and *Q. simulata* KNOWLTON from the Miocene floras of North America (CHANEY and AXELROD, 1959; KNOWLTON, 1926). Another similar species is *Q. nathorsti* KRYSHTOFOVICH commonly found from the Middle Miocene of Japan (TANAI, 1961; HUZIOKA, 1963), but somewhat differs in marginal serration.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine; Pon-Shitakara, Yubetsu; Shoro.

Collection: H.U.M.P., holotype no. 259344; paratypes nos. 25935, 25936.

Family ULMACEAE

Planera ezoana OISHI and HUZIOKA

Pl. 10, figs. 2, 4, 5

Planera ezoana OISHI and HUZIOKA, Jap. Jour. Geol. Geogr. vol. 24, p. 141, pl. 14, figs. 7–9, 1954.

Ulmus nipponica ENDO, Bull. Natl. Sci. Mus., vol. 11, nos. 4, p. 426, pl. 25, figs. 4, 5; pl. 26, figs. 2, 7, 1968.

Ulmus yubariensis ENDO, (in part). ibid., p. 427, pl. 22, figs. 6, 7 (not p. 24, fig. 6), 1968.

Betula ezoensis ENDO. ibid., p. 423, pl. 5, fig. 6, 1968.

Remarks: A number of well-preserved leaves from all the localities of the Kushiro field resemble leaves of *Chaetoptelea*, *Ulmus* and *Zelkova*, but are referred to this species by their characteristic venation and crenato-serrate margin: many secondary veins are forking at some distance inward from the margin; the marginal teeth are single, double, or mixed. However, no characteristic fruits of *Planera* have been found. These leaves are closely similar in venation and margin to the modern *P. aquatica* GMELIN of the southeastern United States, though somewhat differs in basal character. *P. ezoana* is closely similar to *P. microphylla* NEWBERRY, *P. inaequilateralis* (LESQ.) KNOWLTON, and *P. hickmanensis* BERRY from the Paleogene of North America (NEWBERRY, 1868; BROWN, 1962; KNOWLTON, 1923; BERRY, 1924), and especially is closer to the last. A single leaf figured as *P. aquaticiformis* by HOLLICK (1936) from the Tertiary of Alaska closely resembles *P. ezoana* in venation, but not similar in margin; it seems doubtfully referable to this genus. All leaves described as *Ulmus nipponica* and *Betula ezoensis*, and two leaves of *Ulmus yubariensis* from the Ikushunbetsu flora are quite identical with *Planera ezoana* in their venation and marginal characters, and they represent small leaves of *Planera*.

The similar living species, *P. aquatica*, is a water-loving trees, and is confined in its habitat to swamps covered with water during several months of the year, or to low river banks. The abundant occurrence of *P. ezoana* in the Harutori flora may show a similar habitat in the Harutori basin.

Occurrence: Harutori mine; Tokomuro; Pon-Shitakara, Yubetsu; Shoro; Shiranuka; Onbetsu coal mine.

Collection: H.U.M.P., hypotypes nos. 25937–25939.

Trema asiatica (BORSUK) new combination

Pl. 8, figs. 3, 4; pl. 9, fig. 9

Celtis asiatica BORSUK. Paleogene flora of Saghalien, p. 44, pl. 9, figs. 6–9, 1956.

Supplementary description: Leaves ovate-lanceolate to oblanceolate, triplinerved, 3.5 to 5 cm. long (estimated) and 0.9 to 2.1 cm. wide; apex missing; base asymmetrically obtuse; midrib stout below, rather slender distad; a pair of basal secondaries diverging at small angles, arising up along the margin, making a loop within marginal border; other secondaries slender, 4 or 5 subopposite paris, diverging at 25 to 50 degrees, curving up, near the margin abruptly arising up, making a distinct loop; slender subsecondaries sometimes diverging among interscondary spaces; a few branches from the secondaries giving off on marginal side, looping or ending in marginal teeth; tertiary veins mainly forming a coarse network but with occasional percurrent crossties; nervilles indistinct, finely reticulate; margin finely serrate, with acute teeth; texture subfirm; petiole stout, but nearly missing.

Remarks: These leaves are similar to *Boehmeria*, *Debregeasia*, *Aster*, *Celtis* and *Trema* in general appearance, and most closely resemble those of the last genus in venation and marginal serration. They are closely similar to those of the modern *T. cannabina* Lour. living in subtropical and tropical regions of southeastern Asia, though they are somewhat smaller in size and cuneate at the base. The leaves described as *Celtis asiatica* from the Paleogene of Saghalien are rather different in secondary venation from *Celtis*. They are closely similar to our specimens, and are conspecific. *T. asiatica* somewhat resembles leaves of the modern *Aster argeratoides* TURCZ. var. of Japan and Formosa in shape and venation, but differs in finely serrate margin. Our species somewhat resembles *Populites heeri* (LESQ.) MACGINITIE in shape and venation from the Oligocene Florissant flora of the western United States (MACGINITIE, 1953), but distinctly differs in marginal serration and detailed venation.

The closest modern species, *T. cannabina* is widely distributed in southern China, Formosa, Malaysia, Philippine, and Australia.

Occurrence: Harutori mine; Tokomuro.

Collection: H.U.M.P., hypotypes nos. 25940–25942.

Ulmus harutoriensis OISHI and HUZIOKA

Pl. 7, fig. 8; pl. 10, figs. 3, 10

Ulmus harutoriensis OISHI and HUZIOKA, Jap. Jour. Geol. Geogr. vol. 24, p. 129, pl. 15, fig. 2, 1954.

Ulmus shimogawarae OISHI and HUZIOKA, ibid. p. 132, pl. 15, fig. 1.

Remarks: This species is represented by a number of well-preserved leaves from all the localites, which are highly variable in shape; the smallest one is 3.2 cm. wide and 4.3 cm. long, and the largest 8.5 cm. wide and 13.5 cm. long. A single leaf figured as *U. shimogawarae* from the Ishikari coal field by OISHI and HUZIOKA (1954) is inseparable from *U. harutoriensis* in all characters excepting of smaller size, because our specimens include many intermediate forms between these two species. *U. harutoriensis* closely resembles *U. shiragica* HUZIOKA, which is a common elm in the Lower Miocene of Japan (HUZIOKA, 1951; TANAI, 1961; TANAI and N. SUZUKI, 1963), but differs in more inequilateral shape and more deeply biserrate margin. Another similar species is *U. appendiculata* HEER from the Lower Miocene of Saghalien and Hokkaido (HEER, 1878; OISHI and HUZIOKA, 1954; TANAI, 1961), but *U. appendiculata* is strongly asymmetric at the base, from obliquely cordate to truncate.

Among the living elms *U. harutoriensis* is somewhat similar to the modern *U. davidiana* PLANCH. of North China and *U. fulva* MICHX. of eastern North America.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Pon-Shitakara, Yubetsu; Shoro; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25943–25945.

Zelkova kushiroensis OISHI and HUZIOKA

Pl. 10, figs. 1, 6–8

Zelkova kushiroensis OISHI and HUZIOKA, Jap. Jour. Geol. Geogr. vol. 24, p. 136, pl. 16, figs. 7–11, 1954.
Zelkova takahashii OISHI and HUZIOKA, ibid. p. 136, pl. 15, fig. 8, 1954.
Zelkova tibae OISHI and HUZIOKA, ibid. p. 137, pl. 16, figs. 3–6, 1954.
Ulmus yubariensis ENDO (in part), Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 427, pl. 24, fig. 6 (not pl. 22, figs. 6, 7), 1968.

Remarks: A number of well-preserved leaves are found at all localities in the Kushiro coal field are referred to *Z. kushiroensis*. These leaves are highly variable in shape, size, marginal teeth, and number of secondary veins: they range from elliptical to ovate in shape, and in number of secondaries from 7 to 15 pairs, mostly 9 to 12. *Z. takahashii* and *Z. tibae* from the Paleogene of the Ishikari and Rumoe coal fields, central Hokkaido were distinguished from *Z. kushiroensis* by OISHI and HUZIOKA (1954), having less secondary veins and roundly obtuse marginal teeth. However, there is intergradation of such variants in the writer's collection, and so it is impossible to distinguish these 3 species by foliages. Only one leaf figured as *Z. tibae* from the Miocene flora of Korea by HUZIOKA (1951) is closely similar to some type of *Z. kushiroensis*, but is distinguishable by more deep marginal serration. *Z. kushiroensis* closely resembles *Z. ungeri* which is commonly found in the Neogene of Japan and Europe, but differs in marginal serration. One of the leaves described as *Ulmus yubariensis* from the Ikushunbetsu flora (ENDO, 1968, pl. 24, fig. 6) may represent a small leaf of *Zelkova kushiroensis*.

Z. kushiroensis is closely similar to the modern *Z. serrata* MAKINO of Japan, but is generally more obtuse in marginal teeth and apex; in such foliage appearance *Z. ungeri* is more closely related to the modern species.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Ponki; Pon-Shitakara, Yubetsu; Chinomizawa, Shoro; Shinshiranuka mine; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25946–25949.

Family MORACEAE

Broussonetia sp.

Pl. 11, figs. 4, 6

Description: Leaves trilobed, variable in shape, cordate to oval, 4.5 to 5 cm. long (estimated) and 3.5 to 3.8 cm. wide; medial lobe rhombic, with a pair of small lobes, lateral lobes elliptical; base broadly rounded to obtuse; apice of each lobe acute; midrib medium, nearly straight; lateral primaries leaving midrib about 1 mm. above the base, at angles of about 40 degrees, a pair of subprimaries diverging from the base, extending along the basal margin; secondary veins not preserved; margine finely serrate; texture subfirm; petiole thick, incomplete, more than 3 mm. long.

Remarks: These specimens surely represent leaves of the Moraceae in their peculiar shape and margin, though they are very ill-preserved. They are rather referred to *Broussonetia* than to *Morus* in marginal serration, and are closely similar to trilobed or young leaves of *B. papyrifera* VENT. and *B. kazinoki* SIEB. of Japan and China. No fossil leaves of *Broussonetia* in the world are comparable to our species.

Occurence: Harutori mine.

Collection: H.U.M.P., no. 25950a, b.

Ficus sp.

Pl. 12, fig. 4

Description: Leaves very incomplete, unknown in general outline and length, 5 to 7.5 cm. wide; upper half missing; base obtuse to rounded; midrib stout, nearly straight; secondary veins stout, numerous, opposite to alternate, somewhat irregularly spaced, diverging at angles of 70 to 90 degrees, nearly straight and subparallel, their distal ends connected by acrodrome marginals, which are arching from secondary to secondary; a few slender subsecondary veins diverging from midrib among intersecondary spaces; tertiaries among the intersecondary spaces thin, forming large, polygonal mesh; tertiaries of marginal border branching from acrodrome marginals, camptodrome; nervilles thin, finely reticulate; texture thick; petiole thick but incomplet, more than 5 mm. long.

Remarks: Two fragmentary leaves from the Harutori mine show characteristic secondary venation, though their upper portion is missing. They resemble some leaves of the Myrtaceae, Apocynaceae and Moraceae, and have a close similarity to leaves of *Ficus cuspidatocaudata* HATAYA and *F. vasculosa* WALL of Formosa in their shape and venation. They are also similar to leaves of *Syzygium kuskusuense* MORI of Formosa, but differs in shape and size. These fossil leaves somewhat resemble *F. spiculifolia* NAGAI from the Upper Eocene Kuma flora of Shikoku (NAGAI, 1957), but differs in details of secondary venation.

Occurrence: Harutori mine.

Collection: H.U.M.P., nos. 25951, 25952.

Family NYMPHAEACEAE

Nelumbo nipponica **ENDO**

Pl. 11, fig. 7

Nelumbo nipponica ENDO (in part), Jap. Jour. Geol. Geogr. vol. 11, nos. 3–4, p. 255, pls. 36, 37 (not pl. 38), 1934.
ENDO, Icon. Fos. Plants Jap. Isl., pls. 11a, 12, 1955.
TANAI, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 324, pl. 19, figs. 1, 2, 1961.

Remarks: Several incomplete leaves of *Nelumbo* from the Harutori coal mine are identified as *N. nipponica* by 21 stout primary veins and mode of their furcation. A fragmentary rhizome of *Nelumbo* occurred from the same locality, and may be referred to this species. *N. nipponica* resembles, at a general appearance, *N. endoana* OISHI and HUZIOKA commonly found from the Middle Miocene of Hokkaido and Honshu (TANAI, 1961), but distinctly differs in thick primaries and mode of their dichotomy. *N. nipponica* is closely similar to *N. protospeciosum* SAPORTA from a Oligocene flora of France (SAPORTA, 1890) and *N. protoluteum* (BERRY) LAMOTTE from the Eocene Wilcox flora of the United States (BERRY, 1917), though it is generally larger in size and less in number of primaries. Recently, on the basis of leaves from the Tertiary of Kazakhstane VASILIEV (1961) placed synonymy all Tertiary *Nelumbo* species of East Asia to *N. protospeciosum*, but these species are distinctly distinguishable.

N. nipponica is closely similar to the modern *N. nucifera* GAERTN., which is distributed natively in northern Australia, Iran, India and southern China. This living species is widely cultivated in ponds and marsh of Japan.

Occurrence: Harutori mine.

Collection: H.U.M.P., hypotype no. 25953; no. 25954.

Family CERCIDIPHYLLACEAE

Cercidiphyllum eojaponicum FNDO

Pl. 7, fig. 9; pl. 11, figs. 2, 3, 8

Cercidiphyllum eojaponicum ENDO, Bull. Cent. Nat. Mus. Manch. no. 3, p. 41, pl. 16, fig. 5, 1952.
ENDO, Icon. Fossil Plants Jap. Isl. pl. 28, fig. 1, 1955.
Cercidiphyllum elongatum BROWN. ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 433, pl. 10, figs. 3, 4; pl. 21, fig. 1, 1968.
Cercidiphyllum paleojaponicum ENDO, ibid., p. 433, pl. 9, fig. 4; pl. 15, figs. 3–5, 1968.
Cerdiphyllum japonicum var. *orientalis* ENDO, ibid., p. 434, pl. 8, fig. 7, 1968.
Cercidiphyllum arcticum BROWN, ENDO (in part), ibid., pl. 21, figs. 5–8; pl. 26, figs. 5, 6, 9 (not figs. 1, 3, 4), 1968.
Celastrus taurinensis WARD. ENDO, ibid., p. 437, pl. 17, fig. 2, 1968.

Supplementary description: Leaves highly variable in shape, from broadly to deltoid, sometimes cordate to reniform, usually symmetrical, 3.8 to 12 cm. wide; base variable, mostly broadly cuneate to rounded with a slightly cordate form, but sometimes deeply cordate; apex acute, frequently with a slightly elongate tip; midrib stout, nearly straight; 2 pairs of lateral primaries diverging from the base or very near the base, an inner pair stout as similar as in the midrib, forming acute angles with the midrib, then nearly parallel to midrib, acrodrome, an outer pair rather slender, making wider angles with the midrib, curving up along the lower margin, in the middle part of blade forming large loops with secondaries branching from the inner primaries; a pair of thin primaries diverging from the inner primaries; a pair of thin primaries diverging from the base in most outside, creeping up along the lower margin; 5 to 7 pairs of secondary veins leaving from the midrib and lateral primaries at various angles, irregularly spaced, making distinct loops; tertiary veins from the lateral primaries and secondaries in the marginal border forming distinctly small loops: tertiaries among secondaries or primaries irregularly percurrent or coarsely reticulate; nervilles thin, forming fine network; margin regularly rounded-dentate to crenate except basal part where it is entire; marginal glands existing within teeth: texture thin; petiole rather slender, more than 2.8 cm. long.

Remarks: A number of leaf impressions from all the localities, including many complete specimens, are referred to *Cercidiphyllum* by their margin, venation and marginal glands, though they are highly variable in shape and size. These leaves are closely similar to some type of the modern *C. japonicum* SIEB. and ZUCC.

of central and northern Japan, though most of ordinary leaves of the modern species are cordate to reniform. On the basis of broadly elliptical leaves from the Oligocene Fushun flora of Manchuria, ENDO (1942, 1955) established a new species of *C. eojaponicum* with no valid description; however our specimens include broadly elliptical leaves which are identical with *C. eojaponicum*. On the one hand, there is intergradation of foliage character among our variable leaves so that it is impossible to distinguish different species. Accordingly, the author uses *C. eojaponicum* for our specimens with redesignation. The most leaves are estimated to be 4 to 5 cm. long and 5 to 7 cm. wide in average; a largest leaf (11 cm. long and 14 cm. wide) is probably that of young trees, and is referred to this species.

BROWN (1939) investigated extensively a number of specimens of *Cercidiphyllum* and the leaves of *Populus* and other genera which may be mistaken for *Cercidiphyllum* in North America; he attempted to distinguish 4 species, *C. arcticum* (HEER) BROWN, *C. ellipticum* (NEWBERRY) BROWN, *C. elongatum* BROWN, and *C. crenatum* (UNGER) BROWN. Most of our leaves are closely similar to those of *C. elongatum* BROWN from the Middle Eocene to the Lower Miocene of North America (BROWN, 1939; MACGINITIE, 1941). However, some of them also closely resemble *C. arcticum* from the Paleocene to the Middle Eocene. In actual, it seems frequently difficult to distinguish two types of *C. arcticum* and *C. elongatum* on the basis of Japanese specimens which the author has collected from the Paleogene. On the one hand, most of European authors has favoured to use *Trochodendroides arctica* (HEER) BERRY for the leaves of *C. arcticum* type, which was originally described as *Populus* by HEER (1866). *C. eojaponicum* is closely similar to *C. crenatum* from the Miocene floras of Japan (TANAI, 1961; TANAI and N. SUZUKI, 1963), but differs in nearly symmetrical shape. Two incomplete leaves figured as *C. eojaponicum* from the Upper Eocene Kuma flora of Shikoku (NAGAI, 1957) are entire-margined, and so they are rejected from *C. eojaponicum*. An incomplete leaf of *C. takashimensis* MATSUO lately established from the Eocene Takashima flora of Kyushu (MATSUO, 1967), falls in the variation of *C. eojaponicum*, and is conspecific.

C. eojaponicum is commonly found not only through the Urahoro group, but through the Ishikari and Uryu groups of central Hokkaido. It was one of the most common deciduous broad-leafed trees in Paleogene forest of Hokkaido.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shakubetsu mine; Ponki; Pon-Shitakara; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 25955–25958; nos. 25959–25962.

Family MENISPERMACEAE

Cocculus ezoensis new species

Pl. 11, figs. 1, 5; pl. 12, fig. 2

Cercidiphyllum japonicum SIEB. and ZUCC.. ENDO, Bull. Natl. Sci. Mus., pl. 21, figs. 3–5, 1968.

Cercidiphyllum arcticum BROWN. ENDO (in part), ibid., pl. 20, figs. 3,4 (not fig. 5); pl. 21, fig. 9 (not figs. 5–8); pl. 26, figs. 1, 3, 1968.

Description: Leaves oval or orbicular to depressed orbicular or depressed obovate, 3.7 to 6.5 cm. long and 3.2 to 9 cm. wide; apex obtuse to truncate with slightly cordate form; primary veins three; midvein nearly straight, more stout than lateral primaries, usually having 2 or 3 secondary veins in the upper portion; lateral primaries diverging nearly along the midrib, then turning up at 20 to 40 degrees, curving upward, reaching near apex, joining the lowest pair of secondaries on the midvein; abaxial secondaries from lateral primaries 5 to 6, gently curving up, forming loops near the margin; tertiary veins among intersecondary spaces forming coarse, irregularly polygonal network; tertiaries of marginal border branching from secondaries, forming small marginal loops; nervilles finely reticulate; margin nearly entire, irregularly undulate, sometimes irregularly shallowed-lobed; texture thin; petiole thick, but rather slender, 3 to 4 cm. long.

Remarks: A number of well-preserved leaves from the all localities are closely similar to *Hedera*, *Cocculus* and *Sinomenium* in general appearance, and are referred to *Cocculus* by their marginal and venation characters. They show highly variable shape and size as similar as in the leaves of the living *Cocculus*. Leaves figured as *C. heteromorpha* (KNOWLTON) BROWN from the Miocene floras of Honshu and Hokkaido (TANAI, 1961), are similar to *C. ezoensis*, but differs in marginal characters. This new species is closely similar to some leaves of *C. flabella* (NEWBERRY) WOLFE from the Paleogene of Alaska (WOLFE, 1966) in their shape and venation. But a single leaf figured by WOLFE (WOLFE, 1966; pl. 1, left figure of fig. 2), is rather referred to *Disanthus*, and is closely similar to *D. nipponicus*. Several leaves described as *Cercidiphyllum japonicum* and *C. arcticum* (in part) from the Ikushunbetsu flora (ENDO, 1968) have undulate margin, and are undoubtedly referred to *Cocculus ezoensis*.

Occurrence: Harutori mine; Nakanosawa, Yubetsu.

Collection: H.U.M.P., holotype no. 25906b; paratype no. 25964; hypotype no. 25965.

Family HAMAMELIDACEAE

Disanthus nipponicus TANAI

Disanthus nipponicus TANAI. Trans. Proc. Palaeont. Soc. Japan, N.S., no. 66, p. 58, pl. 6, figs. 3, 7, 1967.
Disanthus eocercidifolius MATSUO. Ann. Sci. Kanazawa Univ., vol. 4, p. 51, pl. 7, figs. 4–6, 1967.

Remarks: This species was lately established on the basis of well-preserved leaves from the Paleogene of the Kushiro and Ishikari coal fields. It is closely similar to the modern *Disanthus cercidifolius* MAXIM., which is rarely living in Honshu and Shikoku, Japan, and in central China. *D. eocercidifolius* recently established from the Eocene Takashima flora of Kyushu (MATSUO, 1967) is more similar to the modern species in their shape, but is inseparable from *C. nipponicus*.

Occurrence: Harutori mine.

Hamamelis kushiroensis TANAI

Hamamelis kushiroensis TANAI, Trans. Proc. Palaeont. Soc. Japan, N.S., no. 66, p. 59, pl. 6, figs. 5, 6, 1967.
Viburnum nordenskioldi HEER, ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p.. 441, pl. 19, figs. 1–3, 1968.

Remarks: This species was recently established on the basis of well-preserved leaves from the Harutori coal mine, and is closely similar to the modern *Hamamelis japonica* SIEB. and ZUCC. widely distributed from Hokkaido to Kyushu. Two leaves described as *Viburnum nordenskioldi* from the Ikushunbetsu flora (ENDO, 1968) are referred to *Hamamelis* in their secondary venation and undulate margin, and are included in *H. kushiroensis*.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25863; hypotype no. 25864.

Liquidambar miosinica HU and CHANEY

Pl. 15, fig. 8

Liquidambar miosinica HU and CHANEY, Palaeont. Sinica, new ser. A, no. 1, p. 46, pl. 23, figs. 1, 2, 1938.
TANAI, Trans. Proc. Palaeont. Soc. Japan, N.S., no. 66, p. 60, pl. 7, figs. 2–6,

1967.

Liquidambar protoformosana var. *eocenica* ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 435, pl. 24, figs. 1–4, 1968.

Remarks: *Liquidambar* leaves from the Paleogene of Hokkaido were already discussed by the writer (TANAI, 1967), and all of them are closely similar to the modern *L. formosana* HANCE of East Asia. A single specimen from the Yubetsu formation is five-lobed, but is closely similar to the five-lobed leaves of *L. formosana* in their venation character. A compressed fruit covered with a number of long spines from the Harutori mine, is referred to *Liquidambar* by its characteristic feature.

Occurrence: Harutori mine; Nakanosawa, Yubetsu.

Collection: H.U.M.P., hypotypes nos. 25865, 25966.

Family PLATANACEAE

Platanus aceroides GOEPPOERT

Pl. 12, fig. 9

Platanus aceroides GEOPPERT, Die tertiare Flora von Schossnitz in Schlesien, p. 21, pl. 9, figs. 1–3, 1855.

ENDO, Tokyo Hakubutsugaku-zashi, vol. 35, p. 390, text-figs. 2, 5, 1937.

OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 7, p. 106, pl. 15; pl. 16; pl. 17, fig. 1, 1943,

Platanus aceroides GOEPPERT subsp. *yubariensis* ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 434, pl. 16, figs. 1–4,; pl. 17, fig. 1; pl. 26, fig. 8, 1968.

Remarks: A number of large leaves, though most of them are incomplete, are identical with *P. aceroides* in their cordate base, characteristic venation and marginal serration, which was widely distributed in the Paleogene of the northern hemisphere. As already stated by OISHI and HUZIOKA (1943), *P. aceroides* along with *P. guillelmae* is commonly found in th Paleogene coal-bearing formations of the Kushiro, Ishikari and Rumoe coal fields, Hokkaido. These two Paleogene plane-trees only survived in the lower-Middle Miocene of southwestern and central Hokkaido. *P. aceroides* is closely similar to the modern *P. occidentalis* LINN. of the southeastern United States and *P. orientalis* LINN. of western Asia and southeastern Europe.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine; Pon-Shitakara, Yubetsu; Shoro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotype no. 25967.

Platanus guillelmae GOEPPERT

Pl. 12, fig. 6

Platanus guillelmae GOEPPERT, Die tertiare Flora von Schossontz in Schlesien, p. 21, pl. 11, figs. 1, 2; pl. 12, fig. 5, 1855.
ENDO, Tokyo Hakubutsugaku-zashi, vol. 35, p. 389, text-fig. 4, 1957.
OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 7, p. 110, pl. 17, figs. 2, 3; pl. 18, figs. 2, 3, 1943.
Sassafras yubariensis ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 433, pl. 24, fig. 5, 1968.

Remarks: A number of fragmentary leaves are referred to *P. guillelmae* by their cuneate base and venation. A single incomplete leaf established as *Sassafras yubariensis* from the Ikushunbetsu flora (ENDO, 1968) is probably referred to *Platanus guillelmae* by its venation and basal form, though its upper portion is lacking. *P. guillelmae* was considered to be synonymous with *P. aceroides* by some European and North American authors such as KRÄUSEL and MEYER (1917) and MACGINITIE (1941), because there are intermediate leaf forms between these two species. On the other hand, there are many authors who consider them to be specifically distinguishable, such as OISHI and HUZIOKA (1943), ENDO (1937), KRYSHTOFOVICH (1956), and HEER (1878). The author have only smal collection of these well-preserved sycamore leaves, and so will discuss in future paper.

Occurrence: Harutori mine; Tokomuro; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotype no. 25968.

Family ROSACEAE

Spiraea kushiroensis new species

Pl. 7, figs. 3,4

Description: Leaves nearly orbicular, 2.5 to 3.7 cm. long and 2.1 to 3.4 cm. wide; base rounded; apex obtuse; midrib stout, thick, somewhat flexuous; secondary veins prominent but rather slender, 5 or 6 pairs, subopposite to subalternate, diverging at angles of 30 to 40 degrees on the middle, at larger angles in the lower, slightly wavy, craspedodrome; a few branches near the margin originating from secondaries, ending in marginal small teeth; tertiaries thin, forming large network; nervilles finely reticulate; margin somewhat incised, doubly serrate, with rather obtuse teeth; texture thin; petiole thick, more than 3 mm. long.

Remarks: Two leaves, though somewhat incomplete, are referred to *Spiraea* on secondary venation, and is closely similar in shape, venation and margin to leaves of *S. betulifolia* PALL. and *S. nervosa* FRANCH. and SAV. of Japan. No fossil *Spiraea* in the world is comparable to our specimens.

Occurrence: Harutori mine; Shoro.

Collection: H.U.M.P., holotype no. 25969; paratype no. 25970.

Family RUTACEAE

Zanthoxylum oblongatum new species

Pl. 12, figs. 5, 8

Description: Leaflets oblong to ovate-lanceolate, 4.2 to 7 (estimated) cm. long and 1.2 to 2.8 cm. wide; apex abruptly acute; base asymmetrically rounded, slightly cordate; midrib stout, nearly straight; secondary veins slender, 10 to 12 pairs opposite to subopposite, somewhat narrowly spaced at lower part, diverging at angles of 50 to 60 degrees at the middle, at nearly right angle in the basal part, gently curving up, ending in marginal teeth, sometimes forking in the half way; tertiaries thin, making irregularly quadrangular mesh; nervilles finely reticulate; margin finely serrate, with remote but acute teeth which include a gland respectively; texture thin; petiolule missing.

Remarks: These leaflets are suggestive of *Sorbus* or *Spiraea* in shape and venation character, but are apparently referred to *Zanthoxylum* in having glands on marginal teeth. They are closely similar to leaflets of the modern *Z. planispinum* SIEB. and ZUCC. of East Asia. No similar leaflet of *Zanthoxylum* is comparable to *Z. oblongatum*, though a number of species of *Zanthoxylum* have been reported from the Tertiary of Europe and North America. Three leaflets figured as *Fagara ailanthoides* SIEB. and ZUCC. (Syn. *Z. ailanthoides*) from the Late Miocene Omi flora of north-central Honshu (KONNO, 1931) are somewhat similar to *Z. oblongatum*.

The modern equivalent, *Z. planispinum*, is distributed in central and western Honshu, Shikoku and Kyushu, and extends into southern Korea, China, Ryukyu islands and Formosa.

Occurrence: Harutori mine; Nakanosawa, Yubetsu.

Collection: H.U.M.P., holotype no. 25971; hypotype no. 25972; no. 25973.

Family BURSERACEAE

Canarium ezoanum new species

Pl. 13, figs. 3, 7

Description: Leaflets ovate, 7.5 to 11.5 cm. long and 4.1 to 6 cm. wide; apex abruptly rounded and prolonged to an acute tip; base asymmetric, rounded on one side, cuneate on the other; midvein stout, nearly straight; secondary veins rather slender, 6 to 7 pairs, opposite to alternate, somewhat irregularly spaced, leaving midrib at angles of 50 to 60 degrees in the middle portion of blade, gently arched, near the margin curving upward, branching and looping with the adjacent secondaries; the lowest pair of secondaries just within and parallel to margin; subsecondary veins slender but prominent, nearly parallel to secondaries; tertiaries percurrent, enclosing large quadrangular meshes; nervilles thin, forming fine network; margin entire; texture firm; petiolule missing.

Remarks: Several impressions of well-preserved leaflets are closely similar to those of the modern *C. album* RAEUSCH in asymmetric base and secondary venation, which is living in Kwangtung and Hainan provinces of southern China. No fossil leaflets in Japan is comparable to this new species, but several seeds of *C. album* were reported from the Upper Miocene floras of Nara Prefectue, western Honshu (KOKAWA, 1955). *C. ezoanum* closely resembles *C. californicum* from a Middle Eocene flora of central Sierra Nevada, the western United States (MACGINITIE, 1941).

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25974; paratype no. 24975.

Family MELIACEAE

Cedrela kushiroensis new species

Pl. 14, fig. 6

Description: Leaflets ovate to broadly elliptical, 6.5 to 8 cm. long and 3.4 to 4 cm. wide; apex somewhat acuminate; base obtuse to broadly cuneate, slightly asymmetrical; midrib rather stout, slightly arched; secondary veins thin, 8 to 11 pairs, opposite to subopposite, somewhat irregularly spaced, diverging at nearly right angle on the lower half, at about 70 degrees on the upper half, near the margin abruptly curving up, making a distinct loop with upper secondaries; tertiary veins forming a coarse polygonal network; nervilles thin, finely reticulate; margin nearly entire, sometimes with remote and obtuse teeth; texture thin; petiolule stout, 2 mm. long.

Remarks: These leaflets are suggestive of *Rhus* or *Spondias* in shape and secondary venation, but are referred to *Cedrela* in the presence of marginal obtuse teeth. They closely resemble leaflets of the modern *C. sinensis* JUSSIEU of southern China, though they are, in general, somewhat shorter than the modern leaflets. Leaflets of *C. sinensis* show the combination of entire to serrat margin, and are rather usually remote-serrate; on the one hand, leaflets of *Cedrela* now living in tropical America and West Indies are usually entire-margined.

The fossil *Cedrela* has been widely recorded through the Tertiary of the northern hemisphere; three species has been known in East Asia. *C. kushiroensis* resembles *C. nipponica* recently described from the Miocene Yoshioka flora of southwestern Hokkaido (TANAI and N. SUZUKI, 1963), but differs in secondary venation and serrate margin. Another similar species is *C. lancifolia* (LESQ.) BROWN having leaflets with serrate margin, from the Lower Oligocene Florissant flora of Colorado, the western United States (MACGINITIE, 1953), but our new species distinctly differs in shape.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25976.

Family EUPHORBIACEAE

Glochidion japonicum new species

Pl. 13, figs. 1, 5

Description: Leaves ovate to ovate-lanceolate, 9.5 to 10 cm. (estimated) long and 4.8 to 5 cm. wide; apex acuminate; base rounded to broadly cuneate; midrib stout, straight; secondary veins slender, about 5 subopposite pair, irregularly spaced, diverging at 40 to 50 angles, gently curving up, along the margin extending upward, forming distinct loop; slender 1 or 2 subsecondaries in each intersecondary spaces diverging at angles of 65 to 70 degrees, reaching marginal loops; a pair of slender subsecondaries originating near the base, extending up along the basal margin; tertiaries among intersecondary spaces thin, forming large, irregularly polygonal network, tertiaries near the base forming small loops or irregular network outside of secondary loops; nervilles thin, finely reticulate; margin entire; texture firm; petiole thick, but almost missing.

Remarks: This new species is described on the basis of several incomplete leaf impressions from the Harutori mine. Though fragmentary, these leaves have a characteristic venation, and are closely similar in shape and venation to those of the modern *Glochidion philippicum* (CAB.) C. B. ROB. of tropical and subtropical

Asia. The fossil leaves are also similar to leaves of *Lindera* and *Meratia*; they especially resemble those of the modern *Lindera glauca* (SIEB. and ZUCC.) BLUME and *L. umbellata* THUNB. of East Asia, and those of *Meratia praecox* REHD. and WILS. of China. But these modern leaves of *Lindera* have scarce subsecondary veins originating from midrib. *G. japonicum* is the first record of this genus in the Tertiary of East Asia, and has no definitely similar fossil leaves. It is somewhat similar to *L. gaudini* (NATHORST) TANAI from the Middle Miocene of Honshu, Japan (TANAI, 1961), but differs in details of venation. *G. japonicum* is also similar to *Rhamnus eoutilis* ENDO described from the Ikushunbetsu flora (ENDO, 1968) in secondary venation, but differs in marginal character.

The close living species, *G. philippicum*, is widely distributed in Formosa, southern China, extending into Malaysia and Philippines.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25977; paratype no. 25978.

Mallotus hokkaidoensis new species

Pl. 13, fig. 8

Description: Leaves variable in size and shape, commonly ovate to oval, somewhat asymmetaical, 6.5 to 10.5 cm. long and 3.6 to 6.7 cm. wide; apex acute or somewhat acuminate; base broadly cuneate to rounded; palmately veined, with 5 primaries; midrib stout, nearly straight; inner pair of primaries stout as similar as midrib, making angles of 25 to 35 degrees with midrib, gently curving up, camptodrome, branching off 4 or 5 abaxial secondaries; outer pair slender, usually parallel with the margin, unbranched; 3 to 5 pairs of secondaries, subopposite, diverging at angles at 40 to 50 degrees, then gently curving up, subparallel to the inner primaries; all primaries and secondaries abruptly curving up just within the margin, making distinct loops; tertiaries distinctly percurrent; nervilles finely reticulate; margin entire, but somewhat undulate in the upper part; texture firm; petiole thick, more than 1 cm. long.

Remarks: Only one complete leaf and several fragmentary specimens from the Harutori mine are referred to *Mallotus* in the venation character, though glands are not preserved at the base on underside of blade. These leaves are closely similar to those of the modern *M. philippensis* (LAM.) MUELL.-ARG. of tropical regions of Asia and *M. japonicus* MUELL.-ARG. of Japan and China, particularly most similar to the former. Among the fossil *Mallotus M. hokkaidoensis* closely resembles *M. oregonensis* SANBORN in shape and venation, which was described from the Upper Eocene Comstock flora of west-central Oregon (SANBORN, 1937). Another similar species is *M. ripairius* MACGINITIE from a Middle Eocene flora of the central

Sierra Nevada, the western United States (MacGinitie, 1941), but *M. riparius* is somewhat different in secondary venation. *M. hokkaidoensis* is closely similar to *Ficus columboides* Endo and *F. ezoensis* Endo from the Ikushunbetsu flora (Endo, 1968), and further collection of more specimens may show that these three are conspecific.

The closest living species, *M. philippensis,* is widely distributed in the tropical and subtropical regions of Asia: India to southern China, the Philippines southward to New South Wales of Australia, and Formosa to Ryukyu islands.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25979.

Family CORIARIACEAE

Coriaria sp.

Pl. 13, figs. 2, 4

Description: Leaves broadly lanceolate, 3.2 to 5 cm. (estimated) long and 1.2 to 2.9 cm. wide; apex probable acuminate; base rounded; midvein straight, prominent; proximal pair of prominent subprimary veins leaving midvein about 1.5 mm. above the base at angles of 20 degrees, then roughly conforming to margin, acrodromous; a pair of thin, distal subprimaries arising from the base, parallel to the margin through half the blade; about 8 pairs of secondary veins thin, leaving midrib at angles of about 50 degrees, curving up; nervilles indistinct, finely reticulate; margin entire; texture thin; petiole subsessile.

Remarks: Two incomplete impressions of small, triplinerved leaves from the Okotsu pit are identical with *Coriaria* in their shape and prominent palmate venation. They are closely similar to leaves of the modern *C. intermedia* Matsumura, which is common in valley bottoms and mountain slopes in Formosa. This fossil species somewhat resembles *Smilax* at a general appearance, but differs in primary and secondary venation; for instance, it is closely similar to *S. rubyensis* Becker from a Oligocene flora of southwestern Montana, the western United States (Becker, 1961), but the distal subprimaries of *S. rubyensis* diverge from the base.

Our specimens are the first record of *Coriaria* from the Tertiary of Japan. As already stated by Maekawa (1960), *Coriaria* is one of the older shrubs having primitive flower structure, and shows disjunct distribution in tropical or subtropical regions of the world.

Occurrence: Harutori mine.

Collection: H.U.M.P., nos. 25980, 25981.

Family AQUIFOLIACEAE

Ilex obovata new species

Pl. 13, fig. 6

Description: Leaves obovate, 5.5 to 12 cm. long (estimated) and 2.1 to 4.5 cm. wide; apex incomplete but probably acuminate; base cuneate to acute; midrib stout, somewhat arcuate; secondary veins rather thick, prominent, 5 pairs, opposite to subopposite, diverging at angles of 40 to 45 degrees, near the marging curving up, forming distinct loops; a slender subsecondary vein diverging from the midrib among each intersecondary spaces, parallel to the secondaries; tertiaries thin, coarsely reticulate; nervilles indistinct, making fine, polygonal network; margin slightly recurved, crenulate; texture subfirm; petiole stout, incomplete, more than 5 mm. long.

Remarks: These fossil leaves from the Harutori mine are referred to *Ilex* by their secondary venation and crenulate margin. They are also similar to leaves of *Celastrus* and *Euonymus*, but differs by thin, indistinct tertiary venation. No fossil leaves of *Ilex* in the world are similar to *I. obovata*. It resembles *Celastrus aralensis* BUDANTSEV from the Oligocene of North Aralian region, Kazakhstane, U.S.SR. (RUDANTSEV, 1959), but looping of secondary veins in *C. aralensis* is nearer to marginal border. Among the living *Ilex* of the world, *I. obovata* is closely similar to the modern *I. kanehirai* KOIDZUMI and *I. kusanoi* HAYATA of Formosa, though the living species usually have somewhat smaller leaves.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25982; no. 25983.

Family ACERACEAE

Acer arcticum HEER

Pl. 14, figs. 3, 7

Acer arcticum HEER. Flora fossilis Arctica, vol. 4, pl. 86, pl. 22; pl. 23, pl. 24, figs. 1, 2; pl. 25, fig. 1, 1877.

NATHORST, Pal. Abhandl. vol. 4, p. 11, pl. 3, fig. 1, 1888.

OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. Ser. 4, vol. 7, pl. 87, pl. 9, figs. 1–5, 1943.

ENDO, Proc. Trans. Palaeont. Soc. Jap. N.S., no. 50, p. 66, pl. 10, figs. 4, 5, 1963.

Remarks: Many leaf impressions from all localities are identified as *A. arcticum* HEER by their shape, venation and margin, which was widely distributed in the Paleogene of Eurasia and Alaska. No modern maples in the world is definitely comparable to *A. arcticum*; however *A. arcticum* is somewhat similar to some leaves of the modern *A. spicatum* Lam. living in the northeastern United States and adjacent Canada.

Occurrence: Harutori mine; Tokomuro; Shiranuka.

Collection: H.U.M.P., hypotypes nos. 25984, 29985.

Acer kushiroanum new species

Pl. 20, fig. 1

Description: Leaf penatgonal in general outline, 10.3 cm. long and 13 cm. wide, palmately five-lobed by narrow sinus; medial and lateral lobes oblong in shape, the basal pair of lobes smaller than others, somewhat triangular in outline; base broadly cordate; margin of lobes roughly dentate with unequal dents; marginal dents pointed, numbering 3 or 4 on one side of each lobe, one of these dents is usually large; apex of each lobe gradually narrowed, acute; medial primary veins stout, nearly straight, somewhat tapered at apex; lateral primary veins straight, leaving the midrib at angles of about 40 degrees; basal pair of primary veins leaving the midrib at angles of 70 to 75 degrees, slightly arcuate; secondary veins from the medial and lateral primaries thin, 4 or 5 pairs, diverging at angles of 30 to 40 degrees, mostly craspedodrome, entering into marginal dents; 1 or 3 subsecondary veins leaving the primaries, slender, nearly parallel to the secondary veins, camptodrome to the margin; tertiary veins irregularly percurrent, enclosing fine, polygonal network; nervilles thin, finely reticulate; texture thin; petiole strong, 1.5 mm. thick, more than 3.5 cm. long.

Remarks: A single leaf of maple from the Yubetsu formation, though somewhat incomplete, is undoubtedly referable to the section Platanoidea in its characteristic feature; it is closely similar to the modern *Acer miyabei* MAXIM. of Japan and *A. cappadocicum* GLEDIT. of Small Asia and Caucasas. It is also similar to the modern *A. campestre* LINNE of Europe, which belong to the section Campestria.

Among the fossil maples this new species is closely similar in general outline to *A. ezoanum* OISHI and HUZIOKA commonly found in the Lower and Middle Miocene of Japan (OISHI and HUZIOKA, 1943 b; TANAI, 1961), but differs in marginal dentation. Leaves of this Miocene maple have usually larger, more than two dents in each lobe excepting the basal pair. Another similar species is *A. fatsiaefolia* HUZIOKA from the Middle Miocene of Korea (HUZIOKA, 1943), but this Miocene species is distinctly different in marginal character. *A. kushiroanum* is also similar in general appearance to leaves of *A. paleosaccharinum* STUR from the Late Oligocene flora of Czechoslovakia (KNOBLOCH, 1961), but differs in marginal dentation.

Occurrence: Nakanosawa, Yubetsu.

Collection: H.U.M.P., holotype no. 25990.

Acer oishii new species

Pl. 14, figs. 1, 4, 5; pl. 20, fig. 4

Acer trilobatum productum (Al. BRAUN) HEER. HOLLICK, U.S.G.S. Prof. Pap. 182, p. 135, pl. 76, fig. 2, 1936.

Acer sp. OISHI and HUZIOKA, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 7, p. 97, pl. 14, fig. 1, 1943.

Description: Leaves pentagonal in general shape, shallowly 3-lobed, apical lobe marked by 2 prominent lateral lobes midway and one or more pairs of smaller lobes toward the apex; length 8 to 13 cm., width 7 to 12.5 cm.; base deeply cordate; margin irregularly serrate except at the base; midrib stout, nearly straight, somewhat tapered apically; lateral primary veins leaving the midrib at the angles of 45 to 50 degrees, branching abaxially 8 or more craspedodrome secondary veins; secondary veins leaving the midrib, 6 or 7 pairs, rather slender, nearly parallel to lateral primaries, craspedodrome except the lowest pairs which fork near the margin and loop around the sinus; tertiary veins irregularly percurrent, enclosing fine, polygonal network; nervilles thin, distinct, finely reticulate; texture thin; petiole stout, long, the longest about 7 cm. Samara oblong, about 1.8 cm. long; wing 1.5 cm. long, and 0.6 cm. wide at the upper part, gradually narrowed to the base, rounded at the apex; outer margin nearly straight, inner margin gently convex; veins indistinct, numerous, curving inward and dichotomously branching; seeds oval, about 4 mm. in diameter.

Remarks: This new species is represented by a number of well-preserved impressions of incomplete leaves from the Harutori and Yubetsu formations. These leaves are closely similar to the modern *A. pycnanthum* K. KOCH. of Japan, and to the living *A. rubrum* LINNE of North America, especially most similar to the latter. *A. pycanthum* is living in the valley bottoms along the Kiso river of central Honshu, Japan. Incomplete samaras referable to this species were found with the leaves from the Harutori mine, and they closely resemble those of the modern *A. rubrum* in shape and size.

Among the fossil *Acer*, *A. oishii* most closely resembles *A. aequidentatum* LESQ. from the Middle Eocene floras of North America (LESQUEREUX, 1878; MACGINITIE, 1941), which resembles the modern *A. rubrum.* It is also closely similar to leaves frequently described as *A. trilobatum productum* from the Tetriary of

Eurasia and North America (HEER, 1859; LESQUEREUX, 1873; OISHI and HUZIOKA, 1943; ENDO, 1959), but the European species is more deeply lobed and smaller in lateral lobes. However, a fragmentary leaf figured as *A. trilobatum productum* by HOLLICK (1936) from the Paleogene of Alaska is difficult to spearate from *A. oishii* in all characters.

A. oishii is named in honour of late Dr. Saburo OISHI, the former Professor of Paleontology at Hokkaido University, who did a number of excellent works on East Asian paleobotany.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shakubetsu mine; Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 25986; paratypes nos. 25987, 25988, 25989.

Family HIPPOCASTANACEAE

Aesculus sp.

Pl. 15, fig. 3

Description: Leaflets incomplete, upper portion missing, obovate, 6 to 7.5 cm. wide, length unknown; base gradually narrowed, cuneate, somewhat asymmetric; midrib stout, nearly straight, 1 mm. thick; secondary veins, thick, prominent, diverging at 50 to 60 degrees, and at more angles near the base, nearly straight or slightly curved, near the margin forking, entering marginal teeth; tertiaries thin, indistinct, percurrent; nervilles thin, finely reticulate; margin irregularly crenato-dentate; texture thin.

Remarks: Two incomplete leaflets from the Harutori mine are referred to *Aesculus* by their shape and secondary venation. They are more closely similar in their marginal character to the living *A. hippocastanum* LINNE than the living *A. turbinata* BLUME of Japan. Our fossils are separable from Miocene species, *A. majus* (NATHORST) TANAI, which was described from the Miocene of Honshu and Hokkaido (TANAI, 1961; HUZIOKA, 1964). These fossil leaflets are similar in general appearance to *Carya ezoensis* described in the preceding page, but differ in margin and venation.

The modern equivalent, *A. hippocastanum*, is widely cultivated in Europe, but its native home is said to be southeastern Asia, from Himalaya region to Greece.

Occurrence: Harutori mine.

Collection: H.U.M.P., no. 25991.

Family SAPINDACEAE

Cupania japonica new species

Pl. 12, figs. 3, 7

Description: Leaflets somewhat inequilateral, lanceolate, 10.3 to 13.5 cm. long., 3.5 to 4.5 cm. wide; apex gradually narrowed, acute; base asymmetrical, gradually narrowed, broadly cuneate; midrib stout, slightly curving; secondary veins strong, 10 to 12 pairs, mostly subopposite, somewhat irregular at diverging angles, on the wide side of leaflets diverging mostly at angles of 45 to 60 degrees, on the narrow side mostly at 30 to 45 degrees, these secondaries curving up regularly, craspedodrome; tertiary veins thin, irregularly percurrent, or forming irregular network in the intersecondary areas; near the margin 1 or 2 slender tertiaries branching from the secondaries, ending in smaller teeth; nervilles thin, indistinct, finely reticulate; margin coarsely serrate, teeth pointing upward or outward; texture rather thick, probably subcoriaceous; petiolule stout, 8 mm. long.

Remarks: This species was recognized by the author on the basis of well-preserved leaflets from the Ikushunbetsu formation of the Ishikari coal field, though it has been not published. Several leaflets from the Kushiro field are referred to this species in shape and margin, though somewhat differ in secondary venation. However, such difference seems to fall within the variation. The fossil leaves are closely similar to those of *C. vernalis* CAMBESS of South America in venation, margin and shape, though the modern leaves are obtuse in apex.

No fossil specimens have previously referred to *Cupania* in East Asia, but several species of *Cupania* and its related genus, *Cupanites*, have been described mainly from the Paleogene of North America and Europe. Among them, *C. japonica* closely resembles *Cupanites oregona* CHANEY and SANBORN from the Eocene of the western North America (CHANEY and SANBORN, 1933; MACGINITIE, 1941).

Occurrence: Harutori mine; Nakanosawa and Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 25992; paratype no. 25993.

Family RHAMNACEAE

Zizyphus harutoriensis new species

Pl. 13, fig. 9; pl. 14, fig. 2

Melastomites cf. *quinquiervis* HEER. ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, pl. 23, figs. 3, 4, 1968.

Description: Leaves oblong-ovate, 4.5 to 11 cm. (estimated) long and 2.3 to 6 cm. wide; apex acuminate; base somewhat asymmetrical, broadly obtuse; midrib prominent, nearly straight; a pair of subprimaries or strong lateral secondaries branching off near the base at angles of about 30 degrees curving upward for approximately four-fifths length of leaf; several slender secondaries branching from the midrib at the upper part of leaves, the uppermost extending nearly into the apex; numerous slender subsecondaries branching abaxially from subprimaries, forming loops along the margin; numerous fine tertiaries branching from the midrib and secondaries, trending mostly at right angles to the midrib, forming coarse network; nervilles finely reticulate; margin crenulate-dentate; texture firm; petiole more than 1 cm. long.

Remarks: These fossil leaves from the Harutori coal mine are similar to *Paliurus* and *Zizyphus* in their general appearance, and are referred to the latter by their secondary venation. This new species is closely similar to the modern *Z. jujuba* MILLER, though the living leaves are coarser in marginal serration and rather obtuse in apex.

Z. harutoriensis is closely similar to *Z. miojujuba* HU and CHANEY, which is commonly found in Middle and Late Miocene floras of Japan. But Miocene species is more akin to the modern species, having coarser marginal teeth. A single leaf described as *Melasomites* cf. *quinquiervis* from the Ikushunbetsu formation (ENDO, 1968) is closely similar to our new species, and is included in *Z. harutoriensis*. The living equivalent, *Z. jujupa*, is widely distributed over most of China.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25994a; hypotype no. 25994b.

Family ACTINIDIACEAE

Actinidia harutoriensis new species

Pl. 16, figs. 1, 5, 7

Description: Leaves cordate to oval, 5.5 to 8.5 cm. long and 5 to 8 cm. wide; apex abruptly acute; base rounded to broadly cordate, sometimes slightly cordate; midrib stout, prominent, nearly straight; secondary veins rather thin but prominent, somewhat irregularly spaced, 8 to 12 pairs, opposite to alternate, diverging at angles of 50 to 60 degrees in the middle part of blade, at larger angles in the lower part, nearly straight or gently curving upward, frequently forking near the margin, craspedodrome; tertiaries among intersecondary spaces thin but distinct, irregularly percurrent, near the margin tertiaries branching off abaxially, ending in marginal small teeth; nervilles finely reticulate; margin doubly serrate, with acute, fine teeth; texture thin; petiole stout, more than 2.5 cm. long.

Remarks: Several well-preserved leaves in our collection are referred to *Actinidia* in their shape and venation character. They are closely similar in secondary venation and margin to leaves of the modern *A. chinensis* PLANCH, which is widely distributed in China and Formosa, especially common along the Yangtze valley.

A. harutoriensis is closely similar in venation character to *A. ovata* MACG. from the Oligocene Weaverville flora of California (MACGINITIE, 1937), but differs in leaf shape. It is similar to a leaf described as *Actinidiophyllum ovatum* from a Late Eocene flora of Hungary (RASKY, 1962), but this Hungarian fossil is also an ovate leaf.

Occurrence: Harutori mine; Tokomuro; Pon-Shitakara; Shoro; Shiranuka.

Collection: H.U.M.P., holotype no. 25995; paratype no. 25996; hypotype no. 25997.

Family THEACEAE

Gordonia japonica new species

Pl. 16, fig. 3

Description: Leaf oblong-lanceolate, 2.6 cm. at the widest part, more than 8 cm. long; base sharply cuneate; apex missing; midrib very thick, slightly arched; secondary veins very thin, indistinct, numerous, diverging at angles of 60 to 70 degrees, twice or thrice forking, anatomosing, and forming elongate-polygonal network; nervilles indistinct; margin revolute, entire at the lower half, and remotely serrate with fine, obtuse teeth at the upper part; texture coriaceous; petiole stout, 1 cm. long and 2 mm. wide.

Remarks: A single well-preserved leaf, though missing its upper part, is closely similar to leaves of the modern *Gordonia axillaris* (ROXB.) DIETR. in its shape, margin and venation character. Our specimen shows a close resemblance to som genera of Apocynaceae in general appearance, and such leaves have frequently been assigned to the genus *Apocynophyllum*. In actual, *G. japonica* is similar to *Apocynophyllum wilcoxense* BERRY from the Eocene Wilcox flora of the eastern United States (BERRY, 1916), but differs in its secondary venation and serrate margin. Another similar species is *Ternstroemites eolignitious* BERRY from the same flora (BERRY, 1916). Two fossil species of *Gordonia* have been known from the Eocene and the Miocene of North America. They are, however, rather similar to the modern *G. lasianthus* ELL. living in the southeastern United States, and are not similar to our species.

The genus *Gordonia* is now distributed in tropical and subtropical Asia and the southeastern United States. The close similar living species, *G. axillaris*, is distributed in Indo-China, southern China and Formosa; in Formosa it grows in broad-leafed forest at low and middle altitudes.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 25998.

Family FLACOURTIACEAE

Idesia kushiroensis new species

Pl. 15, fig. 6

Description: Leaves orbicular to cordate in general outline, 9 to 14 cm. long (estimated) and 7.5 to 11 cm. wide; apex somewhat acuminate; base cordate to broadly cordate; primary veins 5, midrib stout, straight or slightly arched; an inner pair of lateral primaries stout, straight or slightly arched; an inner pair of lateral primaries stout, at the base forming angles of 35 to 40 degrees with midvein, gently curving up, somewhat zigzag, having 3 or more secondaries on the marginal side; an outer pair of lateral primaries slender, at nearly right angles to the midvein, given off 5 or more secondaries which end in the marginal teeth or form marginal loops; secondary veins from the midrib prominent, 3 subopposite pairs, nearly parallel to the inner secondaries, forming loops or craspedodrome, near the margin giving off a few subsecondary veins; tertiary veins thin, forming large, irregularly polygonal network; nervilles thin, finely reticulate; margin irregularly and coarsely serrate, with rounded teeth in which include frequently glands; texture thin; petiole thick, but incomplete.

Remarks: These leaves resemble those of *Populus*, *Cercidiphyllum*, *Grewiopsis* and *Ficus* in general outline, but are referred to *Idesia* in their margin, venation and marginal glands. They are closely similar to leaves of *I. polycarpa* MAXIM. of East Asia, though the secondary veins in the modern leaves are mostly camptodrome to the margin. The modern leaves have usually a pair of glands at the top of petiole, but these glands seem not preserved in the fossils. *I. kushiroensis* is closely similar to *I. cordata* MACGINITIE from the Lower Oligocene Weaverville flora of California (MACGINITIE, 1937), but somewhat differs in venation. OISHI and HUZIOKA (1943) described an incomplete leaf as *Tilia harutoriensis* from the Harutori coal mine. It is similar to *I. kushiroensis* in general appearance, but somewhat differs in number of secondary veins. The author could not get any additional materials referable to *Tilia* during his collection. Further study will show that this linden species may be included in *I. kushironeis*.

The modern similar species, *I. polycarpa*, is widely distributed in Honshu, Shikoku and Kyushu, Japan, and also in Formosa and central and southwestern China.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shakubetsu mine.

Collection: H.U.M.P., holotype no. 25999; no. 26000.

Family ALANGIACEAE

Alangium basiobliquum (OISHI and HUZIOKA) TANAI

Pl. 18, figs. 4, 5; pl. 19, fig. 1

Alangium basiobliquum (OISHI and HUZIOKA) TANAI, Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 372, pl. 30, fig. 11, 1961.
Marlea basiobliqua OISHI and HUZIOKA. OISHI, Illust. Cat. East Asia. Fos. Plants, p. 171, pl. 49, fig. 8, 1950.
Ficus tiliaefolia HEER. NAGAI, Mem. Ehime Univ. sec. 2, vol. 2, no. 4, p. 77, pl. 1, figs. 3, 4, 1957.
Celtis hokkaidoensis ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, p. 427, pl. 22, fig. 8, 1968.
Ficus planicostata LESQ.. ENDO, ibid., p. 430, pl. 12, fig. 4, 1968.
Ficus tiliaefolia (BRAUN) HEER. ENDO, ibid., p. 432, pl. 15, figs. 1, 2, 1968.

Remarks: These leaves from all the locality, including several complete specimens, are referred to *A. basiobliquum* by oblique base and well-defined venation. This species is common in the Harutori flora as well as in the Paleogene flora of the Ishikari coal field, central Hokkaido. Two leaves described as *Ficus tiliaefolia* HEER from the Eocene Kuma flora of Shikoku, western Japan (NAGAI, 1957) are included in *A. basiobliquum* by their shape and characteristic venation, although their base is not strongly oblique. Four leaves described as *Ficus tiliaefolia*, *F. planicostata* and *Celtis hokkaidoensis* from the Ikushunbetsu flora (ENDO, 1968) are quite similar to *Alangium basiobliquum* in their venation character and oblique base. *A. basiobliquum* is closely similar to *A. thomae* (CHANEY and SANBORN) LAKHANPAL from the Oligocene Rujada flora of West-central Oregon, North America (LAKHANPAL, 1958).

Among the modern *Alangium A. basiobliquum* is most similar to *A. chinense* (LOUR.) HARMS. living in central and southern China, and Formosa.

Occurrence: Harutori mine; Tokomuro; Nakanosawa, Yubetsu; Shoro; Pon-Shitakara; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotypes nos. 26001–26003.

Alangium basitruncatum (OISHI and HUZIOKA) new comb.

Pl. 17, fig. 1

Marlea basitruncata OISHI and HUZIOKA. OISHI, Illust. Cat. East-Asiatic Fossil Plants. p. 170, pl. 49, fig. 7, 1950.
Ficus tennesseensis BERRY. ENDO, Bull. Natl. Sci. Mus. p. 431, pl. 13, figs. 3, 4, 1968.
Ficus yubariensis ENDO, ibid., p. 432, pl. 14, figs. 1, 2, 1968.

Remarks: The original specimens from the Ikusumbetsu formation of the Ishikari coal filed, was described as *Marlea* by Oishi (1950), but it must be referred to *Alangium* in the present taxonomy. Our specimens, though incomplete, are referred to *A. basitruncatum* by their trilobed shape and well-defined secondary veins. This species are comparatively common along with *A. basiobliquum* in the Paleogene of Hokkaido. *A. basitruncatum* is somewhat similar to *Alangiophyllum petiocaulum* POTBURY from the Eocene LaPorte flora of California (Potbury, 1935), but distinctly differs in the base. Three leaves described as *Ficus tennessensis* and *F. yubariensis* from the Ikushunbetsu flora (ENDO, 1968) are inseperable from *A. basitruncatum* in their truncate base and venation character.

A. basiturncatum is closely similar to the modern *A. plantanifolium* HARMS. living in central China and southern Japan, and is also somewhat close to the lobed leaves of the modern *A. chinense* (LOUR.) HARMS. of China.

Occurrence: Harutori mine; Nakanosawa, Yubetsu; Shoro; Pon-Shitakara, Yubetsu; Shiranuka; Onbetsu mine.

Collection: H.U.M.P., hypotype no. 26004; no. 26005.

Family ARALIACEAE

Aralia ezoana new species

Pl. 15, figs. 1, 2, 4

Description: Leaflets ovate to elliptical, 3.2 to 10 cm. long and 1.6 to 4.9 cm. wide; apex acute, somewhat tapered; base cuneate to broadly cuneate; midrib stout, straight; secondary veins rather stout, 7 to 9 opposite pairs, diverging angles of 40 to 50 degrees, nearly straight, near the margin becoming slender, slightly curving up, craspedodrome, sometimes bifurcating; tertiaries near the margin branching from the secondaries, ending in marginal teeth; tertiaries among inter-secondary spaces, forming irregular, large network; nervilles thin, finely reticulate; margin coarsely serrate, with blunt, large teeth, basal margin entire; texture thin;

petiolule missing.

Remarks: These specimens are similar to leflets of *Rosa*, *Aralia* and *Sorbus* in general outline, but are referred to *Aralia* in their venation and margin, though somewhat incomplete. The fossil leaflets are closely similar to those of the living *A. chinensis* LINN. of central China and the living *A. spinosa* LINN. of the eastern United States. *A. ezoana* resembles *A. miobippinata* TANAI from the Middle Miocene of Honshu in the shape and margin (TANAI, 1961), but distinctly differs in details of secondary venation. Another similar species is *A. taurinensis* (WARD) SANBORN from the Paleocene and Eocene Floras of the United States, (SANBORN, 1935; pl. 10, figs. 1, 2 excluding fig. 4).

Occurrence: Harutori mine; Nakanosawa and Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 26006; hypotypes nos. 26007, 26008.

Family MYRSINACEAE

Maesa nipponica new species

Pl. 18, fig. 1

Description: Leaves oblong, 8 to 10.5 cm. long and 2.8 to 3.7 cm. wide; apex acuminate; base acute; midrib stout, nearly straight; secondary veins rather slender, about 8 opposite pairs, diverging at angles of 30 to 40 degrees, nearly straight or gently curving up, craspedodrome, sometimes 1 or 2 branches near the margin ending in small teeth; tertiary veins not prominent, irregularly percurrent, or forming coarse network; nervilles thin, reticulate; margin somewhat undulate, remotely serrate with small, aristate teeth; texture subcoriaceous; petiole missing.

Remarks: These leaves including a well-preserved specimen from the Harutori pit show a close similarity in all characters to the modern *Maesa japonica* MOR. and *M. tenera* MEZ. living in warm or subtropical regions of East Asia. They somewhat resemble leaves of *Quercus* and *Castanopsis* in general appearance, but distinctly differ in slender venation. No fossil leaves in Japan are comparable to *M. nipponica.* It is somewhat similar to *Castanopsis logipetiolatum* (KNOWLTON) MACG. from the Eocene floras of the western United States (MACGINITIE, 1941), but differs in secondary venation character.

The most close living species, *M. japonica,* is distributed in southern Honshu, Shikoku and Kyushu of Japan, and in southern China, Formosa and Malaysia.

Occurrence: Harutori mine; Tokomuro.

Collection: H.U.M.P., holotype no. 26009; no. 26010.

Family OLEACEAE

Chionanthus nipponicus new species

Pl. 16, fig. 4; pl. 17, figs. 2, 3

Description: Leaves variable in shape and size, elliptical to oval, 4 to 7.5 cm. long (estimated) and 2 to 4.5 cm. wide; apex acute; base rounded to decurrently cuneate; midrib stout, nearly straight; secondary veins slender, 8 to 10 pairs, opposite to alternate, diverging at various angles, usually 60 to 80 degrees except near apex, gently curved or nearly straight, near margin forming loops, giving off a few branches on outer side near margin, smaller branches looping; tertiary veins thin, coarsely reticulate; nervilles indistinct; margin usually entire, but sometimes finely and remotely serrate with minute teeth; texture subfirm; petiole thick, 1.2 to 1.5 cm. long.

Remarks: These leaves are referred to *Chionanthus* in shape, secondary venation and long petiole, and are closely similar to those of the modern *C. retusa* LINDL. and PAXT. of Japan and China. These fossil leaves resemble those of the modern *Cotinos coggygraia* SCOPOLI of China and *C. americanus* NUTTAL of North America, but the leaves of Cotinus are usually entire in margin. On the other hand, the mature leaves of *Chionanthus* are mostly entire in margin, while the young are sometimes finely serrulate. No fossil leaves of *Chionanthus* in the world are similar to *C. nipponicus*. *C. nipponicus* resembles *Cotinus fraterna* (LESQ.) COCKERELL in shape and venation, which were described from the Oligocene floras of the western United States (MACGINITIE, 1953; BECKER, 1961), but differs in marginal character.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 26011; paratype no. 26012; hypotype no. 26013.

Family APOCYNACEAE

Melodinus japonicus new species

Pl. 16, fig. 1

Description: Leaf broadly elliptical, 10 cm. long. (estimated) and 4.6 cm. wide; apex gradually narrowed, obtuse; base cuneate; midrib thick, nearly straight prominent on under surface; secondary veins rather thin, opposite to subopposite, about 11 pairs, originating at angles of 60 to 70 degrees on the middle part of leaf, subparallel, looping well within the margin, interspersed and anastomosing with numerous subsecondaries, forming elongated meshes; tertiaries thin but well developed, dividing the narrow intersecondary spaces into rectangular or polygonal units and forming series of small marginal loops; nervilles indistinct; margin entire, somewhat revolute; texture subcoriaceous; petiole missing.

Remarks: A single, nearly complete leaf from the Harutori mine has a characteristic secondary venation, and clearly indicates similarity to leaves of several genera of the Apocynaceae, Myrtaceae, Myrsinaceae and Annonaceae. Correspondance with leaves of the modern *Melodinus monogynus* ROXB. are very close. This living species is distributed in the broad-leafed forest of southern China. There are also some resemblances to leaves of certain living species of *Kopsia*, *Linociera* and *Calyptranthes*.

This new species is the first record of *Melodinus* in the Tertiary of East Asia. Among the fossil leaves, *M. japonicus* closely resembles *Calyptranthes arbutifolia* CHANEY and SANBORN from the Goshen flora of the United States (CHANEY and SANBORN, 1933) in general appearance, but differs in details of venation character. It is also similar to *Eugenia arenaceaeformis* (COCKERELL) MACGINITIE from the Oligocene Florissant flora of Colorado (MACGINITIE, 1953), but differs in narrow leaves and marginal loops of secondaries.

Occurrence: Harutori mine.

Collection: H.U.M.P., holotype no. 26014.

Family BORAGINACEAE

Cordia japonica new species

Pl. 19, figs. 2, 4; p.. 20, fig. 3

Description: Leaves ovate to broadly ovate, 5.5 to 13.5 cm. long and 3.8 to 9 cm. wide; apex acute; base rounded to broadly obtuse; midvein rather stout, nearly straight; secondaries 6 or 7 pairs, opposite to subopposite, diverging at angles of 25 to 35 degrees, somewhat curved up, craspedodrome; a pair of basal secondaries leaving midvein about 5 mm. above the base of leaf, giving off 4 or 5 subsecondaries abaxially, gently curving up, craspedodrome; a few branches from other secondaries ending in marginal teeth; tertiries thin, irregularly percurrent; nervilles indistinct, finely reticulate; margin undulate-dentate, with obtusely pointed teeth; texture firm; petiole medium, more than 1.5 cm. long.

Remarks: A number of well-preserved leaf impressions closely resemble produced by *Hamamelis*, *Corylopsis* and *Cordia*, and are most closely similar to those of the modern *Cordia dichotoma* FORST. in their basal form, margin and basal secondary venation. Our leaves are somewhat similar to those of the modern *Corylopsis spicata* SIEB. and ZUCC. of southern Japan, but differ distinctly in marginal character.

This new species is the first fossil record of *Cordia* in Japan. *Cordia* is not native in Japan, but is living in Formosa, southern China, extending southwestward in tropical Asia. *C. japonica* is closely similar to the modern *C. dichotoma* FORST. of southeastern Asia, and to *C. alba* (JACQUIN) ROEMER and SCULT. of Central America. Five species of *Cordia* have been described from the Tertiary of North America; *C. japonica* is closely similar to *C. prealba* MACGINITIE from the Late Miocene Kilgore flora of northern Nebraska, the western United States (MACGINITIE, 1962).

The modern equivalent, *C. dichotoma* is one of the common shrubs in subhumid, shrubby forest of Formosa, Philippines, Malaysia and southern China. The abundant occurrence of *C. japonica* in the Harutori flora may show a similar habitat during the Harutori time.

Occurrence: Harutori mine; Tokomuro.

Collection: H.U.M.P., holotype no. 26015; hypotypes nos. 26016, 26017.

Family CAPRIFOLIACEAE

Viburnum ezoanum new species

Pl. 18, figs. 6, 7

Description: Leaves ovate to broadly ovate, 5.3 to 7 cm. long and 3.8 to 4.3 cm. wide; apex acute; base rounded to broadly rounded; midrib stout, nearly straight; secondary veins 5 or 6 pairs, opposite to subopposite, diverging at angles of 30 to 40 degrees, subparallel, nearly straight, near the margin becoming slender, curving up or branching off a few slender veins, craspedodrome, the first pair of secondary veins originating from the base, branching off abaxially 3 or 4 subsecondaries, which end in marginal teeth; a pair of slender subsecondary veins originating from the base, running up along the basal margin; tertiaries irregularly percurrent, or forming polygonal, coarse network; nervilles finely reticulate; margin crenately dentate, with obtuse teeth; texture subfirm; numerous, very small glands existing on undersurface of blade; petiole stout, 8 mm. long.

Remarks: A number of leaves from the Harutori mine are indubitably referred to *Viburnum* in their secondary venation and margin, and are closely similar in all characters to those of the modern *V. japonicum* (THUNB.) SPRENG. of southern Japan, though the modern leaves are frequently larger. The modern leaves have numerous glands on their undersurface as similar as observed in the fossil leaves. The fossil leaves somewhat resemble *V. phlebotrichum* SIEB. and ZUCC. of Japan. *V. ezoanum* is closely similar to leaves figured as *V. whympferi* HEER from the Paleogene of Alaska HOLLICK (1936), and is probably conspecific. However, the original figures of *V. whympferi* described by HEER (1869, 1870) from the Paleocene of

Greenland distinctly differ from our specimens in venation character. Another similar species is *V. variabilis* MACGINITIE from the Middle Eocene flora of the centural Sierra Nevada, the western United States (MACGINITIE, 1941); but the American species has more irregular secondary venation and acute marginal teeth.

The most close living species, *V. japonicum*, is an evergreen shrub distributed in warm regions such as southwestern extreme of Honshu, and Kyushu, extending into Ryukyu islands and Formosa.

Occurrence: Harutori mine; Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 26018; hypotype no. 26019.

Viburnum basiobliquum new species

Pl. 17, fig. 4; Pl. 18, fig. 2; Pl. 19, fig. 6

Description: Leaves asymmetrically ovate to oval or orbicular, 4 to 10 cm. long and 3.2 to 8.3 cm. wide; acute or abruptly acuminate; base inequilateral, shallowly to deeply cordate; midrib very thick, nearly straight or slightly arcuate; secondary veins stout, prominent, 7 to 9 pairs, somewhat irregularly spaced, diverging at angles of 55 to 65 degrees in one side, at angles of 40 to 50 degrees in another side, the basal pair extending at nearly right angles, nearly straight, then gently curving up, near the margin mostly bifurcating, ending in marginal teeth; a few tertiaries near the margin branching off, craspedodrome, tertiaries among intersecondary spaces distinct, forming coarse, polygonal mesh; several slender branches from basal pair of secondaries extending abaxially, craspedodrome; nervilles finely reticulate; margin coarsely serrate, with large, deltoid teeth; texture thin; petiole stout, 1 to 2.5 cm. long.

Remarks: These leaves are referred to *Viburnum* in their marginal and venation characters, though its identification is somewhat questionable. They resemble leaves of the modern *V. tomemtosum* THUNB. of Japan in their venation, but somewhat differs in shape. They are also similar to leaves of the modern *V. dentatum* LINNE. and *V. pubescens* PURSH of North America, but these modern leaves are narrower in the diverging angles of secondaries. Our leaves somewhat resemble those of the modern *Euptelea polyandra* SIEB. and ZUCC. of Japan in shape and venation, but distinctly differs in marginal serration. No fossil species of the world are similar to *V. basiobliquum*.

Occurrence: Harutori mine; Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 26020; hypotypes. nos. 26021, 26022; no. 26023.

INCERTAE SEDIS

Form genera assigned to unidentifiable plant fossils have been frequently abused in Japan. SCHIMPER (1874) proposed the name *Carpites* for fruits and seeds of Cretaceous and Tertiary plants which are unable to refer to the living genera. He distinguished them from those of different plants of older age, especially of the Carboniferous for which the name *Carpolithes* STERNBERG is reserved. BRONGNIART (1822) proposed the form genus *Antholithes* for floral structures of Mesozoic and Tertiary plants which cannot be assigned to existing genera. *Phyllites* BRONGNIART (1822) and *Dicotylophyllum* SAPORTA (1894) are used as form genera for dicotyledonous leaves of uncertain affinity.

Antholithes cruciatus new species

Pl. 16, fig. 6

Description: Four sepals cruciate in arrangement; sepals elliptical, 7 mm. long, 3 mm. wide at the middle part, acute at apex; definite midrib not visible, but prominent ridge longitudinally running from the base to apex; finer veins not seen; margin entire; texture firm.

Remarks: These small cross-shaped fossils represented by two specimens appear to be persistent calyx remains. Their general appearance suggests calyces of some plants such as *Abelia*, *Porana*, *Astronium* and *Diospyros*, particularly the last, but it is difficult to determine its definite taxa. Until additional materials are available for comparison with living plants, these calyces are referred to *Antholithes*.

Such fossils similar to our specimens have been described from the Tertiary of Europe and North America. Especially, our fossils closely resemble *Hetrocalyx ungeri* SAPORTA from the Eocene of Hungary (RASKY, 1962), and from the Middle Oligocene of France (SAPORTA, 1873). Another similar species is *Abelia quadrialata* REID and CHANDLER from the Oligocene Bembridge flora of England (REID and CHANDLER, 1926), but *Abelia* calyx has more distinct venation.

Occurrence: Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., holotype no. 26024.

Carpites japonicus (ENDO) new Combination

Pl. 19, figs. 3, 5

Cercidiphyllum arcticum (HEER) BROWN. HUZIOKA, Cenozoic Research, no. 11, pl.

15, fig. 118, 1950.
ENDO, Bull. Natl. Sci. Mus., vol. 11, no. 4, pl. 20, fig. 5, 1968.
Orites japonica ENDO, Icon. Fossil Plants from Jap. Isl. pl. 11, fig. 2, 1955.

Description: Pods or capsules ellipsoidal, dehiscent, 1 to 1.5 cm. long (excluding acuminate tip), 0.7 to 1 cm. wide at the middle part; apex abruptly pointed, frequently with acuminate, spiny tip (0.5 cm. long); base acute to obtuse, sometimes twisted; surface crossedly striated; many longitudinal ridges running from the apex to the base; numerous fine striations transversely running around the pod, closely spaced; stalk strong, 1 to 1.5 cm. long.

Remarks: These characteristic fruits once named under various genera, was assigned to *Cercidiphyllum* by BROWN (1939), who had extensively investigated on such fossils of North America. Then, many paleobotanists have frequently referred such fruits widely found from the Tertiary of northern hemisphere to *Cercidiphyllum*. However, several paleobotanists did not agree this assignments (KRYSHTFOVICH, 1958; TRALAU, 1963; others); for instance, KRYSHTOFOVICH described such fruits as *Trochodendrocarpus arcticus* (HEER), considered similarity to *Trochodendron*.

In actual, our fossils are quite not similar to any pod of the living *Cercidiphyllum* in their shape and ornamentation, though a number of leaves in our collection are closely similar to those of this genus. On the other hand, our fossil fruits are not similar to those of the living *Trochodendron*. Accordingly, the author places such fruits in the form genus *Carpites*, rejecting from *Cercidiphyllum*. Our fossils are inseparable from *Orites japonicus* ENDO figured from the Ishikari coal field, Hokkaido (ENDO, 1955).

Occurrence: Harutori mine; Shoro; Pon-Shitakara, Yubetsu.

Collection: H.U.M.P., hypotypes nos. 26025, 26026.

Nordenskiödia borealis HEER

Pl. 15, fig. 5

Nordenskiöldia borealis HEER, Flora fossilis arctica, vol. 2, pt. 4, p. 65,pl. 7, figs. 1–13, 1870.

Remarks: A single well-preserved organ from the Yubetsu coal mine is referred to *N. borealis*, which was originally described from the Paleocene of Spitzbergen, northern Europe (HEER, 1870). This species representing only by fruits has been widely recorded from the Paleogene of the northern hemisphere, mostly from the Paleocene and the Eocene, though not abundant. However, *N. borealis* has no valid botanical relationship: HEER (1870) and some others considered it to belong to the Tiliaceae, and recently KRYSHTOFOVICH (1956) and other Russian authors to the Trochodendraceae. Actually *N. borealis* shows some similarity in general appearance to fruits of the modern *Trochodendron aralioides* SIEB. and ZUCC., which is distributed in Japan, Formosa, southern China and southern Korea. *N. borealis* is closely similar to fruits of *Glochidion*, especially of *G. philippicum* (CAB.) C. B. ROB. living in tropical Asia. The occurrence of *Glochidion* leaves from the Kushiro field appears to highly suggest this similarity.

Occurence: Nakanosawa, Yubetsu.

Collection: H.U.M.P., hypotype no. 26027.

References

ANDREANSZKY, G. (1966): On the Upper Oligocene Flora of Hungary. *Stud. Biol. Acad. Sci. Hung.*, no. 5, 150 pp.

ASANO, K. (1952): Paleogene foraminifera from the Ishikari and Kushiro coal-fields, Hokkaido. *Short Papers, IGPS*, no. 4, pp. 23–46.

———— (1958): Some Paleogene smaller foraminifera from Japan. *Sci. Rept. Tohoku Univ. 2nd ser.*, vol. 29, pp. 43–75.

———— (1962): Japanese Paleogene from the view-point of foraminifera with descriptions of several new species. (in Japanese with English Summary) *Contr. Inst. Geol. Paleont. Tohoku Univ.*, no. 57, pp. 1–32.

AXELROD, D. I. (1966a): Pottassium-Argon ages of some western Tertiary floras. *Amer. Jour. Sci.*, vol. 264, pp. 497-506.

———— (1966b): The Eocene Copper Basin flora of northeastern Nevada. *Univ. Calif. Publ. Geol. Sci.*, vol. 59, pp. 1–83.

BECKER, H. F. (1960): The Tertiary Mormon Creek flora from the Upper Ruby River basin in southwestern Montana. *Palaeontogr.* Bd. 107, Abt. B, pp. 83–126.

———— (1961): Oligocene plants from the Upper Ruby River basin, southwestern Montana. *Geol. Soc. Amer. Mem.*, 82, 94 pp.

BELL, W. A. (1949): Upper Cretaceous and Paleocene floras of western Alberta. *Canada, Dept. Mine Res., Geol. Surv. Bull.*, no. 13, 231 pp.

BERRY, E. W. (1916): The Lower Eocene floras of southeastern North America. *U.S. Geol. Surv. Prof. Paper*, 91, 481 pp.

———— (1917): Geologic history indicated by the fossiliferous deposits of the Wilcox group (Eocene) at Meridian, Mississippi. *U.S.G.S. Prof. Paper*, 108-E, pp. 61–72.

———— (1924): The middle and upper Eocene floras of southeastern North America. *U.S. Geol. Surv. Prof. Paper*, 92, 206 pp.

BORSUK, M. O. (1956): Paleogene flora of Saghalien. (in Russian). *Sci. Invest. Geo. Inst.*, pt. 12, 88 pp.

BRAUN, E. L. (1960): Deciduous Forests of Eastern North America. Blakiston Co., Philadelphia, 596 pp.

BRONGNIART, A. (1922): Plantae insertae sedis. *Mem. Mus. Hist. Nat. Paris*, vol. 8, p. 223.

BROWN, R. W. (1935): Miocene leaves, fruits and seeds from Idaho, Oregon and Washington. *Jour. Palaeont.*, vol. 9, no. 7, pp. 572–585.

——— (1937): Additions to some fossil floras of the western United States. *U.S. Geol. Surv., Prof. Paper*, 186-J, pp. 163–206.

——— (1939): Fossil leaves, fruits and seeds of *Cercidiphyllum*. *Jour. Paleont.*, vol. 13, pp. 485–499.

——— (1962): Paleocene flora of the Rocky Mountains and Great Plains. *U.S. Geol. Surv. Prof. Paper*, 375, 119 pp.

BUDANTSEV, L. (1959): Oligocene flora of North Aralian region. (in Russian). *Problem. Botanik.*, vol. 4, pp. 190–252.

CHANEY, R. W. (1927): Geology and Palentology of the Crooked River Basin, with special reference to the Bridge Creek flora. *Carnegie Inst. Wash. Publ.*, 346, pp. 45–138.

——— (1940): Tertiary forests and continental history. *Geol. Soc. Amer. Bull.*, 51, no. 3, pp. 469–488.

——— (1947): Origin and development of natural floristic areas with special reference to North America-Tertiary centers and migration routes. *Ecol. Mong.*, vol. 17, no. 2, pp. 139–148.

——— (1948a): The bearing of the living *Metasequoia* on problems of Tertiary paleobotany. *Proc. Nat. Acad. Sci.*, vol. 34, no. 11, pp. 503–515.

——— (1948b): Redwoods around the Pacific basin. *Pacific Discovery*, 1. no. 5, pp. 4–14.

——— (1951): A revision of fossil *Sequoia* and *Taxodium* in western North America based on the recent discovery of *Metasequoia*. *Trans. Amer. Philos. Soc., New Ser.*, vol. 40, pt. 3, pp. 171–263.

——— (1952): Conifer dominants in the Middle Tertiary of the John Day Basin, Oregon. *Palaeobot.*, vol. 1, pp. 105–113.

——— (1959): Miocene floras of the Columbia Plateau. pt. 1, Composition and interpretation. *Carnegie Inst. Wash. Publ.*, 617. pp. 1–134.

——— (1967): Miocene forests of the Pacific basin: their ancestors and their descendants. *Jubil. Publ. Commem. Prof. Sasa's 60th Birthday*, pp. 209–239.

CHANEY, R. W. & D. I. AXELROD (1959): Miocene forests of the Columbia Plateau. Pt. 2, Systematic Considerations. *Carnegie Inst. Wash. Pub.*, 617, pp. 135–229.

CHANEY, R. W. & E. I. SANBORN (1933): The Goshen flora of west-central Oregon. *Carnegie Inst. Wash. Publ.*, 439, 103 pp.

CHANG, T. P. (1936): Forest flora of Tienmu-Shan, Checkiang. *Agriculture* (*Nung Hsueh*), vol. 2, pp. 77–84. (in Chinese)

CHEN, H. C. (1936): Forest flora of Lu-Shan (Kiangsi). *Jour. Agr. Forest.*, vol. 14, pp. 974–985. (in Chinese).

CHENG, W. C. (1939): Les forêt du Se-tchouan et du Si-Kang oriental. *Trav. Lab. Forest. Toulouse*, tom. 5, vol. 1, art. 2, 233 pp.

CHENG, W. C. et al. (1938): Forests of Szechuan. Szechuan Prov. Governm. (in Chinese).

CHIEN, S. S. (1927): Preliminary notes on the vegetation and flora of Hwang-Shan. *Contr. Biol. Lab. Sci. Soc. China*, vol. 3, pp. 1–85.

CHU, K. & W. S. COOPER (1950): An ecological reconnaissance in native home of *Metasequoia glyptostroboides*. *Ecol.*, vol. 31, no. 2, pp. 260–278.

DEPAPE, G. & J. R. BATALELLER (1950): Flora oligocene de Cervera (Catalogne). *Ann. Escuela Perit. Agrico. Especial. Agropec. Serv. Tecnic. Agricul.*, vol. 9, pp. 5–60.

DORF, E. (1964): The use of fossil plants in paleoclimatic interpretations. *Problems in palaeoclimatology* (edit. by A. NAIRN), pp. 13–31, Intersci. Publ., London.

ENDO, S. (1928): A new Palaeogene species of *Sequoia*. *Jap. Jour. Geol. Geogr.*, vol. 12, no. 6, pp. 27–30.

———— (1931): Cenozoic plants (in Japanese). *Iwanami's Geology and Paleontology series*, Iwanami, Tokyo, 44 pp.

———— (1934): A new species of *Nelumbo* from the Palaeogene of Japan. *Jap. Jour. Geol. Geogr.*, vol. 11, nos. 3–4, pp. 255~258.

———— (1936): New fossil species of *Sequoia* from Far East. *Proc. Imp. Acad. Tokyo*, no. 6, pp. 172–175.

———— (1937): On the fossils of genus *Platanus* from eastern Asia (in Japanese). *Tokyo Hakubutsugaku Zasshi*, vol. 35, no. 6, pp. 368–392.

———— (1942): On the fossil flora from the Shulan coal-field, Kririn province and the Fushun coal-field, Fengtien province (in Japanese). *Bull. Central Nat. Mus. Manchoukuo*, no. 3, pp. 33–43.

———— (1953): Note on the Cainozoic Plants of East Asia 1, 2, *Kumamoto Jour. Sci., Ser. B*, no. 4, pp. 1–4.

———— (1954): Notes on the Cainozoic plants of East Asia (3, 4, 5, 6). *Kumamoto Jour. Sci., Ser. B*, no. 4, pp. 1–9.

———— (1955): Icones Fossil Plant from Japanese Islands (in Japanese). Sangyo-Tokyo, Tokyo.

———— (1961): On the Evolution of the Osmundaceae with description of two new species. *Trans. Proc. Palaeont. Soc. Jap., N. S.*, no. 44, pp. 157–160.

———— (1963): On the genus *Acer* with description of new species. *Trans. Proc. Palaeont. Soc. Jap., N. S.*, no. 50, pp. 65–69.

———— (1968): The Flora from the Eocene *Woodwardia* Formation, Ishikari coal field, Hokkaido, Japan. *Bull. Natl. Sci. Mus.*, vol. 11, no. 4, pp. 411–449.

ENDO, S. & H. OKUTSU (1936): *Glyptostrobus* cone from *Liriodendron* bed near Sendai. *Proc. Imp. Acad. Tokyo*, vol. 12, no. 5, pp. 138–140.

EVERNDEN, J. F. & G. T. JAMES (1964): Potassium-Argon dates and the Tertiary floras of North America. *Amer. Jour. Sci.*, vol. 262, pp. 945–974.

FAN, C. S. (1935): The vegetation of Chiu Hwa Shan, Anhwei. *Bull. Coll. Agr. For. Univ. Nanking, n. s.*, no. 38, pp. 1–7.

FLORIN, R. (1922): Zur Kenntnis der jungtertiären Pflanzenwelt Japans. *Kgl. Sv. Vet.-Akad. Handl.*, Bd. 61, no. 1, pp. 1–71.

FORBES, E. (1851): Notes on fossil leaves represented in Plates II.–IV. in the Duke of Argyll's paper on Tertiary leaf-beds in the Isle of Mull. *Quart. Jour. Geol. Soc.*, vol. 7,

GARDNER, J. S. & C. V. ETTINGSHAUSEN (1879–82): A Monograph of the British Eocene Flora, vol. 1, pp. 1–86. Palaeontographical Soc., London.

GIEBEL, C. (1857): Palaeontologisch Untersuchungen. *Zeitsh. f. d. gesam. Naturwiss.* Bd. 10.

GOEPPERT, H. R. (1855): Die Tertiäre Flora von Schossnit in Schlesien. Görlitz, 52 pp.

——— (1861): Über die Tertiärflora der Polargegenden. *Bull. Acad. Sci. St. Petersb.*, vol. 3, no. 7.

GRAY, J. (1964): Micropalaeobotany, a new dimension in the study of Tertiary vegetation. *10th Int. Bot. Cong. Abst. Pap.*, pp. 29–30.

HARA, H. (1959): An outline of the phytogeography of Japan. *Distributional Maps of Flowering Plants in Japan*, part 2, 96 pp. Inoue-shoten, Tokyo.

HAYASHI, Y. (1952): The flora of Amagi national forest in Izu peninsula. *Rept. Governm. Forest Experim. Station*, no. 63, 71 pp.

HEER, O. (1855–1859): Flora tertiaria Helvetiae. vol. 1–3, Winterthur.

——— (1868–1883): Flora fossilis Arctica. vol. 1–7, Zürich.

HOLLICK, A. (1936): The Tertiary floras of Alaska. *U.S. Geol. Surv. Prof. Paper*, 182, pp. 1–171.

HORIKAWA, Y. & Y. SASAKI (1959): Phytosociological studies on the vegetation of Geihoku district, Hiroshima Prefecture (In Japanese, with English summary). *Sci. Res. Sandankyo Gorge and Yawata Highland*, pp. 85–107.

HOUGH, R. S. (1950): Handbook of the trees of the Northern States and Canada. MacMillan, New York, 470 pp.

HSU, Y. C. (1939): Forest distribution of Saping, Szechuan, and its exploitation. *Southwestern Frontier*, no. 10, pp. 34–44. (in Chinese).

HU, H. H. & R. W. CHANEY (1938): A Miocene flora from Shantung province, China. *Palaeont. Sinica., new series* A., no. 1, 147 pp.

HUZIOKA, K. (1943): Notes on some Tertiary plants from Tyosen. I. *Jour. Fac. Sci. Hokkaido Univ., ser.* 4, vol 7, no. 1, pp. 118–141.

——— (1951): Notes on some Tertiary plants from Tyosen (Korea). II. *Trans. Proc. Palaeont. Soc. Jap., N. S.*, no. 3, pp. 67–74.

——— (1961): A new Palaeogene species of the genus *Comptonia* from Joban coal-field, with reference to the stratigraphical consideration on the Tertiary *Comptonia* in northeastern Japan. *Jour. Min. Col., Akita Univ., ser. A*, vol. 1, no. 1, pp. 60–68.

——— (1963): The Utto flora of northern Honshu. *Tertiary floras of Japan* 1–3, pp. 153–216, Geol. Surv. Jap. 80th Anniv. Comm. Assoc., Tokyo.

——— (1964): The Aniai flora of Akita Prefecture, and the Aniai-type floras in Honshu, Japan. *Jour. Min. Colleg., Akita Univ., ser. A*, vol. 3, no. 4, pp. 1–105.

HUZIOKA, K. & M. KOBAYASHI (1961): The mode of occurrence of fossil plants in the Yubari formation at the Shimizusawa coal mine in the Ishikari coal field, Hokkaido. (in Japanese). *Min. Geol.*, vol. 11, pp. 245–252.

IIJIMA, A. (1959): On relationship between the provenance and the depositional basins of the Upper Cretaceous and Tertiary formations in central and southeastern Hokkaido, Japan. *Jour. Fac. Sci. Univ. Tokyo, sect.* 2, vol. 11, pt. 4, pp. 339–385.

——— (1964a): The chromian distribution in the Paleogene deposits of Hokkaido and its bearing on ultrabasic rock belts. *Jap. Jour. Geol. Geogr.*, vol. 35, no. 1, pp.

17–42.

——— (1964b): The Paleogene paleogeology and paleogeography of Hokkaido. *ibid.* pp. 43–55.

KANEHIRA, R. (1936): Formosan Trees (Rev. edit.) (in Japaese). Dep. Forest. Govern. Res. Inst. Taihoku.

KIRA, T. (1948): On the classification of altitudinal, climatic zone by the warmth index. (in Japanese). *Kanchi-Nogaku* (*Boreal agriculture*), vol. 2, no. 2, pp. 143–173.

——— (1949): Forest zones of Japan. (in Japanese). *Forestry Explanat. Series* no. 17, Jap. Forest. Tech. Assoc., Tokyo, 41 pp.

KNOWLTON, F. H. (1910): Decriptions of fossil plants from the Mesozoic and Cenozoic of North America, 1, *Smiths. Misc. Coll.*, vol. 52, pt. 4, pp. 489–496.

——— (1923): Revision of the flora of the Green River formation with descriptions of new species. *U.S. Geol. Surv. Prof. Paper*, 131 F, pp. 133–182.

——— (1926): Flora of the Latah formation of Spokane, Washington and Coeur d'Alene, Idaho. *U.S. Geol. Surv. Prof. Paper*, 140 A, pp. 17–81.

KOIDZUMI, G. (1914): A phytogeographical survey of Mt. Kiso-Ontake (A preliminary note). (in Japanese). *Bot. Mag. Tokyo*, vol. 28, pp. 5–21; 49–64; 111–127.

KOKAWA, S. (1955): Plant and insect fossils found in the Mikasayama area, Nara prefecture (in Japanese with English summary). *Jour. Geol. Soc. Jap.*, vol. 61, pp. 93–102.

KONNO, E. (1931): Cenozoic flora in central part of Shinano. (in Japanese). In: *Geology of Central Shinano* (edited by F. HONMA). Kokon-shoin, Tokyo, pp. 93–102.

KRÄUSEL, R. (1920): Die Pflanzen des Schlesischen Tertiärs. *Jahrb. Konig. Preus. L-A*, vol. 38. pp. 1–338.

KRUTSCH, W. (1967): Der Florenwechsel im Alttertiär Mitteleuropas auf Grund von sporenpaläontologischen Untersuchungen. *Abh. zentr. geol. Inst. Berlin*, Hft. 10, pp. 17–37.

KRYSHTOFOVICH, A. N. (1918): Two ferns and a palm from the Tertiary of the Takashima coal mines in the Province of Hizen. *Jour. Geo. Soc. Tokuyo*, vol. 25, pp. 25–29.

——— (1936): Contributions to Early Tertiary floras from Saghalien. (in Russian). *Izb. Acad. Nauk USSR.* pp. 697–727.

——— (1956): Oligocene flora from Ashutas mountains of Kazakstane. *Palaeobotanica*, vol. 1, pp. 1–170 (in Russian).

——— (1958): Cretaceous flora of the Anadyrland. (in Russian). *Palaeobotanica*, vol. 3, pp. 9–70.

LAKHANPAL, R. N. (1958): The Rujada flora of west central Oregon. *Univ. Calif. Publ. Geol. Sci.*, vol. 35, no. 1, pp. 1–66.

LESQUEREUX, L. (1873): Enumeration and description of fossil plants from the western Tertiary formations. *U.S. Geol. Surv. Territ., Ann. Rept.*, vol. 6, pp. 371–427.

——— (1878): Contributions to the flora of the Western Territiores, Part II. The Tertiary Flora. *U.S. Geol. Surv., Terr. Rept.*, vol. 7, pp. 1–366.

——— (1883): Cretaceous and Tertiary Flora, *U.S. Geol. Surv., Terr. Rept.*, vol. 8, pp. 1–283.

LI, H. L. (1963): Woody flora of Taiwan. Morris Arboretum, Philadelphia., 974 pp.

LIU, Ta. (1962): A phytogeographic sketch on the forest flora of Taiwan (Formosa). *Acta Phytotax. Geob.*, vol. 20, pp. 149–157.

LIU, Ts. et al. (1961): Ecological survey on Taiwan important forest types. *Bull. Taiwan Forest. Res. Inst.*, no. 72, p. 1–65 (in Chinese with English summary).

MAEKAWA, F. (1960): The palaeo-equator and its relation to the recent distributional area of *Coriaria. Quaternary Res.*, vol. 1, no. 6, pp. 212–218.

MABUTI, S. (1962): A study on sedimentation and tectogenic history of the Paleogene system of the Kushiro coal field. (in Japanese with English summary). *Contr. Inst. Geol. Paleont. Tohoku Univ.*, no. 56, pp. 1–42.

MACGINITIE, D. H. (1937): The flora of the Weaverville beds of Trinity County, California, with descriptions of the plant-bearing beds. *Carnegie Inst. Wash. Publ.*, 465, pp. 83–151.

———— (1941): A Middle Eocene flora from the central Sierra Nevada. *Carnegie Inst. Wash. Publ.*, 534, pp. 1–178.

———— (1953): Fossil plants of the Florissant Beds, Colorado. *Carnegie Inst. Wash. Publ.*, 599, 198 pp.

———— (1962): The Kilgore flora. A Late Miocene flora from northern Nebraska. *Univ. Calif. Publ. Geol. Sci.*, vol. 35, no. 2, pp. 67–158.

MARTIN, P. S. & J. GRAY (1962): Pollen analysis and the Cenozoic. *Science*, vol. 137, no. 3524, pp. 103–111.

MATSUI, M. (1962): Sedimentological study of the Paleogene basin of the Kushiro in Hokkaido, Japan. *Jour. Fac. Sci. Hokkaido Univ., ser.* 4, vol. 11, pp. 431–480.

MATSUO, H. (1953): Three Neogene species of *Osmunda* from Ishikawa and Fukui Prefecture, Central Japan. *Sci. Rept. Kanazawa Univ.*, vol. 2, no. 1, pp. 139–144.

———— (1956): On the occurrence of *Osmunda bromeliaefolioides* from the middle part of Noto Peninsula, (in Japanese). *Jour. Geol. Seoc. Jap.*, vol. 62, no. 735, pp. 718–719.

———— (1959): A revision of the Miocene fern of *Osmunda bromeliaefolioides* MATSUO from Noto Peninsula in the innerside of central Japan. *Sci. Rept. Kanazawa Univ.*, vol. 6, no. 2, pp. 85–90.

———— (1963): The Notonakajima flora of Noto peninsula. *Tertiary Floras of Japan*, 1–4, pp. 219–243. Geol. Surv. Jap. 80th Anniv. Comm. Assoc., Tokyo.

———— (1967): Palaeogene Floras of Northwestern Kyushu. Part I: The Takashima Flora. *Ann. Sci. Kanazawa Univ.*, vol. 4, pp. 15–90.

MIZUNO, A. (1964): Summary of the Paleogene molluscan faunas in North Japan. *Geol. Surv. Jap. Rept.*, no. 207, pp. 1–27.

NAGAHAMA, H. (1961): Explanatory Text of Geological Map of Japan, scale 1 : 50,000, "Kushiro". 53 pp. Hokkaido Develop. Agency.

NAGAI, K. (1957): The Upper Eocene flora of the Kuma group in the Ishizuchi range, Shikoku, Japan. *Mem. Ehime Univ., Sect.* 2, vol. 2, no. 4, pp. 73–82.

NAGAO, T. (1933): The Paleogene Tertiary. (in Japanese). *Iwanami's Geology and Paleontology Series.* Iwanami, Tokyo, 120 pp.

NAKANO, H. (1942a): Composition of the forest communities of the subalpine forest zone in central Honshu (in Japanese). *Shokubutsu-Seitaigaku-ho*, vol. 2, no. 1, pp. 1–17.

——— (1942b): Composition of the forest communities of the deciduous broad-leaved forest zone in Honshu (in Japanese). *Shokubutsu-seitaigaku-ho*, vol. 2, no. 2, pp. 57–72.

NATHORST, A. G. (1888): Zur fossilen Flora Japans. *Pal. Abhandl.* Bd. 4, pp. 197–250.

NEWBERRY, J. S. (1898): The later extinct floras of North America; a post-humous work edited by A. HOLLICK. *U.S.G.S. Mongr.* 35, 295 pp.

OHWI, Z. (1965): Flora of Japan. Rev. edit. (in Japanese). Shibundo, Tokyo.

OISHI, S. (1950): Illustrated catalogues of East Asiatic fossil plants (in Japanese). Chigaku-shisei-shuppan, Kyoto, 235 pp.

OISHI, S. & K. HUZIOKA (1941a): Studies on the Cenozoic plants of Hokkaido and Karahuto. VII. On the Tertiary *Marlea* (*Alangium*) from Hokkaido and Karahuto (in Japanese). *Jour. Geol. Soc. Jap.*, vol. 48, no. 574, pp. 354–356.

——— (1941b): I. Ferns from the *Woodwardia* Sandstone of Hokkaido. *Jour. Fac. Sci. Hokkaido Imp. Univ., ser.* 4, vol. 6, no. 2, pp. 177–192.

——— (1942): New species of *Woodwardia* and *Matasequoia* from the Harutori bed, Kushiro coal-field, Hokkaido (in Japanese). *Jour. Geol. Soc. Jap.*, vol. 49, no. 587, pp. 319–324.

——— (1943a): Studies on the Cenozoic plants of Hokkaido and Karahuto. IV. On the Tertiary *Tilia* from Hokkaido and Karafuto. *Jour. Fac. Sci. Hokkaido Imp. Univ., ser.* 4, vol. 7, no. 1, pp. 71–80.

——— (1943b): V. Tertiary *Acer* from Hokkaido and Karahuto. *Jour. Fac. Sci. Hokkaido Imp. Univ., ser.* 4, vol. 7, no. 1, 81–101.

——— (1943c): VI. On the Tertiary *Platanus* from Hokkaido and Karahuto. *ibid.*, vol. 7, no. 1, pp. 103–115.

——— (1943d): On the so-called Arctic Miocene floras. (in Japanese). *Acta Phytotax. Geobot.*, vol. 13, pp. 130–139.

——— (1954): VIII. Tertiary Ulmaceae from Hokkaido and Karahuto (Saghalien). *Jap. Jour. Geol. Geogr.*, vol. 24, pp. 121–144.

OKAZAKI, Y. (1962): Paleogene pollen-floral sequence of the Kushiro and Ishikari coal fields. (in Japanese). *Fossils*, no. 3, pp. 1–2.

——— (1966): Geology of Kushiro. (in Japanese) *Kushiro series* no. 7, Kushiro City, 326 pp.

OYAMA, K. et al. (1960): Illustrated handbook of Japanese Paleogene Molluscs. Geol. Surv. Japan, Tokyo, 244 pp.

POTBURY, S. S. (1935): The LaPorte flora of Plumas County, California. *Carnegie Inst. Wash. Publ.*, 465, pp. 29–81.

RASKY, K. (1962): Tertiary plant remains from Hungary (Upper Eocene and Middle Oligocene). *Ann. Hist.-Natur. Mus. Hung.*, vol. 54, pp. 31–49.

REID, E. & M. CHANDLER (1926): Catalogue of Cainozoic plants in the Department of Geology. vol. 1, The Bemberidge flora, pp. 1–206.

REIMANN, H. (1919): In KRAUSEL, R.: Die Pflanzen des schlesischen Tertiärs. *Jb. preus. Geol. L.-A., f.* 1917, Bd. 38, Heft. 2, pp. 4–96.

SANBORN, E. I. (1935): The Comstock flora of west central Oregon. *Carnegie Inst.*

Wash. Publ., 465–1, pp. 1–28.

SAPORTA, G. de. (1873) : Etude sur la végétation du sud-set de la France (Aix, Revision). *Ann. Sci. Nat. Bot.*, *s.* 5, tom. 18, pp. 23–146.

——— (1890) : Revue des travaux de paléontologie végétale parus en France en 1880 ou dans le cours des années précédentes. *Rev. génér. de Botanique,* t. 2, pp. 176–192, 225–238.

——— (1894) : Flora fossile du Portugal. Lisbon, Protgal, Direct. Trav. Géol. Acad. Roy. Sci., 286 pp.

SARGENT, C. C. (1922) : Manual of the trees of North America. Houghton Mifflin, 910 pp.

SASA, Y. (1940) : Stratigraphy of the Tertiary deposits in the Kushiro coal field and a critical review of the opinions expressed. (in Japanese). *Jour. Hokkaido Coal Min. Assoc.*, no. 307, pp. 1–19 ; no. 308, pp. 20–43.

SATO, Sh. (1967) : Geostructural development of the Kushiro coal field, Hokkaido. (in Japanese with English summary). *Jubil. Publ. Commem. Prof. Sasa, 60th Birthday*, pp. 441–451.

SATO, Sh. et al. (1967) : The paleocurrent of the Paleogene in the east of Kushiro City. (in Japanese with English summary). *Jour. Geol. Soc. Japan*, vol. 73, pp. 563–572.

SCHIMPER, W. Ph. (1874) : Traité Paléontologie végétale. Paris-London, 2604 pp.

TAKAHASHI, Ke. (1943) : Studies of the vegatation on the volcano Ontake in Kiso (in Japanese, with English summary). *Ecol. Rev.*, vol. 9, pp. 75–90.

TAKEDA, H. (1953) : The Poronai formation (Oligocene Tertiary) of Hokkaido and South Sakhalin and its fossil fauna. *Studies on Coal Geology no.* 3, Hokkaido Assoc. Coal Min. Tech., Sapporo, 103 pp.

TANAI, T. (1952b) : Historical review of research on the original plants of Japanese Cenozoic coals. Outline of Cenozoic Flora in Japan (in Japanese). *Coal Expl. Advis. Commit. Rept.*, no. 2, pp. 61–83.

——— (1955) : Illustrated catalogue of Tertiary plants in Japan. I. Early and Middle Miocene floras. *Geol. Sur. Jap. Rept.*, no. 163, 16 pp.

——— (1956) : On the Geologic age of the Owada and Kabato coal-bearing formations in Hokkaido, Japan. (in Japanese with English summary). *Bull. Geol. Surv. Jap.*, vol. 7, no. 1, pp. 11–20.

——— (1957) : Explanatory Text of Geological Map of Japan, Scale 1 : 50,000, " Onbetsu " (in Japanese with English summary). Hokkaido Develop. Agency, 52 pp.

——— (1961) : Neogene floral change in Japan. *Jour. Fac. Sci. Hokkaido Univ., ser.* 4, vol. 11, no. 2, pp. 119–398.

——— (1963) : Miocene floras of southwestern Hokkaido, Japan. Part 1, Composition and interpretation. *Tertiary floras of Japan.I. Miocene floras,* 2, pp. 9–96. Geol. Surv. Jap. 80th Anniv. Comm. Assoc., Tokyo.

——— (1967) : On the Hamamelidaceae from the Paleogene of Hokkaido, Japan. *Trans. Proc. Palaeont. Soc. Jap. N. S.*, no. 66, pp. 56–62.

——— (1967) : Tertiary floral changes of Japan. *Jubil. Publ. Commem. Prof. Sasa's 60th Birthday*, pp. 317–334.

TANAI, T. & K. HUZIOKA (1967) : Climatic implication of Tertiary floras in Japan. *Ter-*

tiary Correlation and Climatic Changes in the Pacific, pp. 89–94.

TANAI, T. & A. IIJIMA (1958): The geologic age of the coal-bearing formation concealed under the Ishikari Plain in Hokkaido (in Japanese). *Cenozoic Research*, no. 28, pp. 1–7.

TANAI, T. & T. ONOE (1961): A Mio-Pliocene flora from the Nigyo-Toge area on the border between Tottori and Okayama Prefectures, Japan. *Geol. Surv. Jap. Rept.*, no. 187, pp. 1–62.

TANAI, T. & N. SUZUKI (1963): Miocene floras of southwestern Hokkaido, Japan. part 2, Systematic consideration. *Tertiary floras of Japan* 1–2, pp. 97–149. Geol. Surv. Jap. 80th Anniv. Comm. Assoc., Tokyo.

TANAI, T. & N. SUZUKI (1965): Late Tertiary floras from northeastern Hokkaido, Japan. *Palaeont. Soc. Jap. Spec. Paper*, no. 10, 117 pp.

TATEWAKI, M. (1954): Sketch notes on vegetation, A profile of forest vegetation in central Honshu. (in Japanese). Nagoya Forest. Office, Nagoya, 49 pp.

———— (1956): Dr. TATEWAKI's Iconography of vegetation of the natural forest in Japan. I. The central Sanyo district. (in Japanese, with English summary) *Res. Bull. Coll. Exp. Forest., Fac. Agr. Hokkaido Univ.*, vol. 18, no. 1, pp. 1–56.

TRALAU, H. (1963): Asiatic dicotyledonous affinities in the Cainozoic flora of Europe. *Kungl. Svensk. Vet-Akad. Handl.*, vol. 9, no. 3, pp. 1–87.

TSOONG, P. C. (1936): Flora of Hwang-Shan. *Contr. Inst. Bot. Nat. Acad. Peiping*, vol. 4, pp. 25–158.

UCHIO, T. (1961): The foraminifera-faunal sequence of the Paleogene in Hokkaido (in Japanese). Doctorate Thesis presented to Hokkaido Univ.

UJIIE, H. & H. WATANABE (1960): The Poronai forminifera of the northern Ishikari coal-field, Hokkaido. *Sci. Rept. Tokyo Kyoiku Daigaku, Sec. C.*, no. 63, pp. 117–136.

UNGER, F. (1845): Synopsis plantarum fossilium. Leopoldum, Leipzig, 330 pp.

———— (1847): Chloris protogaea. Engelmann, Leipzig, 150 pp.

VASILIEV, Ig. V. (1961): Leaf impressions of *Nelumbo* from the Tertiary deposits of Kazakhstan. (in Russian). *Palaeont. Zhurnal*, 1961-no. 1, pp. 140–143.

WADACHI, K. (1958): Climate of Japan (in Japanese). Tokyo-do, Tokyo, 492 pp.

WALTHER, H. (1967): Ergänzungen zur Flora von Seifhennersdorf (Sachsen). *Abh. Staatl. Mus. Mineral. Geol.*, Bd. 12, S. 259–277.

WANG, C. W. (1961): The Forest of China, with a survey of grassland and desert vegetation. *Maria Moors Cabot Found. Pub. No.* 5, Harvard Univ., Cambridge, 313 pp.

WEYLAND, H. (1943): Beiträge zur Kenntnis der Rheinischen Tertiärflora VI., Vierte Ergänzungen und Berichtigungen zur Flora der Blätterkohle und des Polierschiefers von Rott im Siebengebirge. *Palaontgr.* Bd. 87, Abt. B, s. 96–136.

WOLFE, J. A. (1966): Tertiary plants from the Cook Inlet Region, Alaska. *U.S. Geol. Surv. Prof. Paper*, 398-B, 32 pp.

WOLFE, J. A., D. M. HOPKINS & E. A. LEOPOLD (1966): Tertiary stratigraphy and paleobotany of the Cook Inlet Region, Alaska. *ibid.*, 398-A, 29 pp.

WOLFE, J. A. & D. M. HOPKINS (1967): Climatic changes recorded by Tertiary land floras in northwestern North America. *Tertiary Correlation and Climatic Changes* *in the Pacific*. pp. 67–76.

YUNG, C. (1953): Illustrated manual of Chinese trees and shrubs (in Chinese). Rev. edit. Sci. Tech. Publ., Shanghai.

YABE, H. (1951): Stratigraphical relation of the Poronai and Ishikari groups in the Ishikari coal-field, Hokkaido. *Proc. Japan Acad.*, vol. 27, no. 9, pp. 571–576.

YABE, H. & S. ENDO (1939): Floral changes during the Cenozoic Era in the Japanese Islands. *Proc. Pan-Pacific Congr.* (U.S.A.), pp. 631–642.

PLATE 3 AND EXPLANATION

Explanation of Plate 3

(All natural size unless otherwise stated)

Figs. 1, 2 *Equisetum arcticum* HEER. Hypotypes, H. U. M. P. Reg. nos. 25871, 25872. Harutori pit.

Fig. 3 *Dennstaedtia nipponica* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25877. Okotsu pit.

Fig. 4 *Dennstaedtia nipponica* OISHI and HUZIOKA. Enlargement of figure 3. ×2

Fig. 5 *Osmunda sachalinensis* KRYSHTOFOVICH. Hypotype, H. U. M. P. Reg. no. 25874. Harutori pit.

Fig. 6 *Osmunda sachalinensis* KRYSHTOFOVICH. Hypotype, H. U. M. P. Reg. no. 25873. Okotsu pit.

Fig. 7 *Osmunda sachalinensis* KRYSHTOFOVICH. Hypotype, H. U. M. P. Reg. no. 25875. Okotsu pit.

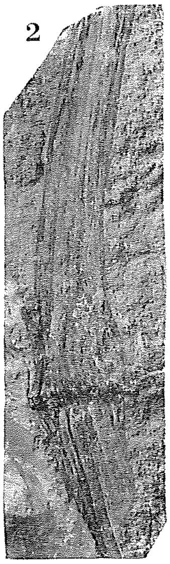
Figs. 8, 9 *Dennstaedtia nipponica* OISHI and HUZIOKA. Hypotypes, H. U. M. P. Reg. nos. 25878, 25879. Okotsu pit.

Fig. 10 *Onoclea hebraidica* (FORBES) GARDNER and ETTINGSHAUSEN. Hypotype, H. U. M. P. Reg. no. 25885. Okotsu pit.

Fig. 11 *Osmunda lignitum* (GIEBEL) STUR. Enlargement of Plate 4, figure 9. ×2

Plate 3


1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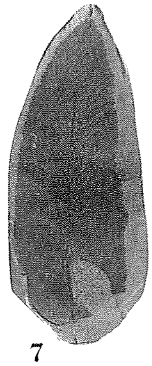
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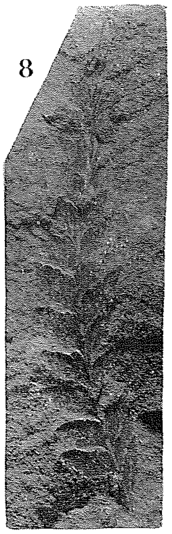
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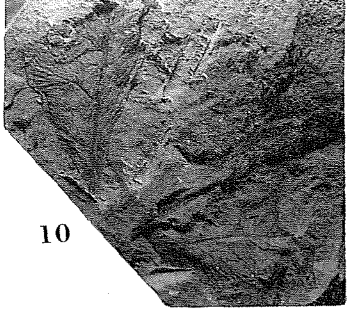
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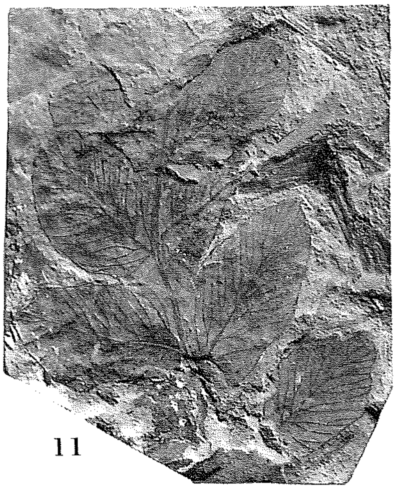
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PLATE 4 AND EXPLANATION

Explanation of Plate 4

(All natural size unless otherwise stated)

Fig. 1 *Woodwardia sasae* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25887. Harutori pit.

Fig. 2 *Woodwardia sasae* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25888. Okotsu pit.

Fig. 3 *Lastrea kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25883. Tokomuro.

Fig. 4 *Lastrea kushiroensis* new species. Hypotype, H. U. M. P. Reg. no. 25884. Okotsu pit.

Figs. 5, 6 *Dennstaedtia nipponica* OISHI and HUZIOKA. Hypotypes, H. U. M. P. Reg. nos. 25880, 25881. Harutori pit.

Fig. 7 *Dennstaedtia nipponica* OISHI HUZIOKA. Enlargement of figure 6. ×3

Fig. 8 *Woodwardia sasae* OISHI and HUZIOKA. Enlargement of figure 1. ×3

Fig. 9 *Osmunda lignitum* (GIEBEL) STUR. Hypotype, H. U. M. P. Reg. no. 25876. Nakanosawa, Yubetsu.

Plate 4


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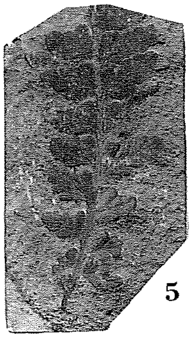
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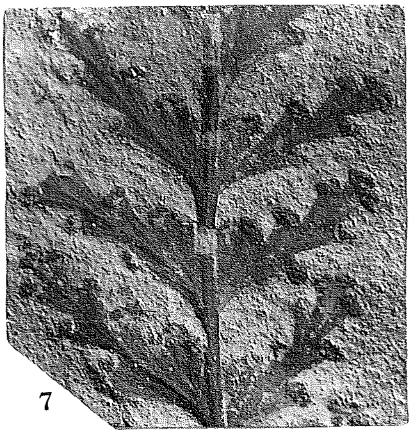
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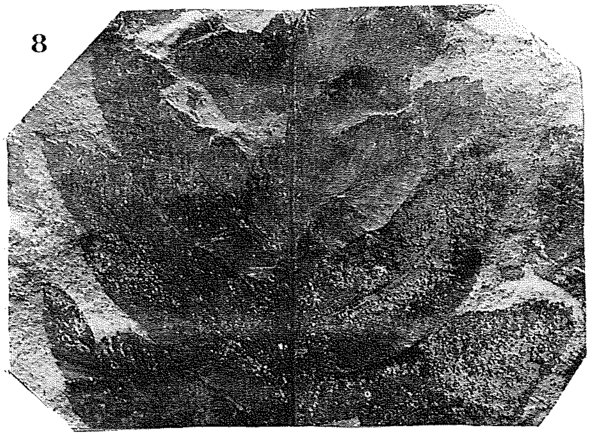
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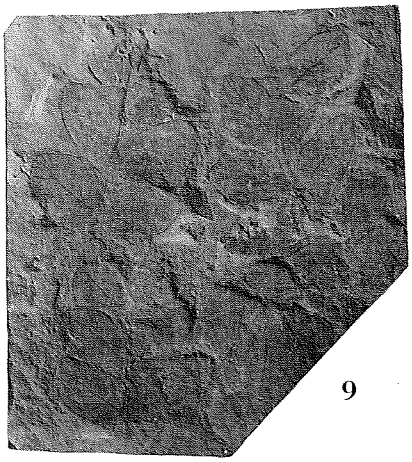
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PLATE 5 AND EXPLANATION

Explanation of Plate 5

(All natural size)

Fig. 1 *Musophyllum nipponicum* new species. Holotype, H. U. M. P. Reg. no. 25902. Harutori pit.

Fig. 2 *Pinus* sp. Hypotype, H. U. M. P. Reg. no. 25891. Okotsu pit.

Figs. 3, 4 *Metasequoia occidentalis* (NEWBERRY) CHANEY. Hypotypes, H. U. M. P. Reg. nos. 25893, 25894. Okotsu pit.

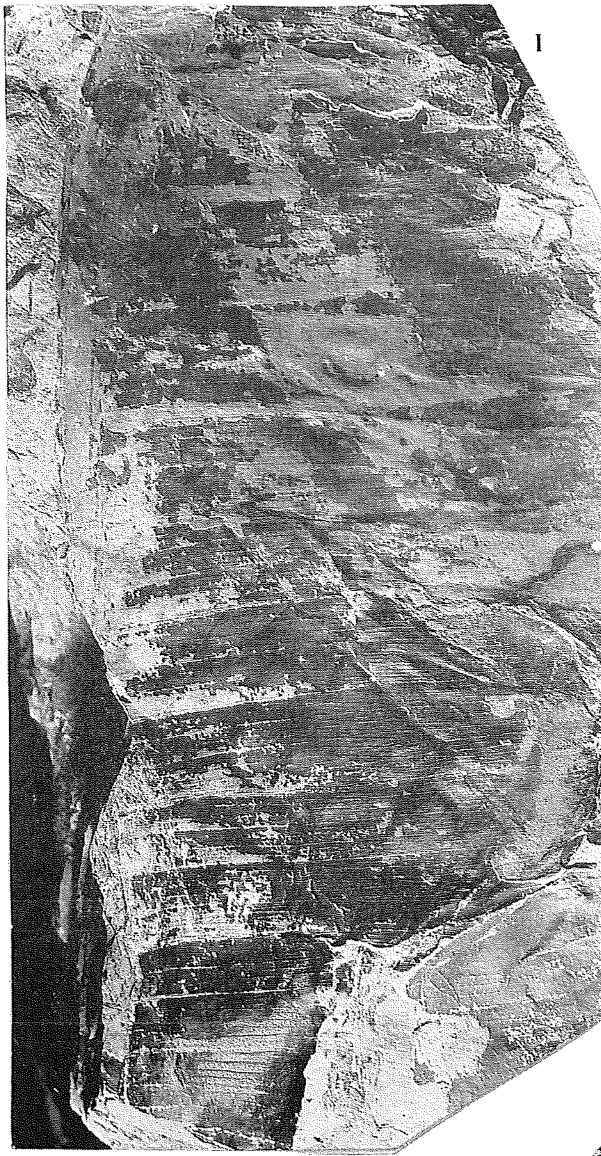
Fig. 5 *Comptonia kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25904. Nakanosawa, Yubetsu.

Figs. 6, 7 *Metasequoia occidentalis* (NEWBERRY) CHANEY. Hypotypes, H. U. M. P. Reg. nos. 25895, 25896. Okotsu pit.

Fig. 8 *Glyptostrobus europaeus* (BRONG.) HEER. Hypotype, H. U. M. P. Reg. no. 25892. Okotsu pit.

Fig. 9 a, b *Metasequoia occidentalis* (NEWBERRY) CHANEY. Hypotype, H. U. M. P. Reg. no. 25897. Harutori pit.

Plate 5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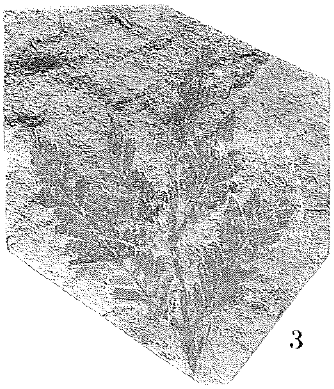
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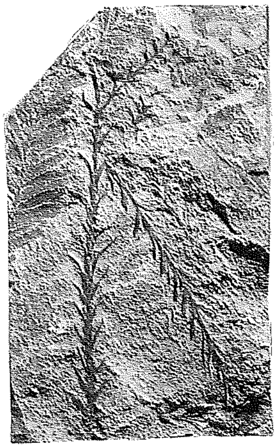
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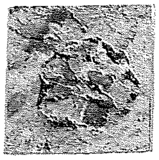
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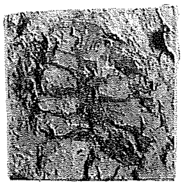
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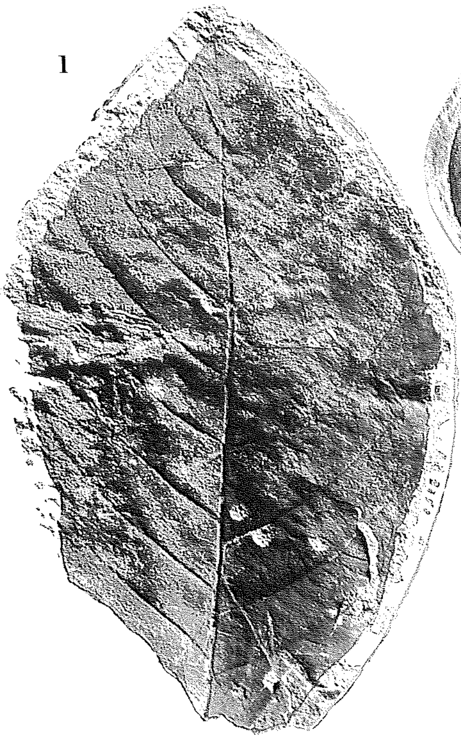
PLATE 6 AND EXPLANATION

Explanation of Plate 6

(All natural size)

Fig. 1 *Carya ezoensis* new species. Holotype, H. U. M. P. Reg. no. 25905. Okotsu pit.
Fig. 2 *Smilax hokkaidoensis* new species. Holotype, H. U. M. P. Reg. no. 25900. Harutori pit.
Fig. 3 *Carya ezoensis* new species. Paratype, H. U. M. P. Reg. no. 25906 a. Okotsu pit.
Fig. 4 *Carya ezoensis* new species. Hypotype, H. U. M. P. Reg. no. 25907. Harutori pit.
Fig. 5 *Platycarya hokkaidoana* new species. Holotype, H. U. M. P. Reg. no. 25910. Harutori pit.
Fig. 6 *Platycarya hokkaidoana* new species. Hypotype, H. U. M. P. Reg. no. 25912. Okotsu pit.
Fig. 7 *Metasequoia occidentalis* (NEWBERRY) CHANEY. Hypotype, H. U. M. P. Reg. no. 25898. Nakanosawa, Yubetsu.
Fig. 8 *Smilax hokkaidoensis* new species. Hypotype, H. U. M. P. Reg. no. 25901. Okotsu pit.

Plate 6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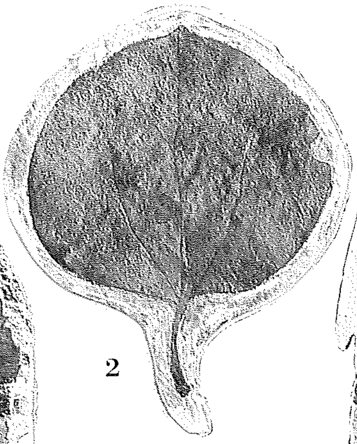
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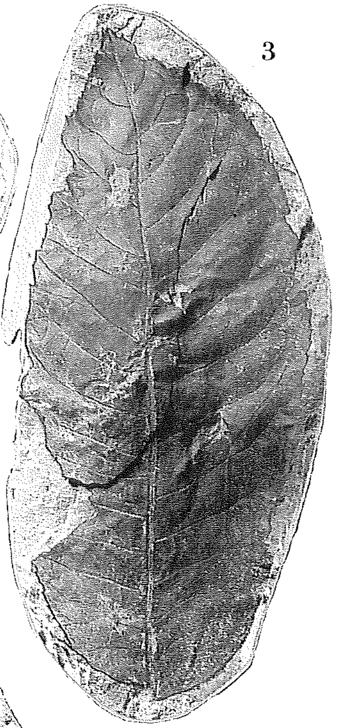
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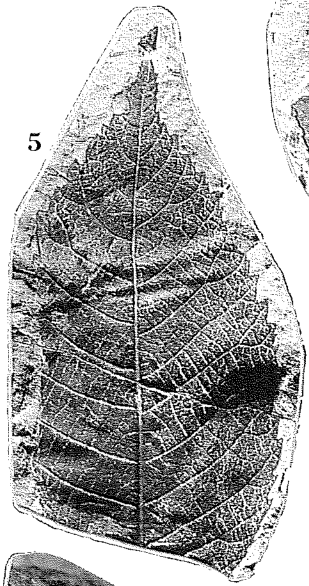
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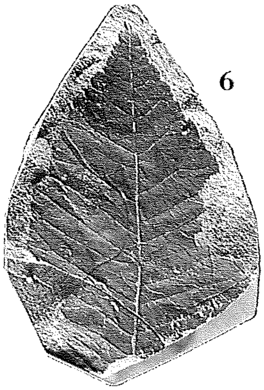
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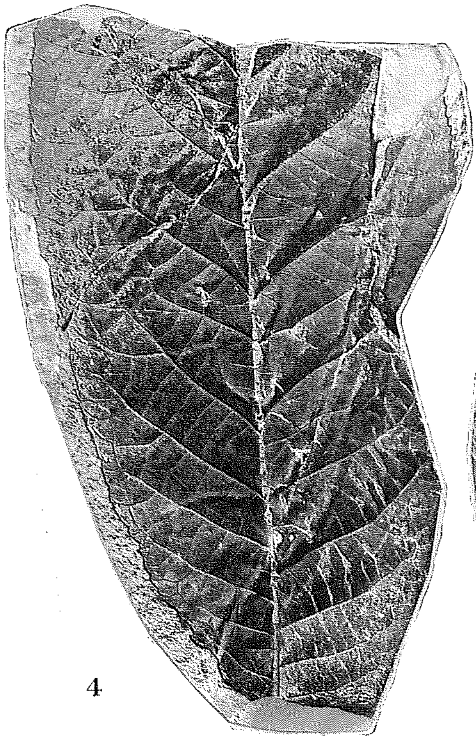
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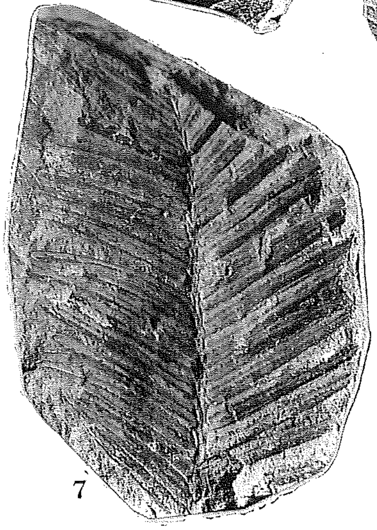
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PLATE 7 AND EXPLANATION

Explanation of Plate 7

(All natural size)

Fig. 1 *Alnus ezoensis* new species. Holotype, H. U. M. P. Reg. no. 25914. Nakanosawa, Yubetsu.

Fig. 2 *Spiraea betulifolia* PALL. The living leaf for comparison.

Fig. 3 *Spiraea kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25969. Okotsu pit.

Fig. 4 *Spiraea kushiroensis* new species. Paratype, H. U. M. P. Reg. no. 25970. Chinomizawa, Shoro.

Fig. 5 *Alnus ezoensis* new species. Paratype, H. U. M. P. Reg. no. 25915. Nakanosawa, Yubetsu.

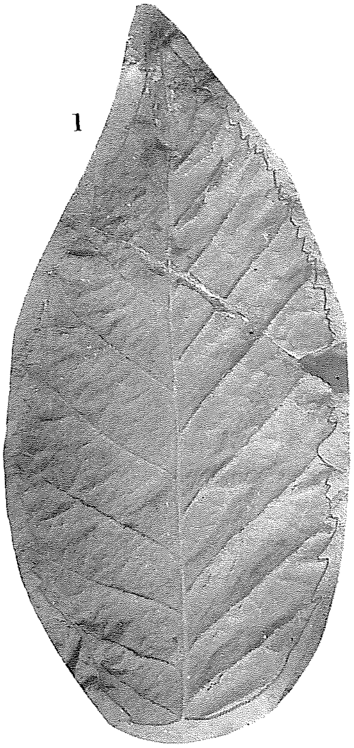
Fig. 6 *Platycarya hokkaidoana* new species. Paratype, H. U. M. P. Reg. no. 25911. Nakanosawa, Yubetsu.

Fig. 7 *Alnus ezoensis* new species. Hypotype, H. U. M, P. Reg. no. 25916. Okotsu pit.

Fig. 8 *Ulmus harutoriensis* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25945. Nakanosawa, Yubetsu.

Fig. 9 *Cercidiphyllum eojaponicum* ENDO. Hypotype, H. U. M. P. Reg. no. 25958. Okotsu pit

Plate 7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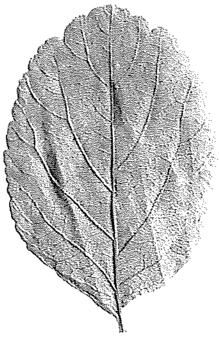
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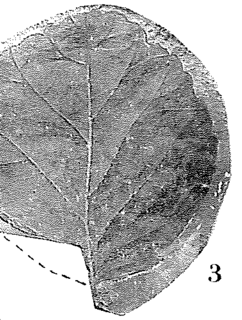
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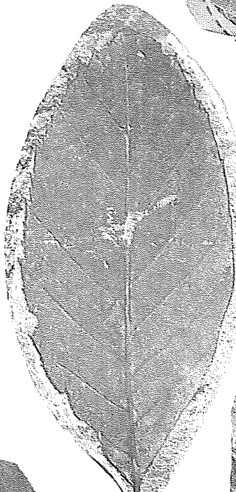
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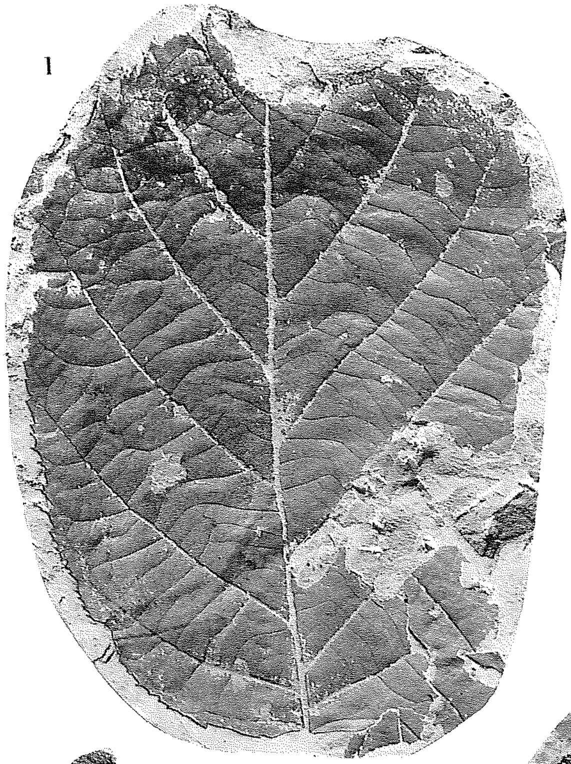
PLATE 8 AND EXPLANATION

Explanation of Plate 8

(All natural size)

Fig. 1 *Alnus kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25921. Harutori pit.
Fig. 2 *Alnus hokkaidoensis* new species. Paratype, H. U. M. P. Reg. no. 25919. Okotsu pit.
Fig. 3 *Trema asiatica* (BORSUK) new combination. Hypotype, H. U. M. P. Reg. no. 25940. Okotsu pit.
Fig. 4 *Trema asiatica* (BORSUK) new combination. Hypotypc, H. U. M. P. Reg. no. 25941. Okotsu pit.
Fig. 5 *Corylus* ezoana new species. Holotype, H. U. M. P. Reg. no. 25929. Shitakara River, Yubetsu.
Fig. 6 *Corvlus ezoana* new species. Hypotype, H. U. M. P. Reg. no. 25933. Okotsu pit.
Fig. 7 *Alnus hokkaidoensis* new species. Holotype, H. U. M. P. Reg. no. 25918. Harutori pit.

Plate 8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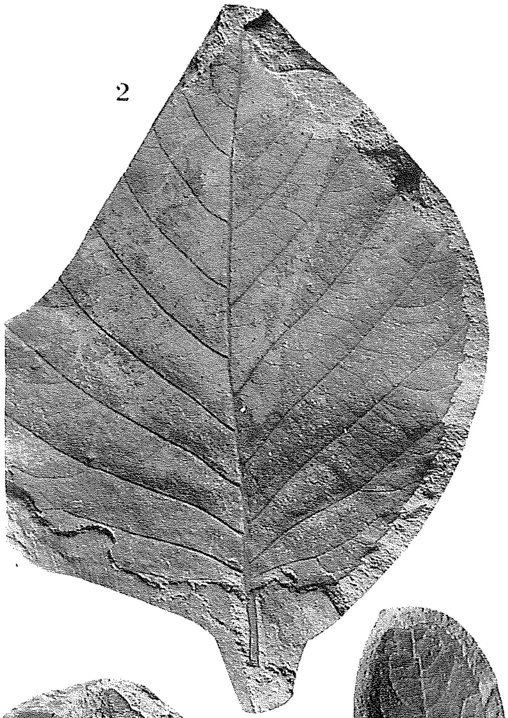
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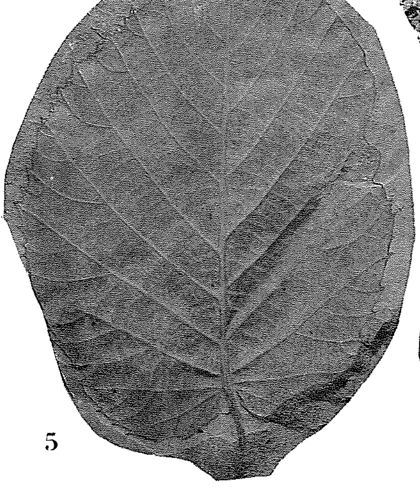
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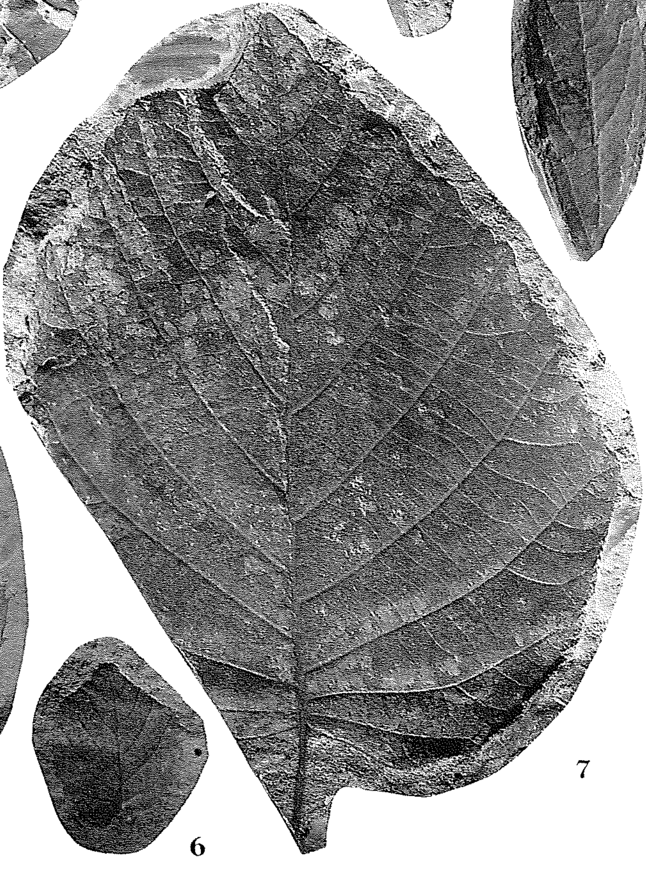
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PLATE 9 AND EXPLANATION

Explanation of Plate 9

(All natural size)

Figs. 1, 3 *Corylus ezoana* new species. Hypotypes, H. U. M. P. Reg. nos. 25932. Harutori pit.

Fig. 2 *Carpinus kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25924. Nakanosawa, Yubetsu.

Fig. 4 *Carpinus kushiroensis* new species. Hypotype, H. U. M. P. Reg. no. 25927. Nakanosawa, Yubetsu.

Fig. 5 *Alnus kushiroensis* new species. Paratype, H. U. M. P. Reg. no. 25922. Okotsu pit.

Fig. 6 *Carpinus kushiroensis* new species. Paratype, H. U. M. P. Reg. no. 25925. Harutori pit.

Fig. 7 *Carpinus kushiroensis* new species. Hypotype, H. U. M. P. Reg. no. 25926. Harutori pit.

Fig. 8 *Carpinus kushiroensis* new species. Hypotype, H. U. M. P. Reg. no. 25928. Okotsu pit.

Fig. 9 *Trema asiatica* (BORSUK) new combination. Hypotype, H. U. M. P. Reg. no. 25942. Harutori pit.

Plate 9

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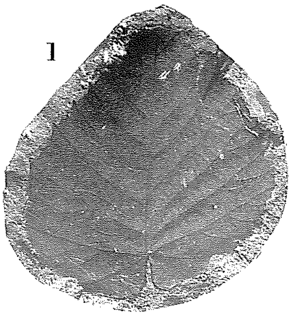

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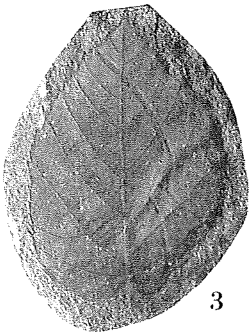

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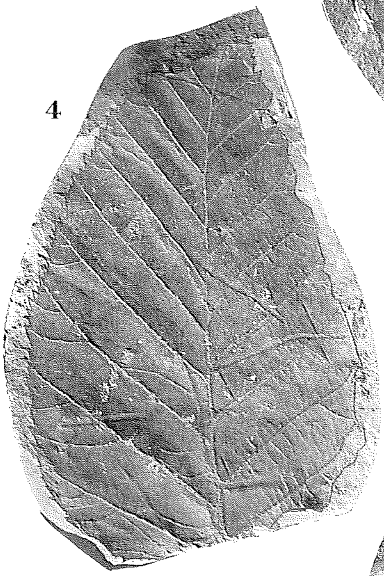

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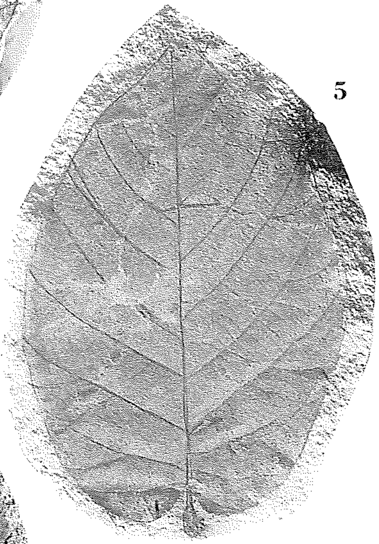

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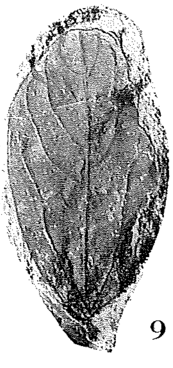

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PLATE 10 AND EXPLANATION

Explanation of Plate 10

(All natural size)

Fig. 1 *Zelkova kushiroensis* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25947. Okotsu pit.

Fig. 2 *Planera ezoana* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25939. Chinomizawa, Shoro.

Fig. 3 *Ulmus harutoriensis* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25943. Harutori pit.

Figs. 4, 5 *Planera ezoana* OISHI and HUZIOKA. Hypotypes, H. U. M. P. Reg. nos. 25937, 25938. Okotsu pit.

Fig. 6, 7 *Zelkova kushiroensis* OISHI and HUZIOKA. Hypotypes, H. U. M. P. Reg. nos. 25948, 25949. Shitakara River, Yubetsu.

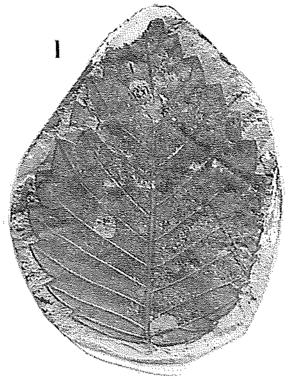
Fig. 8 *Zelkova kushiroensis* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25946. Harutori pit.

Fig. 9 *Quercus kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25934. Harutori pit.

Fig. 10 *Ulmus harutoriensis* OISHI and HUZIOKA. Hypotype, H. U. M. P. Reg. no. 25944. Nakanosawa, Yubetsu.

Fig. 11 *Quercus kushiroensis* new species. Paratype, H. U. M. P. Reg. no. 25935. Okotsu pit.

Plate 10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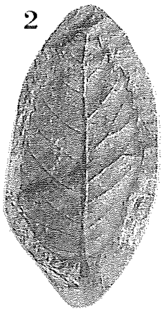
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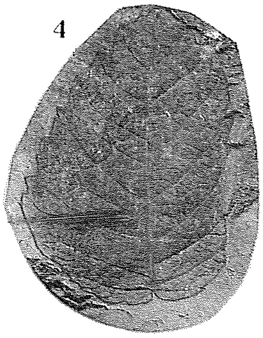
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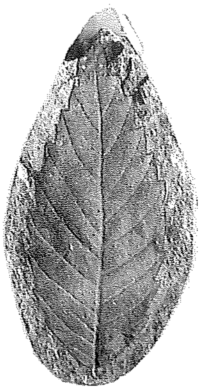
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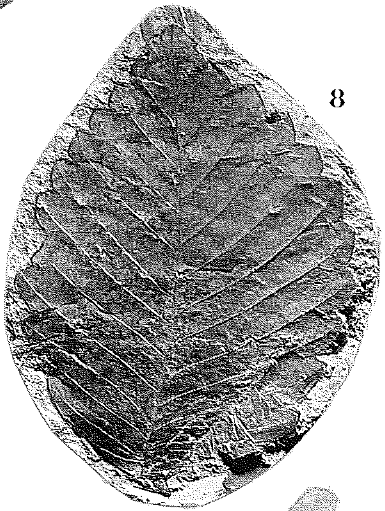
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11

PLATE 11 AND EXPLANATION

Explanation of Plate 11

(All natural size)

Fig. 1 *Cocculus ezoensis* new species. Holotype, H. U. M. P. Reg. no. 25906 b. Okotsu pit.
Fig. 2 *Cercidiphyllum eojaponicum* ENDO. Hypotype, H. U. M. P. Reg. no. 25955. Okotsu pit.
Fig. 3 *Cercidiphllum eojaponicum* ENDO. Hypotype, H. U. M. P. Reg. no. 25956. Okotsu pit.
Fig. 4, 6 *Broussonetia* sp. Hypotype, H. U. M. P. Reg. no. 25950 a, b. Harutori pit.
Fig. 5 *Cocculus ezoensis* new species. Hypotype, H. U. M. P. Reg. no. 25965. Harutori pit.
Fig. 7 *Nelumbo nipponicum* ENDO. Hypotype, H. U. M. P. Reg. no. 25953. Harutori pit.
Fig. 8 *Cercidiphyllum eojaponicum* ENDO. Hypotype, H. U. M. P. Reg. 25957. Harutori pit.

Plate 11

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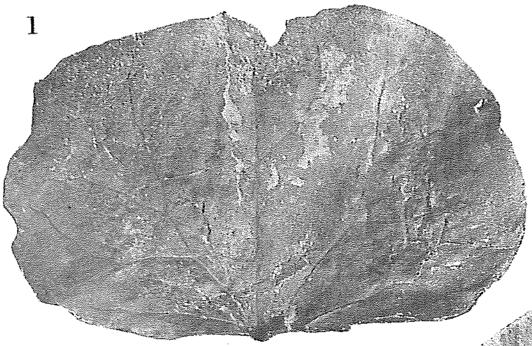

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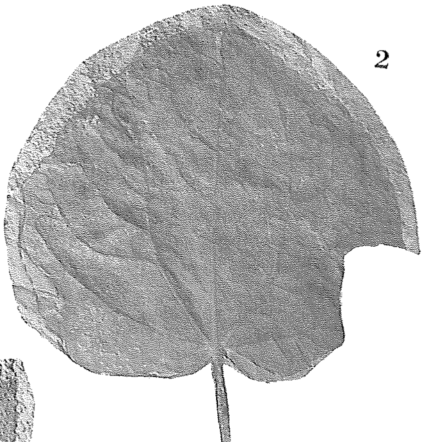

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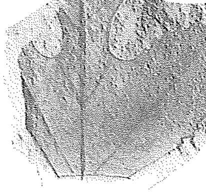

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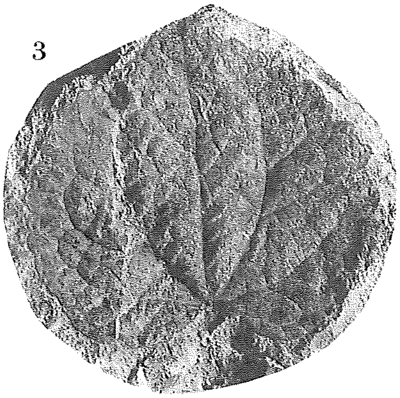

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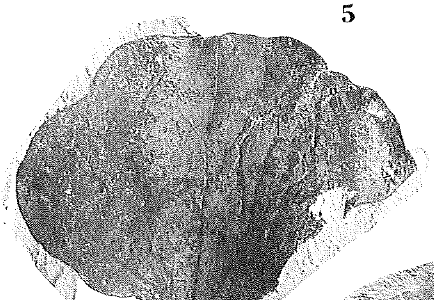

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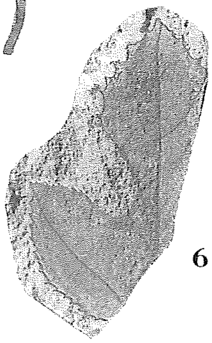

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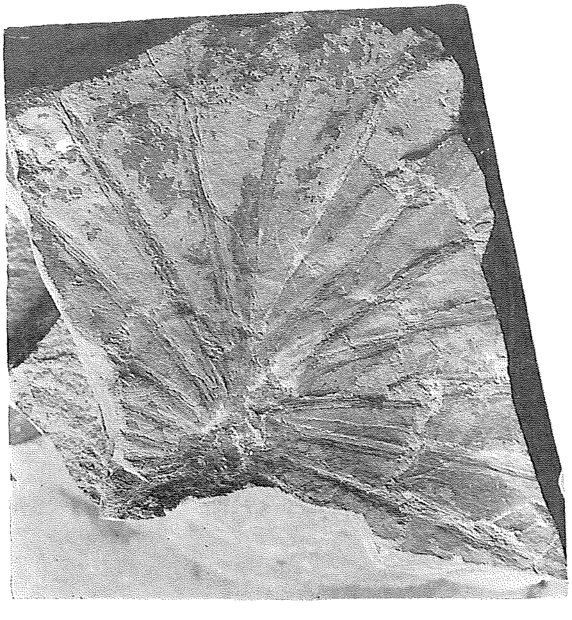

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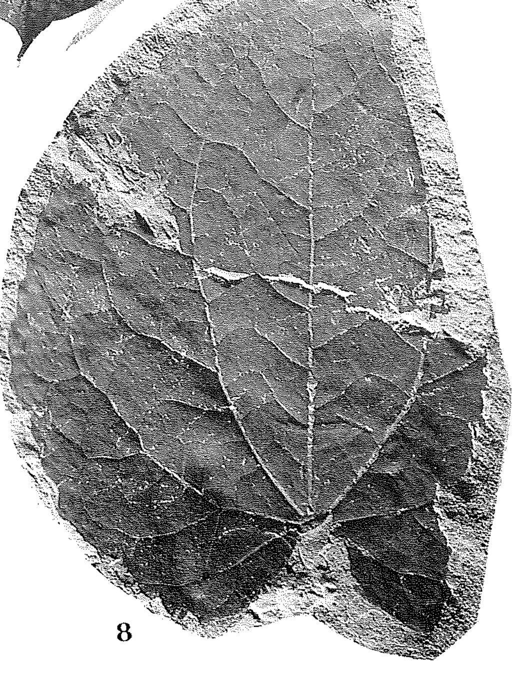


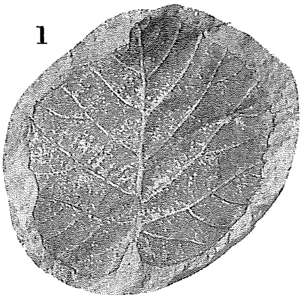
PLATE 12 AND EXPLANATION

Explanation of Plate 12

(All natural size)

Fig. 1 *Corylus ezoana* new species. Paratype, H. U. M. P. Reg. no. 25930. Okotsu pit.
Fig. 2 *Cocculus ezoensis* new species. Paratype, H. U. M. P. Reg. no. 25964. Okotsu pit.
Fig. 3 *Cupania japonica* new species. Paratype, H. U. M. P. Reg. no. 25993. Nakanosawa, Yubetsu.
Fig. 4 *Ficus* sp. Hypotype, H. U. M. P. Reg. no. 25951. Okotsu pit.
Fig. 5 *Zanthoxylum oblongatum* new species. Holotype, H. U. M. P. Reg. no. 25971. Harutori pit.
Fig. 6 *Platanus guillelmae* GOEPPERT. Hypotype, H. U. M. P. Reg. no. 25968. Okotsu pit.
Fig. 7 *Cupania japonica* new species. Holotype, H. U. M. P. Reg. no. 25992. Harutori pit.
Fig. 8 *Zanthoxylum oblongatum* new species. Hypotype, H. U. M. P. Reg. no. 25972. Okotsu pit.
Fig. 9 *Platanus aceroides* GOEPPERT. Hypotype, H. U. M. P. Reg. no. 25667. Harutori pit.

Plate 12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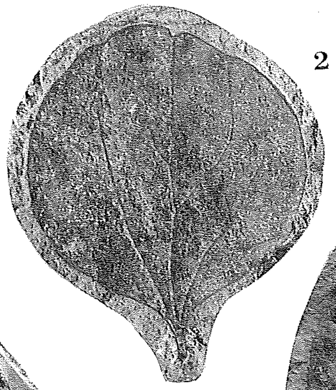
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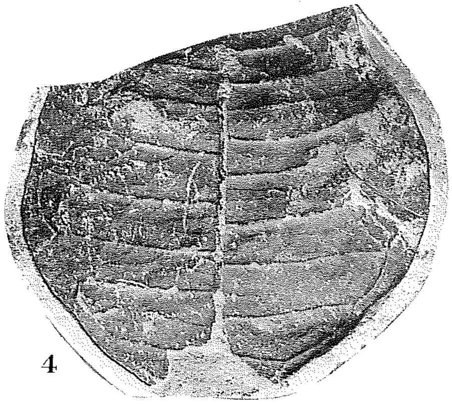
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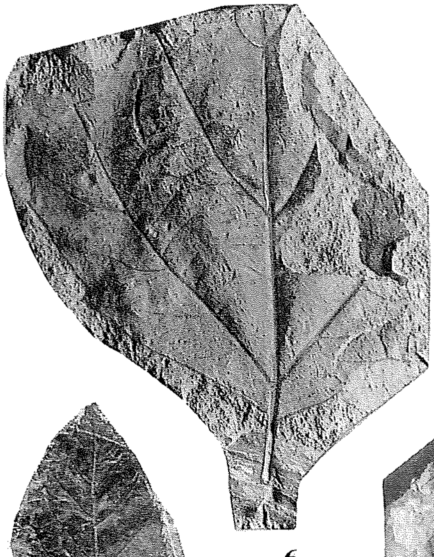
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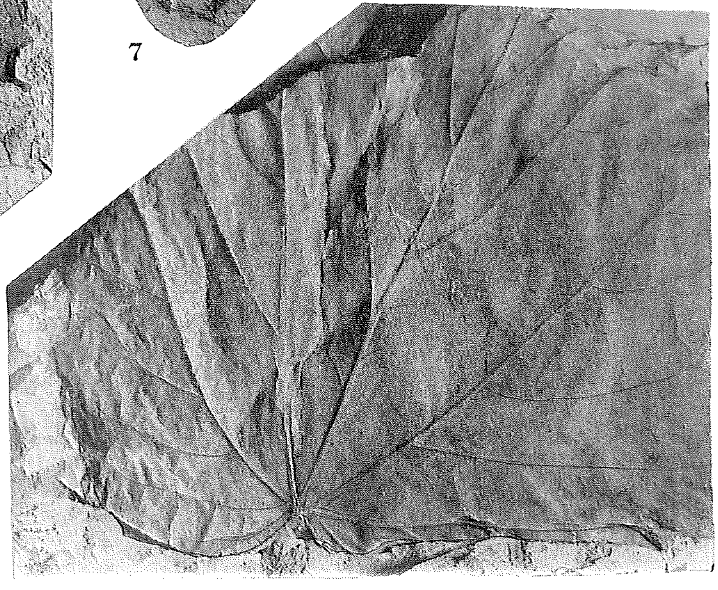
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PLATE 13 AND EXPLANATION

Explanation of Plate 13

(All natural size)

Fig. 1 *Glochidion japonicum* new species. Paratype, H. U. M. P. Reg. no. 25978. Oktosu pit.

Figs. 2, 4 *Coriaria* sp. Hypotypes, H. U. M. P. Reg. nos. 25980, 25981. Okotsu pit.

Fig. 3 *Canarium ezoanum* new species. Holotype, H. U. M. P. Reg. no. 25974. Okotsu pit.

Fig. 5 *Glochidion japonicum* new species. Holotype, H. U. M. P. Reg. no. 25977. Harutori pit.

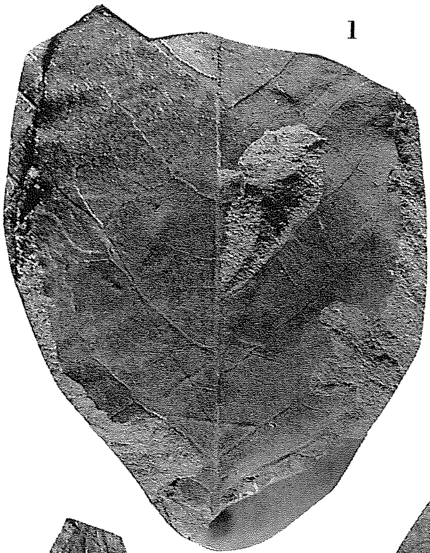
Fig. 6 *Ilex obovata* new species. Holotype, H. U. M. P. Reg. no. 25982. Okotsu pit.

Fig. 7 *Canarium ezoanum* new species. Paratype, H. U. M. P. Reg. no. 25975. Harutori pit.

Fig. 8 *Mallotus hokkaidoensis* new species. Holotype, H. U. M. P. Reg. no. 25979. Harutori pit.

Fig. 9 *Zizyphus harutoriensis* new species. Holotype, H. U. M. P. Reg. no. 25994 a. Harutori pit.

Plate 13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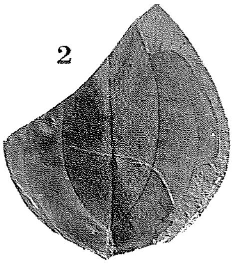
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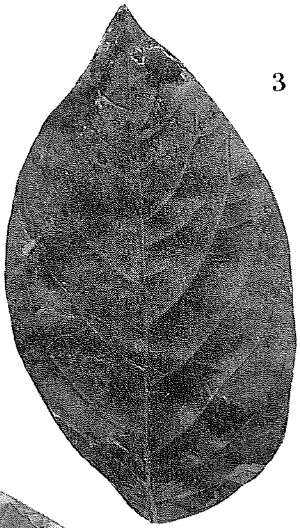
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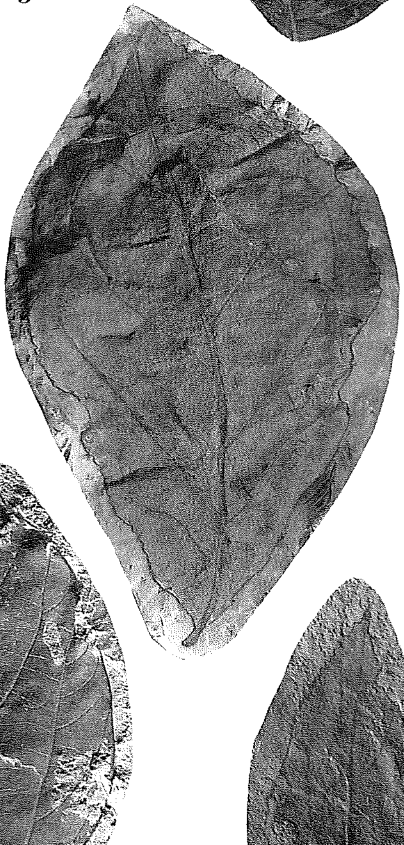
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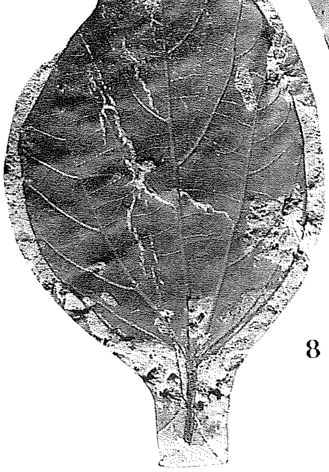
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PLATE 14 AND EXPLANATION

Explanation of Plate 14

(All natural size unless otherwise stated)

Fig. 1 *Acer oishii* new species. Holotype, H. U. M. P. Reg. no. 25986. Okotsu pit.

Fig. 2 *Zizyphus harutorieosis* new species. Hypotype, H. U. M. P. Reg. no. 25994 b. Harutori pit.

Fig. 3 *Acer arcticum* HEER. Hypotype, H. U. M. P. Reg. no. 25984. Okotsu pit.

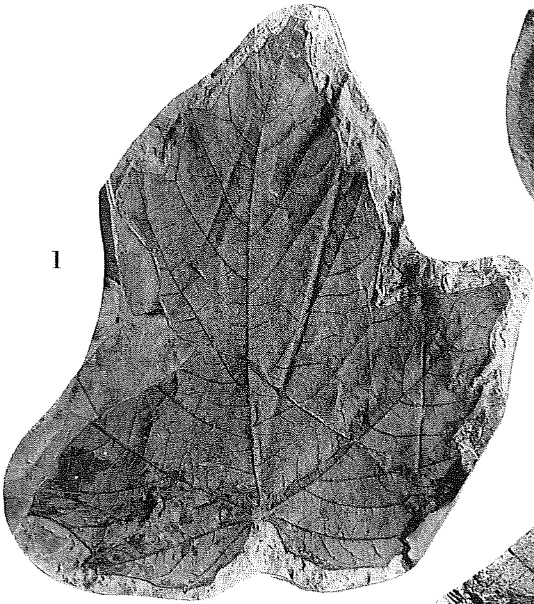
Fig. 4 *Acer oishii* new species. Paratype, H. U. M. P. Reg. no. 25987. Harutori pit. ×2

Fig. 5 *Acer oishii* new species. Paratype, H. U. M. P. Reg. no. 25988. Harutori pit. ×4/5

Fig. 6 *Cedrela kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25976. Okotsu pit.

Fig. 7 *Acer arcticum* HEER. Hypotype, H. U. M. P. Reg. no. 25985. Harutori pit.

Plate 14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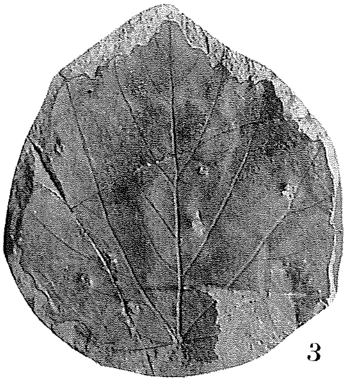
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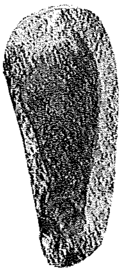
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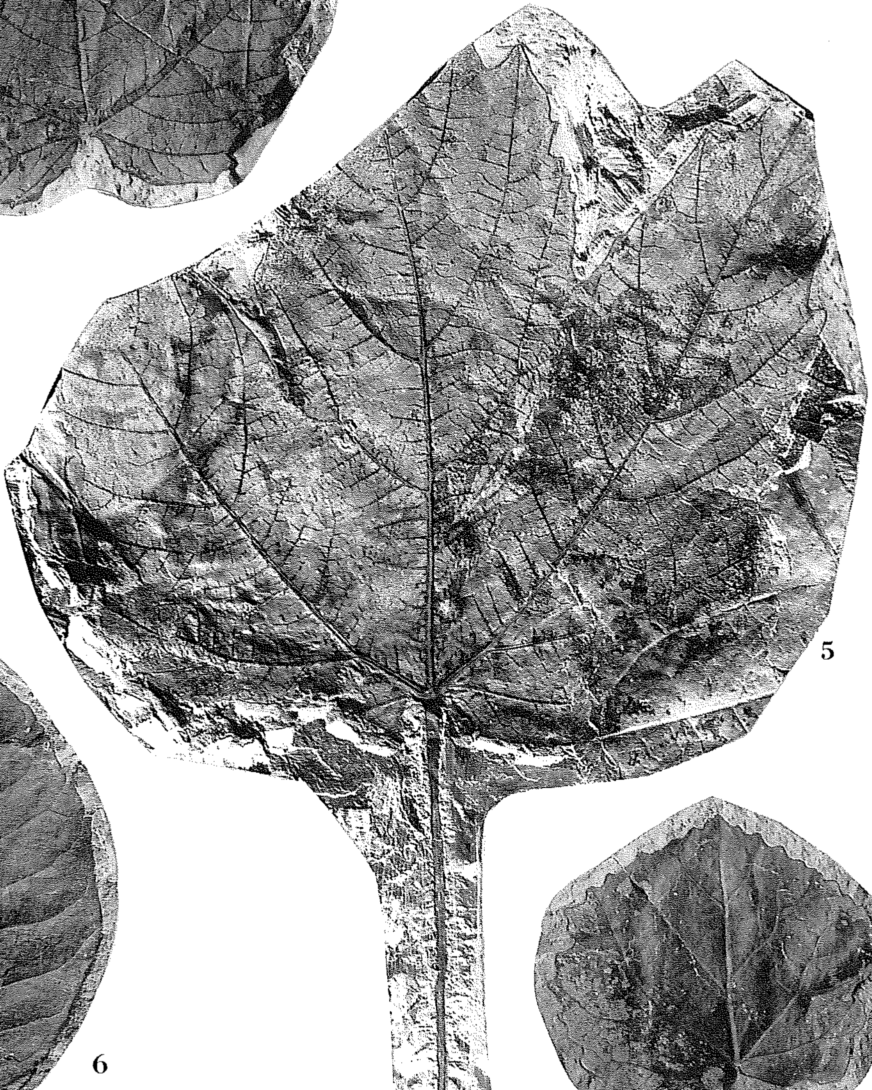
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6


7

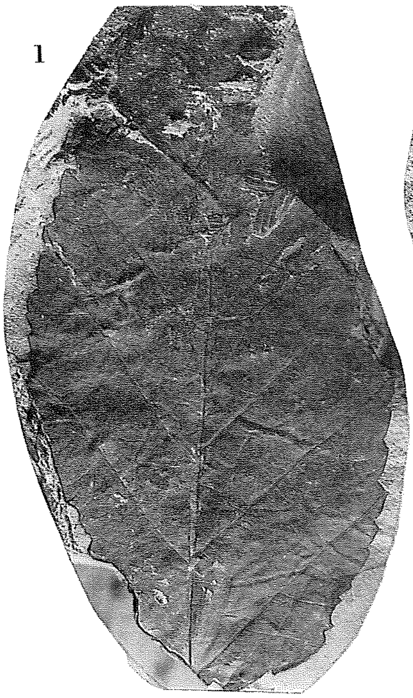
PLATE 15 AND EXPLANATION

Explanation of Plate 15

(All natural size)

Fig. 1 *Aralia ezoana* new species. Hypotype, H. U. M. P. Reg. no. 26007. Harutori pit.
Fig. 2 *Aralia ezoana* new species. Holotype, H. U. M. P. Reg. no. 26006. Shitakara River, Yubetsu.
Fig. 3 *Aesculus* sp. Hypotype, H. U. M. P. Reg. no. 25991. Harutori pit.
Fig. 4 *Aralia ezoana* new species. Hypotype, H. U. M. P. Reg. no. 26008. Nakanosawa,
Fig. 5 *Nordenskioldia borealis* HEER. Hypotype, H. U. M. P. Reg. no. 26027. Nakanosawa, Yubetsu.
Fig. 6 *Idesia kushiroensis* new species. Holotype, H. U. M. P. Reg. no. 25999. Harutori pit
Fig. 7 *Carya ezoensis* new species. Hypotype, H. U. M. P. Reg. no. 25908. Okotsu pit.
Fig. 8 *Liquidambar miosinica* HU and CHANEY. Hypotype, H. U. M. P. Reg. no. 25966. Okotsu pit.

Plate 15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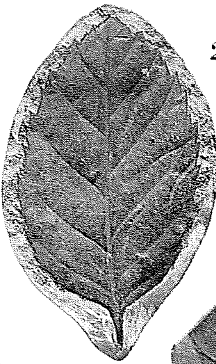
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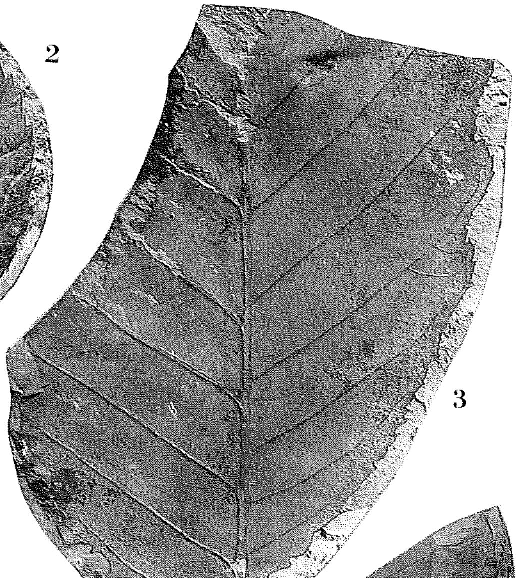
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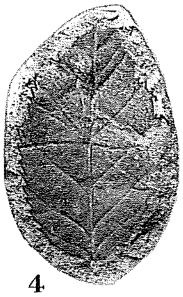
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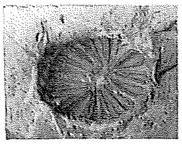
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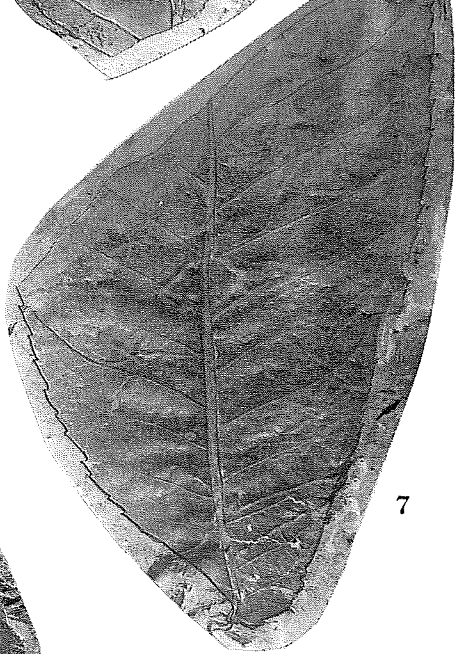
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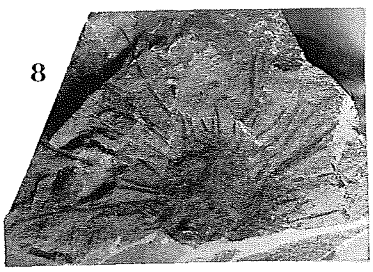
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PLATE 16 AND EXPLANATION

Explanation of Plate 16

(All natural size unless otherwise stated)

Fig. 1 *Actinidia harutoriensis* new species. Holotype, H. U. M. P. Reg. no. 25995. Harutori pit.

Fig. 2 *Melodinus japonicus* new species. Holotype, H. U. M. P. Reg. no. 26014. Harutori pit.

Fig. 3 *Gordonia japonica* new species. Holotype, H. U. M. P. Reg. no. 25998. Harutori pit

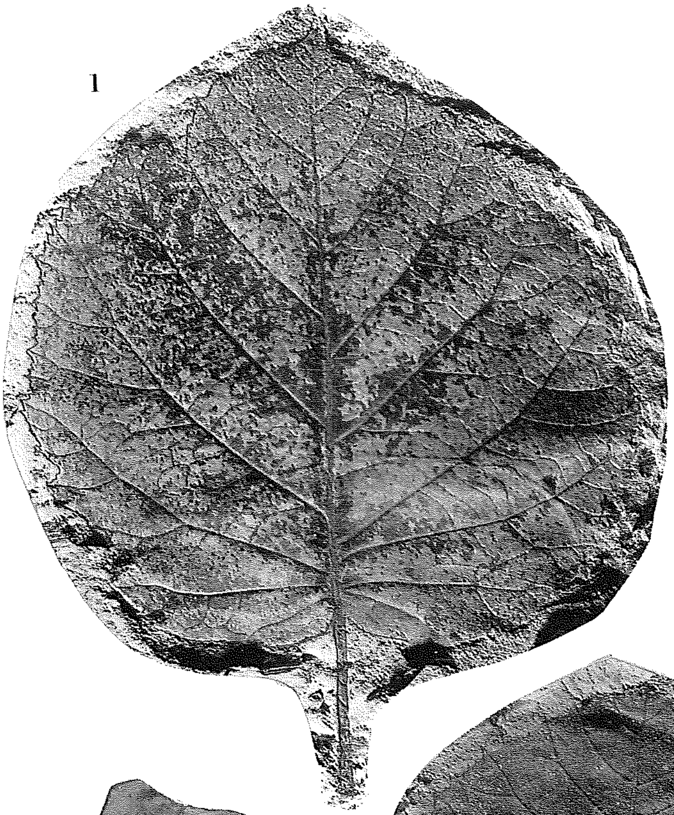
Fig. 4 *Chionathus nipponicus* new species. Holotype, H. U. M. P. Reg. no. 26011. Okotsu pit.

Fig. 5 *Actinidia harutoriensis* new species. Paratype, H. U. M. P. Reg. no. 25996. Okotsu pit

Fig. 6 *Antholithes cruciatus* new species. Holotype, H. U. M. P. Reg. no. 26024. Shitakara River, Yubetsu. ×2

Fig. 7 *Actinidia harutoriensis* new species. Hypotype, H. U. M. P. Reg. no. 25997. Harutori pit.

Plate 16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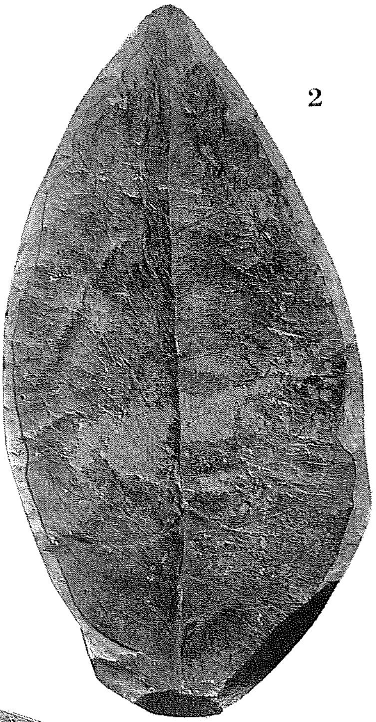
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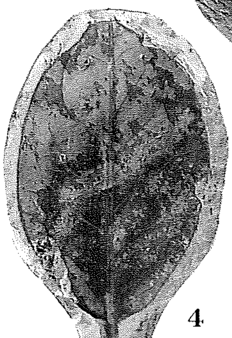
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7

PLATE 17 AND EXPLANATION

Explanation of Plate 17

(All natural size)

Fig. 1 *Alangium basitruncatum* (OISHI and HUZIOKA) new combination. Hypotype. H. U. M. P. Reg. no. 26004. Okotsu pit.

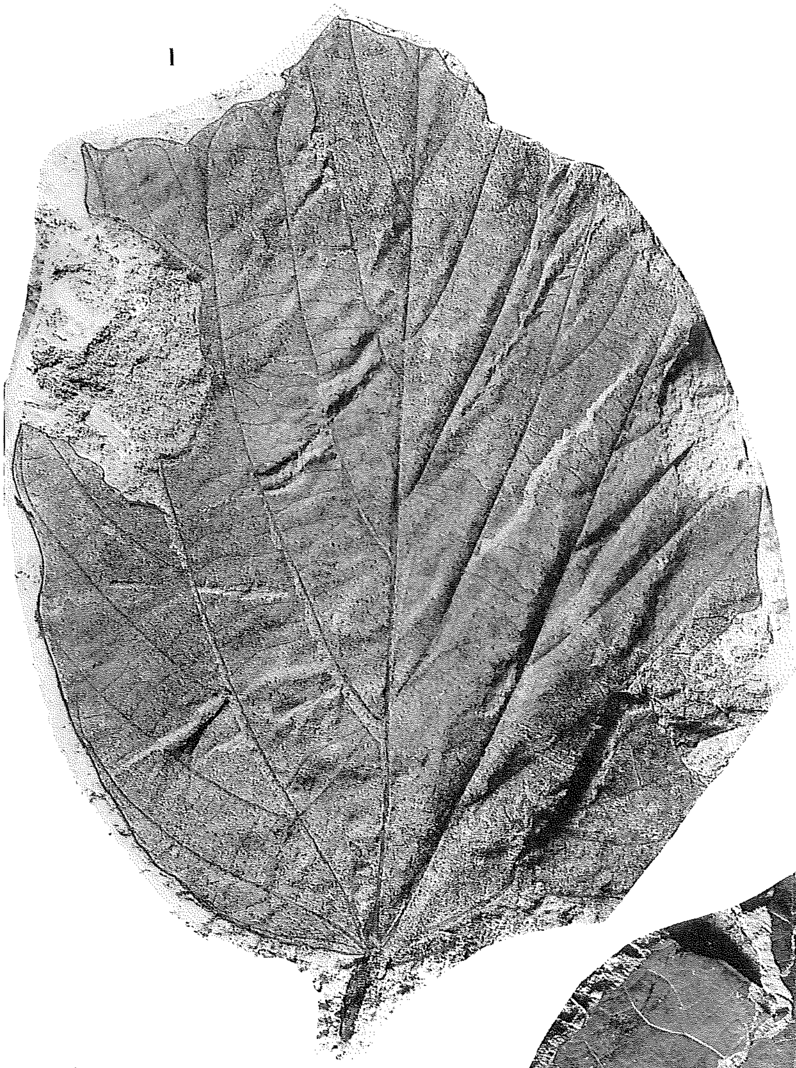
Fig. 2 *Chionanthus nipponicus* new species. Hypotype, H. U. M. P. Reg. no. 26013. Okotsu pit.

Fig. 3 *Chionanthus nipponicus* new species. Paratype, H. U. M. P. Reg. no. 26012. Harutori pit.

Fig. 4 *Viburnum basiobliquum* new species. Holotype. H. U. M. P. Reg. no. 26020. Harutori pit.

Plate 17

1



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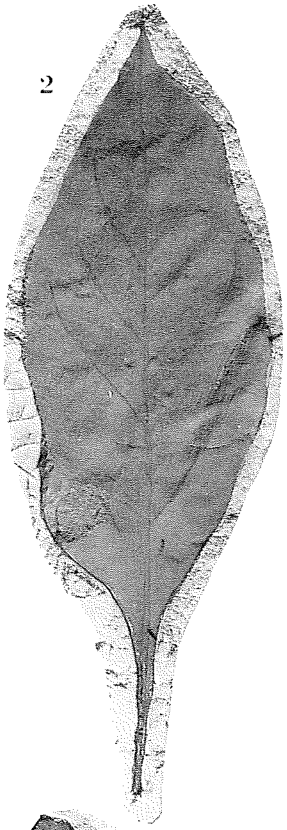

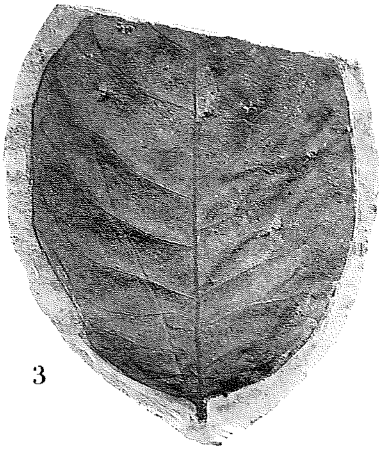

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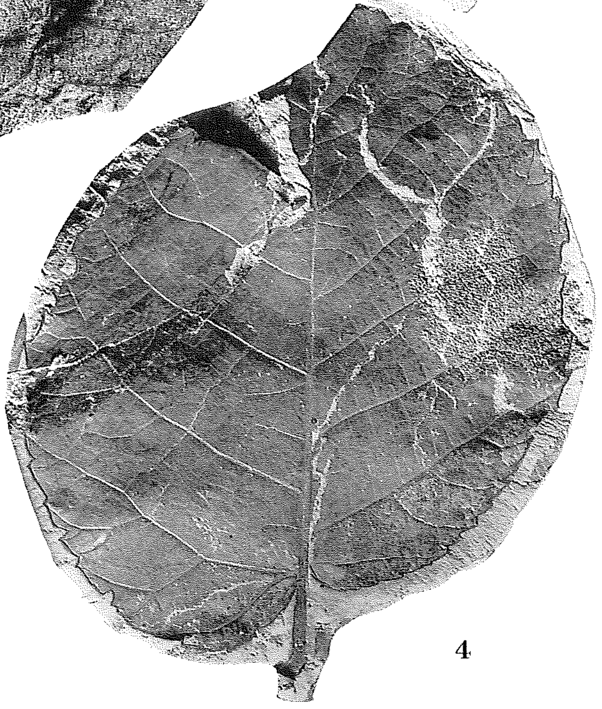


4

PLATE 18 AND EXPLANATION

Explanation of Plate 18

(All natural size)

Fig. 1 *Maesa nipponica* new species. Holotype, H. U. M. P. Reg. no. 26009. Harutori pit.

Fig. 2 *Viburnum basiobliquum* new species. Hypotype, H. U. M. P. Reg. no. 26021. Okotsu pit.

Fig. 3 *Chionanthus retusa* LINDL. and PAX. The Living leaf for comparison.

Fig. 4 *Alangium basiobliquum* (OISHI and HUZIOKA) TANAI. Hypotype, H. U. M. P. Reg. no. 26002. Shitakara River, Yubetsu.

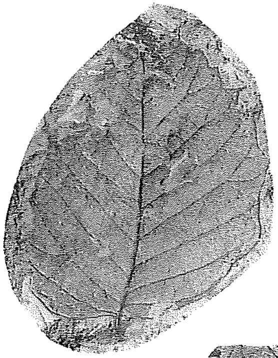
Fig. 5 *Alangium basiobliquum* (OISHI and HUZIOKA) TANAI. Hypotype, H. U. M. P. Reg no. 26001. Okotsu pit.

Fig. 6 *Viburnum ezoanum* new species. Hypotype, H. U. M. P. Reg. no. 26019. Shitakara River, Yubetsu.

Fig. 7 *Viburnum ezoanum* new species. Holotype, H. U. M. P. Reg. no. 26018. Okotsu pit.

Plate 18


1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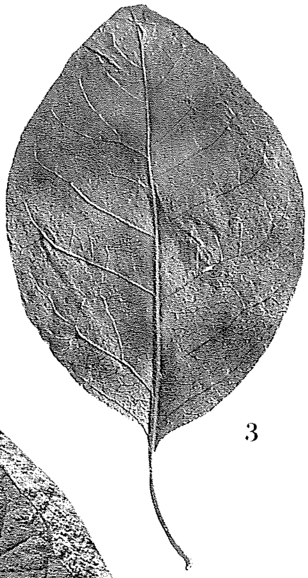
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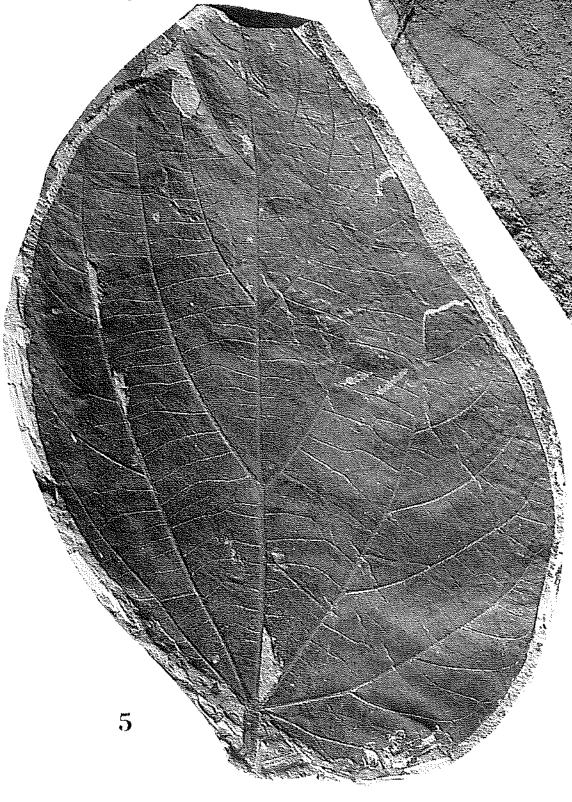
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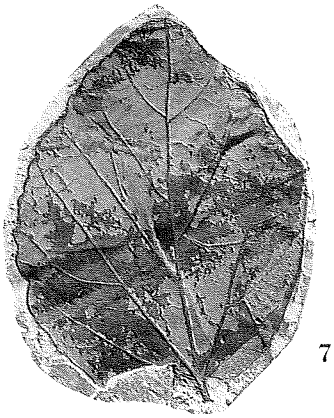
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PLATE 19 AND EXPLANATION

Explanation of Plate 19

(All natural size)

Fig. 1 *Alangium basiobliquum* (OISHI and HUZIOKA) TANAI. Hypotype, H. U. M. P. Reg. no. 26003. Nakanosawa, Yubetsu.

Fig. 2 *Cordia japonica* new species. Holotype, H. U. M. P. Reg. no. 26015. Okotsu pit.

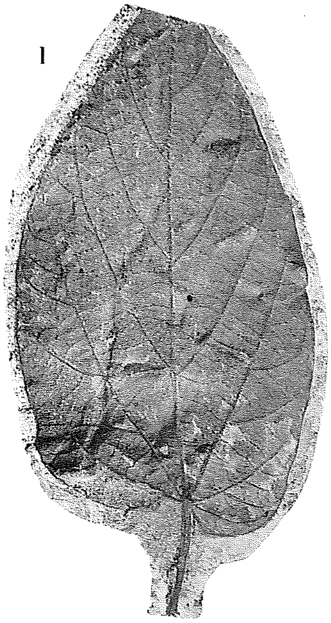
Fig. 3 *Carpites japonicus* (ENDO) new combination. Hypotype, H. U. M. P. Reg. no. 26025. Okotsu pit.

Fig. 4 *Cordia japonica* new species. Hypotype, H. U. M. P. Reg. no. 26016. Harutori pit.

Fig. 5 *Carpites japonicus* (ENDO) new combination. Hypotype, H. U. M. P. Reg. no. 26026. Shitakara River, Yubetsu.

Fig. 6 *Viburnum basiobliquum* new species. Hypotype, H. U. M. P. Reg. no. 26022. Harutori pit.

Plate 19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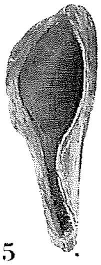
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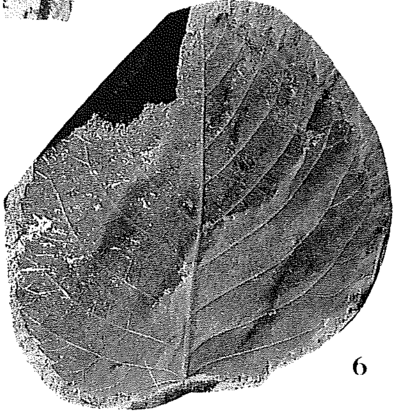
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PLATE 20 AND EXPLANATION

Explanation of Plate 20

(All natural size unless otherwise stated)

Fig. 1 *Acer kushiroanum* new species. Holotype, H. U. M. P. Reg. no. 25990. Nakanosawa Yubetsu. ×0.9

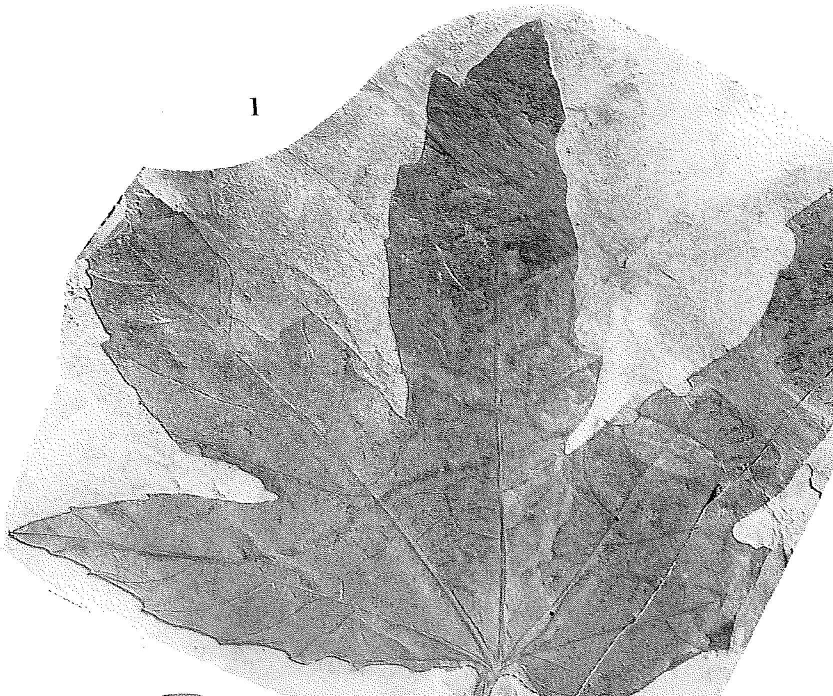
Fig. 2 *Quercus kushiroensis* new species. Paratype, H. U. M. P. Reg. no. 25936. Chinomizawa, Shoro.

Fig. 3 *Cordia japonica* new species. Hypotype, H. U. M. P. Reg. no. 26017. Harutori pit

Fig. 4 *Acer oishii* new species. Hypotype, H. U. M. P. Reg. no. 25989. Okotsu pit.

Fig. 5 *Alangium chinense* (LOUR.) HARMS. The living leaf for comparison.

Plate 20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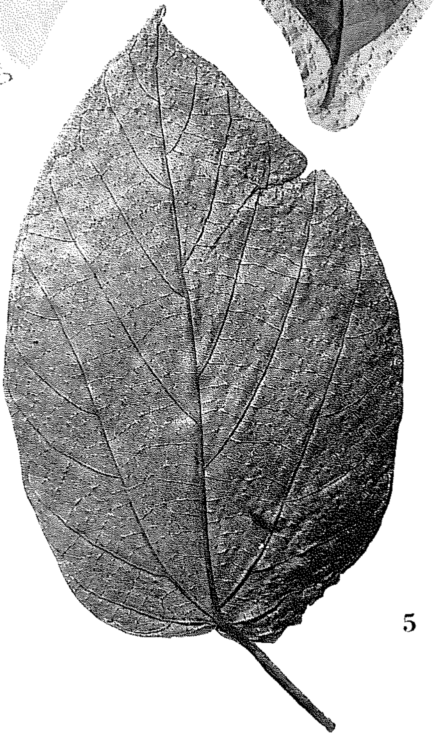
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