PALAEONTOLOGICAL SOCIETY OF JAPAN
SPECIAL PAPERS
NUMBER 10

LATE TERTIARY FLORAS FROM NORTHEASTERN HOKKAIDO, JAPAN

By

Toshimasa TANAI and Nobuo SUZUKI

PUBLISHED BY THE SOCIETY
February 20, 1965

All Communications relating to this Journal should be addressed to the
PALAEONTOLOGICAL SOCIETY OF JAPAN
c/o Geological Institute, Faculty of Science, University of Tokyo, Japan

Special Papers, Palaeontological Society of Japan

Special Publications, Palaeontological Society of Japan

LATE TERTIARY FLORAS FROM NORTHEASTERN HOKKAIDO, JAPAN

By

Toshimasa TANAI

Department of Geology and Mineralogy, Faculty of Science,
Hokkaido University

and

Nobuo SUZUKI

Geological Institute, Kushiro Branch, Hokkaido Gakugei University

CONTENTS

PART I. SYSTEMATICS

By Toshimasa TANAI and Nobuo SUZUKI

Page

Introduction 1
Acknowledgements 2
Systematic Descriptions 2
A Summary of Systematic Revisions 48

PART II. COMPOSITION AND INTERPRETATION

By Toshimasa TANAI

Present Physical Setting 51
Physical Conditions 51
Woody Vegetation 51

The Shanabuchi Flora 52
Introduction 52
Geologic Occurrence 54
Composition 55

Systematic List of Families and Species ... 55
Assumed Growth Habit ... 57
Numerical Representation ... 58
Paleoecology ... 59
Distributional Considerations ... 61
The Elements of the Shanabuchi Flora ... 62
The East Asian Element ... 67
The Central and Northern Honshu Component ... 67
The Central China Upland Component ... 72
North American Relationships ... 75
The Shanabuchi Plant Associations ... 76
Climate ... 82

The Rubeshibe Flora ... 84
Introduction ... 84
Geologic Occurrence ... 85
Systematic List of Families and Species ... 86
Assumed Growth Habit ... 88
Numerical Representation ... 90
Paleoecology ... 94
Distributional Considerations ... 94
The East Asian Element ... 94
North American Relationships ... 96
Comparison of the Rubeshibe and Shanabuchi Percentage Representation ... 97
The Rubeshibe Plant Associations ... 98
Climate ... 100

Other Late Tertiary Floras of Northeastern Hokkaido ... 100
The Samakesaroma Flora ... 100
The Ikutawara Flora ... 102

Correlation and Age ... 102
Stratigraphic Evidence ... 103
Evidence of Floral Composition ... 108
Summary ... 111

Conclusion ... 111

Bibliography ... 113

Index of Fossil Names

Plates

Tables

Table
1 Climatic Data for Abashiri ... 52
2 Assumed Growth Habit of the Shanabachi Plants ... 59
3 Numerical Representation of Shanabuchi Species ... 60
4 Present-Day Distribution of the Shanabuchi Genera ... 63
5 Modern Equivalents of the Shanabuchi Plants and their Distribution in Eastern Asia and North America ... 64
6 Slope Plants of Honshu and Shanabuchi Equivalents ... 68

7 Plants of the Mixed and Subapline Forests of Central and Northern Honshu, and Shanabuchi Equivalents 71
8 Living Equivalents in the Uplands of Central China 73
9 Eastern North American Plants and Shanabuchi Equivalents 74
10 Climatic Data for Several Localities in Japan, China and the United States 83
11 Assumed Growth Habit of the Rubeshibe Plants 88
12 Numerical Representation of Rubeshibe Species 89
13 Present-day Distribution of the Rubeshibe Genera 91
14 Modern Equivalents of the Rubeshibe Plants and their Distribution in Eastern Asia and North America 92
15 Percentage Representation of Species Common to the Rubeshibe and Shanabuchi Floras 97
16 Occurrence of Shanabuchi and Rubeshibe Plants in Other Neogene Floras of Japan.. 104
17 Percentage of Element Representation in Neogene Floras of Japan 110

Figures

Figure
1 Localities of Late Tertiary Plants in Northeastern Hokkaido 53
2 Location of Principal Neogene Floras in Japan 108

LATE TERTIARY FLORAS OF NORTHEASTERN HOKKAIDO, JAPAN

PART I. SYSTEMATICS

By

Toshimasa TANAI and Nobuo SUZUKI

INTRODUCTION

It is the purpose of this paper to describe the floras of the Upper Tertiary sediments of northeastern Hokkaido, and to discuss as fully as possible the physical and environmental conditions under which they lived, as well as their stratigraphic relationships. The recent discovery of Late Tertiary floras in Hokkaido has made available critical information regarding the history of vegetation in northern Japan. There are a good number of records of Tertiary vegetation in Hokkaido, especially at Early and Middle horizons. But there have been few previous records of Late Tertiary floras untill 1961 when the senior authors described several floras from the Upper Miocene and Pliocene of northern and eastern regions. There was in fact no known occurrence of well-preserved Pliocene plants in Hokkaido before the discovery of the plant-bearing deposits at Rubeshibe in 1959.

Recently the Tertiary geology of northeastern Hokkaido has been extensively studied by the Hokkaido branch of the Geological Survey of Japan; through this survey the Upper Tertiary rocks, excellently preserved fossil plants have been found at several localities. The senior author was requested to evaluate the geologic age of these plant-bearing formations by the Geological Survey of Japan in December of 1959. He planned to study these floras as a part of the series of " Research on Tertiary Floras of Japan ", under which theme he has undertaken a research since 1959 in cooperation with Dr. Ralph W. CHANEY, Professor of Palaeontology at University of California. Field work was begun in the summer of 1960, assisted by the junior author, and was continued during the autumn of 1960 and the autumn of 1961. Identification of fossils was first made by SUZUKI; thereafter they have been restudied by TANAI. The two authors are responsible for the decriptions in Part I.

All types and some duplicates of the fossils are stored in the Museum of Paleontology, Hokkaido University at Sapporo. The registered numbers are referred to that museum. Many duplicates are also stored in the Museum of Paleontology, University of California, Berkeley. The localities indicated in the systematic descriptions are to be explained in Part II (see also Text-fig. 1).

ACKNOWLEDGEMENTS

The authors ackowledge their debt of gratitude to Professor CHANEY, who has devoted much time to give advices from his deep experience for the identification of all the described fossils, and has also made fruitful discussions relating to theoretical problems. They also wish to express their appreciation to Dr. Misao TATEWAKI, Professor of Botany at Hokkaido University, for many valuable suggestions in making identification of fossils and in completing the paleoecological discussion. It is the authors' pleasure to express their sincere thanks to Dr. Katsu KANEKO, formerly Director of the Geological Survey of Japan, and Dr. Yasuo SASA, Professor of Geology at Hokkaido University, who have given their continuous encouragement during this study. Acknowledgements are also due to Dr. Konosuke SAWAMURA and many staff members of the Hokkaido Branch of the Geological Survey of Japan, who have discovered some of the fossil localities and have given geological information on fossil localities. The authors are greatly indebted to Dr. Tatsuro MATSUMOTO, Professor of Geology at Kyushu University, who has devoted much time to have edited this manuscript for publishing as the Editor of Special Papers of Palaeontological Society of Japan. Thanks are also due to Dr. Tetsuro HANAI, Assistant Professor at University of Tokyo, who kindly aided to publish this article as the General Secretary of Palaeontological Society of Japan.

This study has been made possible through the financial assistance of several institutions to which the authors owe a real debt of gratitude. The National Science Foundation of the United States provided the principal funds for field work to collect fossils during 1960 and 1961, and for completion of manuscripts, through the cooperation of Professor CHANEY. The Geological Survey of Japan provided a grant to collect additional fossils, and to have a geologic reconnaisance of fossil localities in the autumn of 1961. This study has been partly aided by a Grant for Fundamental Scientific Research from the Ministry of Education during the years from 1961 to 1963. Thanks are due to the Palaeontological Society of Japan for giving a chance which has made possible the publication of this article.

SYSTEMATIC DESCRIPTIONS

Family PINACEAE

Abies protofirma TANAI

Pl. 15, fig. 8, pl. 16, fig. 3

Abies protofirma TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 248, pl. 1, fig. 10, 1961.

Remarks: Several cone scale impressions in our collections, including a complete specimen from the Rubeshibe locality, are identical with this species in their shape and large size. They are closely similar to cone scales produced by the living *A. firma* SIEB. and ZUCC., which is distributed in Honshu, Shikoku, and Kyushu, and commonly associated with deciduous broad-leafed trees.

Occurrence: Shanabuchi and Rubeshibe.

Oollection: Hypotypes U. H. M. P. Reg. Nos. 25740, 25751 (Rubeshibe).

Picea kaneharai TANAI and ONOE

Pl. 7, figs. 2, 3

Picea kaneharai TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 17, pl. 1, fig. 9, 1961.
Picea miocenica TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 253, pl. 1, figs. 12, 15, 1961.
Picea magna MACGINITIE, TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 100, pl. 2, figs. 13, 14, 16, 17, 20, 21, 39, 1963.
HUZIOKA. Ibid. p. 186, pl. 28, figs. 3, 4.
TANAI. Ibid. p. 253, pl. 1, figus. 5-7.

Remarks: *P. kaneharai* is well represented by the impressions of winged seeds in the Shanabuchi flora, but it is comparatively rare in the Rubeshibe. These specimens are somewhat variable in shape, from oval to snub-nosed ovate. Several with a somewhat snub-nosed seeds are inseparable from seeds figured as *P. magna* MACGINITIE from the Middle Miocene floras of southwestern Hokkaido (TANAI and N. SUZUKI, 1963). *P. miocenica* from the Middle Miocene flora of Gifu Prefecture (TANAI, 1961) is also inseparable from *P. kaneharai*. *P. kaneharai* is closely similar to *P. magna* from the Miocene floras of Columbia Plateau (CHANEY and AXELROD, 1959), and some of the American specimens are difficult to distinguish. *P. kaneharai* closely resembles the modern *P. polita* CARR. growing in central Honshu, Shikoku and Kyushu.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25602, 25603 (Shanabuchi).

Pinns sp.

Pl. 9, fig. 3

Description: Leaves, incomplete, linear, slender, lower half missing, but probably in bundles of two; more than 4.5 cm. long, less 1 mm. wide; a single ridge existing below.

Remarks: Several specimens which appear to have needles in bundles of two are found in the Shanabuchi flora. The sheath of these specimens is missing, so their status is somewhat doubtful; but they are closely similar to the modern *P. densiflora* SIEB. and ZUCC. and *P. thunbergii* PARL. of Japan. Our specimens are similar to *P. miocenica* TANAI from Middle Miocene flora of Japan (TANAI, 1961), but they are more slender.

Occurrence: Shanabuchi.

Collection: A representative specimen is U. H. M. P. Reg. No. 25607.

Tsuga oblonga MIKI

Pl. 15, figs. 3, 5

Tsuga oblonga MIKI. Jap. Jour. Bot., vol. 11, p. 257, fig. 6, F-H. 1941.

This will describe the first seed attributed to *T. oblonga*.

Supplementary description: Winged seed small, oblong in general outline, seed ovate in shape, 4 mm. long and 1.8 mm. wide, somewhat acute at distal end, tip rounded where attached to wing; rounded at distal part, nearly straight in outer margin, broadly convex in inner margin, 8 mm. long and 3.5 mm. wide at the middle part.

Remarks: A single well-preserved cone from the Shanabuchi locality is identified as *T. oblonga* by its shape, dimension and cordate base. This species based on cones, twigs, and leaves was reported from the Upper Miocene and Pliocene in 4 localities of Honshu by MIKI (1941, 1957). We found a single winged seed of hemlock at Shanabuchi which is readily identified as hemlock by the wing extending under the lower edge of the seed, rather than attached to the end of the seed as in pine and spruce, and it is included in this species. Two species of *Tsuga*, *T. miocenica* and *T. aburaensis*, have been known from the Middle Miocene flora of southeastern Hokkaido on the basis of cone scales or winged seeds, but they are quite different from our species in size and shape.

T. oblonga is closely similar to the modern *T. diversifolia* MAST. of Honshu in general appearance; its cone is apparently cordate at base, while the cone of the modern species is usually rounded at base. Longer cone scales of this fossil species are similar to those of the modern *T. caroliniana* ENGELM., but the cone of this modern American species is larger.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotypes U. H. M. P. Nos. 25600, 25601 (Shanabuchi).

Family TAXODIACEAE

Taiwania japonica TANAI and ONOE

Pl. 7, fig. 4

Taiwania japonica TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 19, pl. 1, fig. 4, 1961.

Remarks: This species is represented by 2 fragmentary twigs with incurved spiny leaves from the Shanabuchi flora. These leaves are longer and narrower than the original specimens of awl-like shape, which are closely similar to the modern *T. cryptomeroides* HAYATA living in Formosa, southwestern China, and Burma. Our specimens closely resemble leafy twigs produced by young trees or younger shoots of *T. cryptomeroides*, and so they are referred to *T. japonica*.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25608a.

Family CUPRESSACEAE

Juniperus honshuensis TANAI and ONOE

Pl. 5, fig. 5

Juniperus honshuensis TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 20, pl. 1, fig. 3, 1961.

Remarks: A single slender twig covered with lapidoid leaves in the Shanabuchi collection is referable to *J. honshuensis* which is closely similar to the living *J. chinensis* LINN. This living species is growing in the coastal areas of Honshu, Shikoku, and Kyushu, and extends into China and Mongolia. The rare occurrence of *J. honshuensis* may be due either to its occurrence as an evergreen shrub, or to its actual rarity near the sites of Shanabuchi deposition.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25609.

Thuja nipponica TANAI and ONOE

Pl. 8, fig. 6

Thuja nipponica TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 19, pl. 1, figs. 11a, b, 1961. TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 261, pl. 1, fig. 45 (see synonymy), 1961.

Remarks: This species is represented by 13 well-preserved impressions of branched leafy twigs from the Shanabuchi flora, and by a single twig from the Shanabuchi flora, and by a single twig from the Rubeshibe. These specimens well match foliage produced by the living *T. standishii* CARR. of Honshu and Shikoku. Some of our specimens have small globose staminate flowers on the top of leafy shoots, and they are closely similar to those of the modern equivalent.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25610.

Family LILIACEAE

Disporum ezoanum new species

Pl. 20, fig. 1

Description: Leaf broadly elliptical in shape, 5 cm. long and 3 cm. wide; apex incomplete, but probably abruptly-acute; base rounded, somewhat asymmetrical; 7-plinerved at very base; midrib thin but stout, slightly arcuate; lateral primary veins three on each side of midrib, rather stout, but somewhat thinner than midrib, leaving base, ending in apex, acrodrome; thin secondary veins 3 in each space between primaries, leaving base, entering apex; margin entire; texture thin; petiole missing, but probably short.

Remarks: A single well-preserved impression of a nearly complete leaf and its counterpart in the Shanabuchi flora are referred to Liliaceae by its shape and venation, and is especially referable to *Straptopus*, *Polygonatum*, *Lilium*, and *Disporum*. Among them our leaf shows closest similarity to leaves of the living *Disporum smilacinum* A. GRAY and *D. sessile* DON of Japan. These modern vines are commonly growing in hilly areas from Hokkaido to Kyushu.

This is the first record of occurrence of *Disporum* in the Tertiary of Japan.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25613.

Smilax trinervis MORITA

Pl. 7, fig. 5

Smilax trinervis MORITA. Jap. Jour. Geol. Geogr., vol. 9, p. 7, pl. 1, figs. 10-12, 1931.

Remarks: Two fragmentary impressions of oval leaves from the Shanabuchi flora resemble this species in their secondary and tertiary venation. *S. trinervus* is closely similar to the living *S. china* LINNE. which grows commonly in the forest of hilly areas from Hokkaido to Kyushu.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25614.

Family SALICACEAE

Populus balsamoides GOEPPERT

Pl. 3, fig. 1; pl. 8, fig. 2

Populus balsamoides GOEPPERT. Fossil flora von Schossnitz, p. 23, pl. 15, figs. 5, 6, 1855.
ENDO. Icon. Fos. Plants Jap. Isl., pl. 28, fig. 2, 1955.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 269, pl. 4, fig. 8 (not fig. 9), 1961.
MURAI. Rep. Tech. Iwate Univ., vol. 15, no. 2, p. 10, pl. 2, figs. 1-4; pl. 3, figs. 1a-b, 2, 1962.

Remarks: Abundant well-preserved impressions of ovate leaves in the Rubeshibe collections show a close similarity in all characters to leaves produced by the living *P. maximowiczii* HENRY. This modern species is distributed in Hokkaido, and northern and central Honshu, growing commonly in the riparian forest, and it extends into Saghalien, Kamtchatska, Ussurri, Manchuria, and Korea.

There has been much confusion regarding the use of the name *P. balsamoides* in Japan and elsewhere. The true *balsamoides* as described by GOEPPERT (1855) shows a pair of basal secondaries leaving the midrib about 5 mm. above the base of the leaf. It is this type of leaf that we are referring to *P. balsamoides*, and it is noteworthy that the related living species, *P. maximowiczii* shows the same basal venation. On the other hand, K. SUZUKI (1961) and KONNO (1931) described as *P. balsamoides* leaves from the Upper Miocene flora of Honshu, in which the lowest pair of secondaries diverge from the base. HOLLICK (1931) figures as *P. balsamoides* leaves with both types of venation from the Tertiary of Alaska. It seems clear that revision of poplars from the Tertiary of Japan is desirable, and that leaves whose secondaries diverge at the leaf base should be referable to another species. *P. balsamoides* closely resembles *P. eotremuloides* KNOWLTON from the Miocene of the western United States (KNOWLTON, 1898) and *P. alexanderi* DORF from the Pliocene Verdi flora of Calfornia (AXELROD, 1958), which 2 species are compared with the living *P. trichocarpa* TORREY and A. GRAY of the western United States.

Occurrence: Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25745, 25747.

Populus kitamiana new species

Pl. 2, figs. 3, 8

Description: Leaves orbicular-ovate in shape, 8.5 to 13 cm. long and 8.5 to 12 cm. wide; apex acute to shortly acuminate; base rounded to nearly truncate; margin coarsely and irregularly dentate, with deltoid teeth; midrib stout and thick, somewhat flexous in upper part; secondary veins rather thick, 5 or 6 pairs, subopposite to alternate, irregularly spaced, leaving midrib at angles of 45 to 55 degrees, gently curving up, forming marginal loops; 4 or 5 tertiaries from a basal pair of secondaries extending to abaxial side, forming loops or ending in marginal teeth; tertiaries from other secondaries branching off, forming loops or ending in marginal teeth; a pair of slender and thin subsecondary veins leaving base, extending along basal margin; tertiaries in intersecondary spaces irregularly percurrent; nervilles thin but distinct, making a fine polygonal mesh: texture thin; petiole incomplete, stout and thick, more than 3 cm. long; a pair of glands existing on petiole near base of leaf.

Remarks: This species is based on abundant well-preserved leaf impressions, including 2 nearly complete specimens from the Rubeshibe collections, which are most closely similar to leaves produced by the living *P. grandidentata* MICHX. of North America. Our specimens somewhat resemble leaves of the modern *P. sieboldi* MIQ. of Japan and *P. tomentosa* CARR. of central China, but distinctly differ in marginal dentation. This species is common with abundant large-sized leaves in the Rubeshibe flora, while is very rare in other floras. It may suggests that Rubeshibe climate has been rather humid and cool.

Leaves of this new species are closely similar in shape and margin to those of

P. aizuana HUZIOKA and K. SUZUKI from the Upper Shiotsubo flora of northeastern Honshu (HUZIOKA and SUZUKI, 1954), but are distinguishable by the secondary venation at the base. In leaves of *P. aizuana* a basal secondaries diverge slightly above the base; in respect to such character, *P. aizuana* is closely similar to the modern *P. deltoides* MARSH. of eastern North America, and *P. nigra italica* DUROI of Europe, though leaves of these 2 living poplars are more crowded in marginal teeth than those of *P. aizuana*. *P. kitamiana* closely resembles a leaf of *P. latior* AL. BR. from the Miocene Yoshioka flora of southwestern Hokkaido (TANAI, 1961), but differs in shape and marginal dentation. Another allied species is *P. washoensis* BROWN from the Miocene flora of Columbia Plateau (CHANEY and AXELROD, 1959).

The equivalent species, *P. grandidentata*, is distributed in the northeastern United States and adjacent Canada, and is a common tree in the beech-maple forest of this region.

Occurrence: Shanabuchi, Rubeshibe, and Samakesaroma.

Collection: Holotype U. H. M. P. Reg. No. 25743; paratype No. 25749 (all from Rubeshibe).

Populus kobayashii K. SUZUKI

Pl. 3, figs. 2, 3

Populus kobayashii K. SUZUKI. Sci. Rep. Fukushima Univ., no. 10, p. 27, pl. 2, figs. 6, 7, 1961.

Remarks: Two incomplete leaf impressions from the Shanabuchi flora are referable to *Populus* by their shape, margin and venation, and they are closely similar to leaves produced by the modern *P. sieboldi* MIQ. which is widely distributed from Hokkaido to Kyushu. Our leaves closely resemble those of *P. kabayashii* in all characters except basal form, they are considered identical to *P. kobayashii*, because leaves of *P. sieboldi* are usually rounded to cordate at the base. This fossil species was compared with the living *P. nigra* LINNE. of Europe by K. SUZUKI (1961), but it does not resemble these modern leaves in secondary venation. *P. kobayashii* is closely related to the modern *P. sieboldi* of Japan, and *P. tremuloides* MICHX. of North America.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. Nos. 25616, 25617.

Salix crenatoserrulate new species

Pl. 15, fig. 2

Description: Leaves lanceolate to narrowly elliptical in shape, 6 to 8 cm. long (estimated) and 2.6 to 3 cm. wide; apex gradually narrowed, acute or slightly acuminate; base obtuse to rounded; midrib stout, nearly straight or slightly arcuate; secondary veins thin but distinct, numerous, diverging at angles of 40 to 45 degrees in middle part of blade, at lower angles in upper part, more spreading in basal part, gently curving up; tertiaries near margin branching from secondaries, forming loops or ending in teeth; other tertiaries irregularly percurrent, making large polygonal network; nervilles thin, forming fine meshes; margin finely crenate-serrate; teeth very small, slightly incurved, obtuse, having a gland on top of each teeth; texture rather firm; petiole stout, about 7 mm. long.

Remarks: This new species of willow is based on well-preserved, though incomplete leaves from the Ikutawara and Rubeshibe localities. They well match those of the modern *S. chaenomeloides* KIMURA in numerous secondary veins, marginal serration and glands on teeth. *S. chaenomeloides* is a common tree in the stream-side or valley bottom of the lowlands in Honshu, Shikoku, and Kyushu; it extends into Korea and China.

There is no close resemblance between our fossil willow leaves and any previously described East Asian fossil species. Leaves of *S. ramaleyi* COCKERELL from the Oligocene Florissant flora of Colorado (MACGINITIE, 1953) are somewhat similar to those of *S. crenatoserrulata*.

Occurrence: Rubeshibe and Ikutawara.

Collection: Holotype U. H. M. P. Reg. No. 25755 (Rubeshibe).

Salix hokkaidoensis new species

Pl. 15, fig. 6; pl. 16, fig. 7

Salix lavateri HEER, KONNO. Geology of Central Shinano., pl. 8, fig. 5, 1931.

Description: Leaves narrowly lanceolate, 6 to 9 cm. long and 0.8 to 1.2 cm. wide; apex elongate-acuminate; base acute to obtuse, sometimes rounded; midrib stout, nearly straight or slightly arcuate; secondary veins thin and slender, indistinct, 7 to to 10 pairs, alternate to subalternate, diverging at various angles ranging from 30 to 65 degrees, curving up along margin, forming loops; numerous subsecondaries leaving midrib in intersecondary spaces; tertiaries near marginal border branching from secondaries, forming loops or ending in marginal teeth; nervilles indistinct; margin coarsely dentate, with small, fine teeth; texture rather thin; petiole stout but short, 3 to 5 mm. long.

Remarks: Many well-preserved impressions of slender, narrow leaves in the Shanabuchi collections are closely similar to the living *S. koriyanagi* KIMURA, which is native in Korea, and is widely cultivated in Japan. They are also similar to leaves produced by the modern *S. gilgiana* SEEMEN which is distributed in southwestern Hokkaido, Honshu, and Shikoku.

Our specimens closely resemble leaves of *S. longa* AL. BR. from the Tertiary flora of Schlesia, Germany (MEYER in KRÄUSEL, 1917). They are similar to the narrow leaves of *S. denticulate* HEER, which has been widely recorded from the Tertiary of

Eurasia (KRYSHTOFOVICH, 1956). A single specimen figured by KONNO (1931) as *S. lavateri* is closely similar to our specimens, and is inseparable from *S. hokkaidoensis*. There has been so much confusion in applying the name of this variable European species in Japan that we are setting up a new species to include the slender-leafed willows.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25618; paratype No. 25619.

Salix kitamiensis new species

Pl. 4, fig. 5; pl. 18, fig. 7

Description: Leaves broadly elliptical or ovate-elliptical in shape, 7 cm. long and 3.2 to 3.4 cm. wide; apex acute; base acute or rounded; midrib rather stout, nearly straight; secondaries thin and slender, about 7 subopposite pairs, leaving midrib at angles of 35 to 40 degrees, gently arched, curving up along margin, forming small loops; tertiaries near margin branching from secondaries, forming small loops; tertiaries in intersecondary spaces irregularly percurrent or forming large polygonal network; nervilles thin, forming fine polygonal meshes; margin nearly entire or indistinctly undulate; texture thin: petiole stout, 5 mm. long.

Remarks: Two well-preserved impressions of elliptical leaves in the Rubeshibe collection appear to be referable to *Salix* by their slender venation and marginal character. These leaves closely resemble those produced by the living *S. vulpina* ANDERS., which is distributed from Hokkaido to Kyushu, extending northward into southern Kurile islands. They are also similar to leaves of the modern *S. bakko* KIMURA of western Hokkaido and eastern Honshu, and *S. kenoensis* KOIDZ. of Honshu.

S. kitamiensis somewhat resembles *S. raeana* HEER from the Paleocene floras of Greenland and Alaska (HEER, 1868; HOLLICK, 1936), but is distinguishable in secondary venation. There are no similar species in the Tertiary of Japan.

Occurrence: Rubeshibe and Samakesaroma.

Collection: Holotype U. H. M. P. Reg. No. 25753; paratype No. 25754 (all from Rubeshibe).

Salix misaotatewakii new species

Pl. 2, fig. 6; pl. 4, fig. 2

Description: Leaves linear-oblong to elliptical in general outline, 6 to 11 cm. long and 2.2 to 3.8 cm. wide; apex abruptly acute; base cuneate to obtuse; midrib stout and thick, prominent, nearly straight; secondary veins rather thick but slender, 11 to 15 pairs, prominent beneath, irregularly spaced, diverging at angles of 60 to 90 degrees, considerably incurved, slenderly creeping up along margin, connecting with upper ones; 2 or 3 subsecondary veins leaving midrib, slender; tertiaries thin but distinct, irregularly percurrent, oblique to secondaries, forming transversely linear network; nervilles thin, forming fine polygonal meshes within tertiary network; margin nearly entire or finely crenate-serrate, with indistinct and obtuse teeth; texture rather firm, apparently pubescent beneath; petiole stout and thick, 1.2 to 1.6 cm. long.

Remarks: These excellently preserved leaves, though somewhat incomplete, are closely similar to those produced by the living *S. gracilistyla* MIQ., which is a common shrub in the riparian forest from Hokkaido to Kyushu, and extends into Korea, China, and Manchuria. Our leaves somewhat resemble oblong leaves of the living *Populus maximowiczii* HENRY of Japan, but differ distinctly in secondary venation of basal part.

S. misaotatewakii is somewhat similar to the next-described *S. parasachalinensis* in general appearance, but is distinguishable by its wider leaves and considerably incurved secondary veins. Our species also resembles *S. hesperia* (KNOWLT.) CONDIT from Miocene and Pliocene floras of the western United States (AXELROD, 1959; CHANEY and AXELROD, 1959).

This new species is named in honor of Professor Misao TATEWAKI of Hokkaido University, who gave us many useful suggestions for identification of our fossils.

Occurrence: Rubeshibe and Samakesaroma.

Collection: Holotype U. H. M. P. Reg. No. 25756; paratype No. 25757.

Salix parasachalinensis new species

Pl. 2, fig. 5; pl. 4, figs. 1, 4a; pl. 15, fig. 1

Salix sp. KONNO. Geology of Central Shinano., pl. 8, fig. 6, 1931.

Description: Leaves lanceolate, 9 to 14.2 cm. long and 1.8 to 3 cm. wide; apex gradually narrowed, acute; base acute to obtuse; midrib stout and thick, nearly straight or gently arcuate; secondary veins rather thick, 16 to 20 pairs, irregularly spaced, leaving midrib at angles of 70 to 80 degrees, curving up along margin, forming broad loops; 2 or 3 slender subsecondary veins leaving midrib, forming loops with secondaries or making large areolation with tertiaries; several branches from secondaries forming small marginal loops or ending in marginal obtuse teeth; tertiaries in intersecondary spaces thin, forming polygonal meshes; nervilles indistinct; margin nearly entire or coarsely undulate-serrate with small teeth, sometimes slightly warping; teeth obtuse, not prominent; texture firm; petiole stout and thick, 1 to 1.6 cm. long.

Remarks: Eight well-preserved leaf impressions from the Shanabuchi flora, including 2 nearly complete specimens, show typical features of willow in all characters. The great variation in the modern leaves similar to our fossils makes it difficult to determine with any great exactness the living equivalent of this fossil species. Among the modern willows of Japan our leaves are closely similar to those of *S. sachalinensis* FR. SCHM. which is growing in the riparian areas of Hokkaido and the slopes of Honshu and Shikoku, extending northword into Saghalien, Kurile islands, Kamtchatska and Amur region. *S. parasachalinensis* is also close to leaves produced by the living *S. kinuyanagi* KIMURA in shape, marginal serration, and long petiole. *S. kinuyanagi* is widely cultivated in Honshu, Shikoku, and Kyushu, but its areas of origin is uncertain.

Leaves of *S. parasachalinensis* are closely similar to those of *S. varians* GOEPPERT widely distributed in the Tertiary flora of Eurasia (GOEPPERT, 1855; MEYER in KRÄUSEL, 1917), and also to *S. tenera* AL. BR. from the Paleocene flora of Alaska (HOLLICK, 1936). A single incomplete leaf figured by KONNO as *Salix* sp. from the Upper Miocene of Nagano Prefecture (KONNO, 1931) is closely similar to our specimens, and is included in *P. parasachalinensis*.

Occurrence: Shanabuchi and Ikutawara.

Collection: Holotype U. H. M. P. Reg. No. 25621a; paratypes No. 25623, 25624 (all from Shanabuchi).

Family JUGLANDACEAE

Juglans japonica TANAI

Pl. 18, fig 4

Juglaus japonica TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 275, pl. 6, figs. 9, 10, 1961.

Remarks: Abundant leaflet impressions from the Shanabuchi flora, including several nearly complete specimens, are referred to this species by their shape, venation and marginal serration. Our specimens well match leaflets produced by the living *J. ailanthifolia* CARR., which is commonly growing in riparian areas from Hokkaido to Kyushu. The abundant occurrence of this species suggests valley habitats near the sites of Shanabuchi deposition.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. no. 25625.

Pterocarya asymmetrosa KONNO

Pl. 11, fig. 5; pl. 21, figs. 7, 8

Pterocarya asymmetrosa KONNO. Geology of Central Shinano., pl. 16, figs. 5-7, pl. 17, fig. 3, 1931.

Supplementary description: Fruits representing nuts with two wings, 1.5 to 2 cm. high and 3.2 to 3.5 cm. wide; wings reniform in outline, unequal to nearly equal-sized, firm in texture; alate venation consisting of fine, numerous radiating veins, branching dichotomously once or twice near the periphery; two wings connecting each other at the base; nuts 6 to 7 mm. in diameter at transverse section, pointed at apex, with 8 sharp ridges and 8 deep grooves on the surface; axis of nuts perpendicular to the wings.

Remarks: *P. asymmetrosa* is one of the most common species in Neogene flora of Japan and heretofore has been represented only by leaflets, which are closely similar to those produced by the modern *P. rhoifolia* SIEB. and ZUCC. Excellently preserved impressions of several winged nuts from the Shanabuchi flora closely resemble those of the modern *P. rhoifolia* in general character, although there is a minor difference that two wings of our fossils connect at the base, as compared with the modern fruits having usually serrated wings. Our fruits are associated with many leaflets of *P. asymmetrosa* from the Shanabuchi locality, and all seem assignable to the same species. The living equivalent species, *P. rhoifolia*, is widely distributed in valley forests from southwestern Hokkaido to Kyushu.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25628a, 25629, 25631 (all from Shanabuchi).

Pterocarya protostenoptera TANAI

Pl. 21, figs. 4, 5

Pterocarya protostenoptera TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 278, pl. 14, fig. 10 (see synonpmy), 1961.

Supplementary description: Leaflets lanceolate to ovate-lanceolate in general outline, 4 to 10 cm. long, 1.8 to 3 cm. wide; apex bluntly pointed to acute, sometimes acuminate; base somewhat asymmetrical, cordate to rounded; midrib stout, slightly falcate; secondary veins slender, opposite to subalternate with 9 to 14 pairs, irregularly spaced, leaving midrib at angles of 60 to 70 degrees, curving up, weakly looping near the marginal border; tertiaries irregularly and coarsely percurrent; nervilles thin forming fine network; margin finely serrate, with small and blunt teeth; texture thin; petiole subsessile.

Remarks: This species is represented by both leaflets and winged nuts from the Shanabuchi flora, though it was originally established on the basis of only winged nuts from a Late Miocene flora of northeastern Honshu. Our excellently preserved impressions of 3 leaflets and a winged nut well match those of the modern *P. stenoptera* DC. of central China.

P. protostenoptera is not rare in the Late Miocene and Pliocene of Honshu, and MIKI (1955) reported many nuts with detached wings as *P. stenoptera* from various localities in Honshu. Our leaflets are somewhat similar to *P. oregoniana* CHANEY from Pliocene floras of the western United States (CHANEY, 1944).

Occurrence: Shanabuchi.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25633, 25634.

Family BETULACEAE

Alnus miojaponica TANAI

Pl. 20, fig. 3

Alnus miojaponica TANAI. Geol. Surv. Jap. Rep., no. 163, pl. 6, fig. 8, 1955.
TANAI and ONOE. Geol. Surv., Rep., no. 187, p. 24, pl. 2, fig. 7, 1961.

Remarks: A nearly complete leaf, together with fragments of several others, comprise the record of this species in the Shanabuchi flora. Our specimens are similar to leaves of the modern *A. japonica* SIEB. and ZUCC. which is widely distributed in Japan, China, Korea, and Manchuria.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25636.

Alnus protohirsuta ENDO

Pl. 14, figs. 5, 9; pl. 19, fig. 5

Alnus protohirsuta ENDO. Icon. Fos. Plants Jap. Isl., pl. 27, fig. 5, 1955.
TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 22, pl. 2, figs. 1, 5, 1961.

Remarks: Our foliage specimens are identified as *A. protohirsuta* ENDO by their general shape and biserrate margin, which shows a close alliance to the modern *A. hirsuta* TURCZ. of northeastern Asia. These leaves differ from the average produced by the living species in that the fossils all have biserrate teeth which are somewhat finely acute, as compared with the typically coarse and blunt teeth of the modern leaves. However, since the living species occasionally produces leaves that are acutely biserrate or multiserrate in the margin, it is apparently that we are concerned with a species of the *A. hirsuta* group. This fossil species is also close to the modern *A. tenuifolia* NUTT. growing on the Pacific slopes of the western North America.

A. protohirsuta closely resembles *A. harneyana* CHANEY and AXELROD from the Middle Miocene flora of the Columbia Plateau (CHANEY and AXELROD, 1959), *A. smithiana* AXELROD from the Late Miocene Aldrich Station flora of west-central Nevada, the western United States (AXELROD, 1956), and *A. coryliana* KNOWLTON and COCKERELL from the Tertiary flora of Alaska (HOLLICK, 1936).

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25637 (Shanabuchi), 25835, 25836 (Rubeshibe).

Alnus protomaximowiczii TANAI

Pl. 5, fig. 4; pl. 6, fig. 3, pl. 15, fig. 4; pl. 20, fig. 6

Alnus protomaximowiczii TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 283, pl. 7, fig. 4, 1961.

TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 111, pl. 5, figs. 8-10; pl. 7, figs. 5-7; pl. 8, fig. 9 (see synonymy and discussion), 1963.

Remarks: Our foliage specimens are highly variable in size, general shape, and basal form; they vary from ovate to oval in general outline, and from roundly cuneate or rounded to truncate, sometimes with a slightly cordate base; the small one is 3.4 cm. long and 2.7 cm. wide, and the largest one is 12.5 cm. long and 9.5 cm. wide. These leaves are closely similar to those produced by the modern *A. maximowiczii* CALL., which is widely distributed in the cool-temperate regions of northeastern Asia. But there is the minor difference that a few specimens have somewhat obtuse teeth, while the modern leaves usually have acute teeth.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25638 (Shanabuchi), 26736, 26762, 25768 (Rubeshibe).

Alnus subfirma new species

Pl. 5, fig. 3a; pl. 10, fig. 5

Description: Leaves oblong-lanceolate to oval-lanceolate, 5.5 to 6 cm. long and 1.5 to 2.7 cm. wide; apex acute, or somewhat acuminate; base obtuse to rounded; midrib stout and thick, nearly straight; secondary veins stout, 12 to 15 subopposite pairs, leaving midrib at angles of 40 to 50 degrees, more spreading at basal part of blade, nearly straight or slightly curving up, ending in marginal larger teeth, sometimes one or two abaxial branches from secondaries entering smaller teeth; tertiaries distinct, irregulary percurrent; nervilles forming fine polygonal meshes; margin coarsely double-serrate; teeth acute, unequal-sized, one or two small teeth between each secondary; texture rather firm; petiole stout, more than 4 cm. long.

Remarks: This new species is based on 2 excellently preserved leaf impressions in the Shanabuchi collection. They are closely similar in shape, marginal serration and secondary venation to those produced by the living *A. firma* SIEB. and ZUCC., which grows in Honshu, Shikoku and Kyushu. They resemble leaves of such Rosaceae as *Sorbaria*, *Spiraea*, and *Kerria*, but are distinctly different in marginal serration. No fossil leaves of alder in Japan are similar to this new species. Our specimens somewhat resemble leaves of *Ulmus longifolia* UNGER which was widely distributed in Tertiary flora of Eurasia, but are distinguishable in marginal serration and secondary venation. *Ulmus nipponicus* SUZUKI from the Mio-Pliocene floras of Fukushima Prefecture is closely similar to our species in its shape and marginal serration, but differs in having numerous veins. It may represent *A. subfirma*, but we have had no opportunity to examine the type specimens to determine whether this is the case.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25642; paratype No. 25644a.

Betula miomaximowicziana ENDO

Pl. 16, fig. 1; pl. 17, fig. 1

Betula miomaximowicziana ENDO. Icon. Fos. Plants Jap. Isl., pl. 28, fig. 3, 1955.
TANAI. Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 287, pl. 10, figs. 1-3, 5-7 (see synonymy), 1961.

Remarks: This species is represented by several complete leaf impressions and many incomplete specimens from the Rubeshibe flora. Though variable from large to medium-sized, they resemble leaves of the modern *B. maximowicziana* REGEL in shape, marginal serration and secondary venation. Our medium- and small-sized leaves resemble those of *B. protoermani* ENDO, but are distinguishale in having a deeply cordate base and glandular, spiny teeth which secondary veins enter. Another minor difference is that the leaves of *B. miomaximowicziana* have several stout terrtiaries diverging from a basal pair of secondaries on the abaxial side, while in leaves of *B. protoermani* these tertiaries are very slender or absent. Our specimens somewhat resemble those of *B. ootanii* SUZUKI from the Middle Miocene floras of Fukushima Prefecture (SUZUKI, 1961), but they differ in general shape and marginal serration.

The living equivalent species, *B. maximowicziana*, is distributed in montane areas of Hokkaido, and in central and northern Honshu; it grows luxuriantly at altitudes of 1,400 to 1,700 meters in central Honshu.

Occurrence: Rubeshibe and Ikutawara.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25772, 25774.

Betula onbaraensis TANAI and ONOE

Pl. 7, fig. 1; pl. 16, fig. 2

Betula onbaraensis TANAI and ONOE Geol. Surv. Jap. Rep., no. 187, p. 25, pl. 4, figs. 1, 2; text-fig. 2, 1961.

Supplementary description: Leaves ovate to oblong-ovate, 5 to 12 cm. long and 4 to 8 cm. wide; base broadly rounded to roundly truncate, sometimes shallowly cordate, somewhat inequilateral; apex rather acuminate; midrib stout, nearly straight; secondary veins stout, 12 to 15 pairs, subopposite to alternate, diverging at angles of 35 to 45 degrees at the middle, more spreading below, nearly straight, or sometimes slightly curving up, ending in larger teeth; tertiaries in intersecondary spaces irregularly percurrent; nervilles distinct, forming a fine polygonal mesh; margin doubly serrate, with acute teeth; a number of small grands sometimes on under-surface of blade; texture thin; petiole stout, 3 to 3.5 cm. long and 1 to 1.5 mm. thick.

Remarks: The above description is based on 3 complete and many other well-preserved leaf impressions from the Rubeshibe flora. They closely resemble those produced by the modern *B. grossa* SIEB. and ZUCC. and its variety, var. *ulmifolia*

KOIDZ. of Japan.

B. onbaraensis resembles *B. miomaximowicziana* and *B. protoermani* in general appearance; but it is distinguishable from the former by its basal shape and marginal serration, and from the latter by its shape and secondary venation. Excluding these two species, no fossil birch resembles *B. onbaraensis*. The closely similar living species, *B. grossa*, is distributed in the montane areas of Honshu, Shikoku and Kyushu.

Occurrence: Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25777, 25778.

Betula protoermani ENDO

Pl. 16, fig. 6

Betula protoermani ENDO Icon. Fos. Plants Jap. Isl., pl. 28, fig. 3, 1955.
TANI and ONOE. Geol Surv. Jap. Rep., no. 187, p. 24, pl. 3, fig. 4, 1961.
Betula honmashinichii HUZIOKA and NISHIDA. Publ. Sado Mus., no. 3, p. 12, pl. 2, figs. 8-10, 1960.
Betula protoglobispica TANAI and ONOE. Ibid. p. 24, pl. 3, figs. 1, 2.
Betula oobae K. SUZUKI. Sci. Rep. Fukushima Univ., no. 10, p. 38 pl. 7, figs. 5, 6, 1961.

Remarks: Leaf impressions of this birch including several complete specimens, are abundant in the Shanabuchi and Rubeshibe floras, indicating that it was one of the dominant trees in the mountains near sites of deposition during Mio-Pliocene time. It is closely similar to the modern *B. ermani* CHAM., which grows on high mountains in Hokkaido, northern and central Honshu and Shikoku, extending northward into Saghalien, and Kamchatka, and northwestward into Korea, Manchuria, eastern Siberia and Ussurri region. The close affinity of *B. protoermani* to *B. ermani* is indicated by its great variation in leaf size, basal shape, and marginal serration; our specimens vary from broadly cuneate or rounded to truncate, or sometimes shallowly cordate at the base, and have acute to short-acuminate tipped, bisserrate teeth. Such differences correspond to variations which the related modern species displays. In this respect there is no basis of separating the following 3 species from *B. protoermani*: *B. honmashinichii* from the Miocene Seki flora of Sado island, *B. protoglobispica* from the Mio-Pliocene Hoki flora of western Honshu, and *B. oobae* from the Upper Miocene Fuji-toge flora of Fukushima Prefecture.

The leaves of *B. protoermani* are closely similar to those of *B. thor* KNOWLTON which is common in the Middle and Upper Miocene floras of the western United States (CHANEY and AXELROD, 1959). Other allied species are *B. macrophylla* HEER (REIMANN in KRÄUSEL, 1917) and *B. subpubescens* GOEPPERT (REIMANN in KRÄUSEL, 1917), which are described from the Schlesian Tertiary flora of Europe.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25648a (Shanabuchi).

Carpinus stenophylla NATHORST

Pl. 8, fig. 4; pl. 19, fig. 3

Carpinus stenophylla NATHORST. Kgl. Svensk. Vet. Akad. Handl., vol. 20, p. 41, pl. 3, fig. 16, 1883.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol 11, p. 298, pl. 8, fig. pl. 11, figs. 2, 5, 6 (see synonymy), 1961.

Remarks: A well-preserved impression of an oblong leaf and fragments of other specimens are referable to this species, which is closely similar to the modern *C. carpinoides* MAKINO. Our specimens resemble more closely typical leaves of the modern species than the original specimen, which is slightly cordate at base, with more numerous secondary veins. *C. carpinoides* is distributed in Honshu, Shikoku, and Kyushu.

Of the 3 species of this genus in the Shanabuchi flora, *C. stenophylla* can be distinguished by its broad base and usually obovate shape; *C. subcordata* by its cordate, often deeply cordate base, numerous secondaries (more than 15 pairs), and a margin with teeth of about the same size; and *C. subyedoensis* by its slightly cordate or narrowly truncate base, its fewer secondaries (less than 15 pairs), and marginal teeth which are larger at the ends of secondaries than in between. The 3 living species noted in discussion of the fossils also show these differences.

No fruits of *C. stenophylla*, chracterized by many-nerved involueres with coarse teeth, and resembling those of the living *C. carpinoides*, have been found in any of the floras from northeastern Hokkaido, but they have been figured from the Nakamura flora of Middle Miocene age (TANAI, 1961), and at many other Neogene localities, where they are found in association with leaves of *C. stenophylla*.

Occurrence: Shanabuchi and Ikutawara.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25650, 25651 (Shanabuchi).

Carpinus subcordata NATHORST

Pl. 13, figs. 5, 9; pl. 14, fig. 6

Carpinus subcordata NATHORST. Kgl. Svensk. Vet. Akd. Handl., vol. 20, p. 39, pl. 3, figs. 14-18, 20, 1883.
TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 117, pl. 7, fig. 4; pl. 9, figs. 2-5 (see synonymy and discussion). 1963.
Betula onbaraensis TANAI and ONOE, TANAI. Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 289, pl. 11, fig. 9, 1961.

Remarks: A number of leaf impressions including several completely preserved leaves, and unlobed involucres like those of the living *C. cordata*, with few veins, are referred to *C. subcordata* NATHORST, a common species in the Neogene flora of Japan. Our foliage specimens are variable in shape, size, and form cordate base, but they well match various leaves of the modern *C. cordata* BLUME. A single leaf figured as *Betula onbaraensis* TANAI and ONOE (TANAI, 1961) from the Shanabuchi flora, is inseperable, though it has an inequilateral base, and is included in *C. subcordata*.

The living equivalent species, *C. cordata*, is widely distributed in East Asia, and is one of the most common trees in the temperate forest of the *Fagus* Zone.

Occurrence: Shanabuchi, Rubeshibe and Samakesaroma.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25782a, 25789, 25790 (all from Rubeshibe).

Carpinus subyedoensis KONNO

Pl. 13, fig. 8

Carpinus subyedoensis KONNO. Geology of Central Shinano, pl. 7, figs. 2-4, 1931.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 299, pl. 11, figs. 1, 10, 13 (see synonymy), 1961.

Remarks: A single complete leaf impression and 8 fragmentary specimens are identical with *C. subyedoensis* KONNO in their characteristic marginal serration and general outline; this species is one of the most common hornbeams in the Neogene flora of Japan. *C. subyedoensis* closely resembles the modern *C. tchonoskii* MAXIM. of Honshu, Shikoku, and Kyushu.

None of the asymmetrical involucres of the *subyedoensis* type, as figured from the Middle Miocene Yoshioka flora (TANAI, 1961), and resembling those of the living *C. tchonoskii*, have been found in these floras from northeastern Hokkaido.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25656.

Corylus sp.

Pl. 15, fig. 7

Descryption: Leaf imcomplete, renifrom in outline, 19 cm. long and 9.5 cm. wide (both estimated); apex missing, but probably abruptly-acuminate; base cordate; midrib stout, nearly straight; secondary veins rather stout, about 7 pairs, subopposite, curving upward, entering marginal teeth, the lower pairs diverging at angles of 60 to 70 degrees, the upper pairs at angles of 15 to 30 degrees; several branches from abaxial side of each secondary curving up, entering marginal teeth; tertiary veins rather distinct, percurrent; nervilles obscure, forming a fine polygonal mesh; margin shallowly incised, with a finely acute serration; texture thin; potiole missing.

Remarks: A single poorly-preserved leaf impression from the Rubeshibe flora appears similar to some leaves of *Corylus* in its doubly serrate margin and secondary venation. The fossil is so fragmentary that it cannot be identified definitely as a new species, nor can it be compared exactly with any one living species of hazel. Nonethless, our specimen shows a close resemblance to the modern *C. heterophylla*

FISCH. var. *thunbergii* BLUME, which is living in Hokkaido, Honshu, and Kyushu. It resembles *C. macquarrii* (FORB.) HEER from the Miocene Kaminokuni flora of southwestern Hokkaido in marginal serration (TANAI, 1961: pl. 8, figs. 1, 12), but differs in secondary venation.

Occurrence: Rubeshibe.

Collection: A representative specimen is U. H. M. P. Reg. No. 25786.

Ostrya shiragiana HUZIOKA

Pl. 19, fig. 1

Ostrya shiragiana HUZIOKA. Trans. Proc. Palaeont. Soc. Jap. N. S., no. 13, p. 121, pl. 13, figs. 7, 8, 1954.
TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 119, pl. 11, figs. 1, 3, 5, 7 (see synonymy).

Remarks: *O. shiragiana* represented in the Rubeshibe flora by 2 well-preserved impressions of nearly complete leaves. It appears to have been an uncommon member of the Rubeshibe forest during Pliocene time. This species is closely similar to the modern *O. japonica* SARG. growing from Hokkaido to Kyushu, and also to *O. virginiana* (MILL.) KOCH. of the eastern and central United States.

Occurrence: Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25783a.

Family FAGACEAE

Fagus palaeocrenata OKUTSU

Pl. 16, figs. 4, 5.

Fagus palaeocrenata OKUTSU. Sci. Rep. Tohoku Univ. ser. 2, vol. 26, p. 92, pl. 6, figs. 4-9, 1955.
TANAI. Trans. Proc. Palaeont. Soc. Jap., N.S., no. 37, p. 197, pl. 23, figs. 2-7, 9-11 (see synoymy and discussion), 1960.
Fagus crenata BLUME, SUZUKI. Sci. Rep. Fukushima Univ., no. 10, p. 51, pl. 11, figs. 8-15, 1961.
MURAI. Rep. Tech. Iwate Univ., vol. 15, no. 2, p. 25, pl. 6, fig. 6; pl. 7, fig. 3, 1962.

Remarks: Leaves of this beech are distinguished by their relatively small number of secondary veins, and their oval to ovate shape. It is rare as compared with *F. protojaponica* SUZUKI. *F. palaeocrenata* is closely similar to the modern *F. crenata* BLUME of Japan; resemblance between the leaves of these 2 fossil and corresponding living species has been discussed in detail by the senior author (TANAI, 1960). Among our 7 specimens there is only one toothed leaf, and the others have undulate magins like *F. crenata*. Fossil leaves lately described as *F. crenata* from the Upper Miocene floras of northeastern Honshu by SUZUKI and by MURAI, are included in *F. palaeocrenata*.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25791, 25792 (Rubeshibe).

Fagus protojaponica K. SUZUKI

Pl. 6, fig. 2; pl. 16, fig. 8; pl. 20, fig. 5

Fagus protojaponica K. SUZUKI. Monogr. Assoc. Geol. Collab. Jap., no. 9, p. 33, pl. 2, fig. 10, 1959.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol 11, no. 2, p. 308, pl. 15, figs. 5, 6 (see synonymy), 1961.

Supplementary description: Cupules ovoid, 3-valved, covered with many slender prickles, 2 to 2.5 cm. long and 1.5 to 2 cm. wide; peduncle slender, about 1.5 mm. thick, 1.5 to 2 cm. long.

Remarks: Well-preserved leaf impressions of this beech are abundant in Late Tertiary flora of this region, and make up nearly 42 per cent of the total specimens collected at the Rubeshibe locality. Several cupules and many bud scales have also been collected. *F. protojaponica* is closely similar to the modern *F. japonica* MAXIM. which grows in Honshu, Shikoku, and Kyushu, usually on slopes at lower altitudes than *F. crenata*.

This fossil species is distinguished from *F. palaeocrenata* by more numerous secondary veins and more elongata shape, which characters distinguish the living equivalents from each other. Our cupule specimens are closely similar to those of *F. japonica*, though they are somewhat larger.

Occurrence: Shanabuchi, Rubeshibe, Ikutawara, and Samakesaroma.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25794 (Rubeshibe), 25661, 25662 (Shanabuchi).

Quercus protodentata TANAI and ONOE

Pl. 6, figs. 4, 5

Quercus protodentata TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 31, pl. 7, figs. 1, 2 (see synonymy), 1961.

Remarks: These fragmentary oak leaves are identical with *Q. protodentata* TANAI and ONOE by their characteristic basal form and lobed margin. It is a rare species, represented by only 4 incomplete leaves. It is closely similar to the modern *Q. dentata* THUNB., widely distributed from the southern Kurile islands to Kyushu, and in northern China and Korea; it is especially abundant in the lowlands and lower slopes of northern Honshu and Hokkaido.

Occurrence: Rubeshibe and Ikutawara.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25848b, 25849 (Ikutawara).

Family ULMACEAE

Celtis miobungeana HU and CHANEY

Pl. 3, fig. 6

Celtis miobungeana HU and CHANEY. Pal. Sin., New Ser. A., no. 1, p. 39, pl. 13, figs. 2, 5, 6, 1939.

Celtis nordenskioldii NATHORST. Kgl. Svensk. Vet. Akad. Handl., vol. 20, d. 47, pl. 15, fig. 2 (not pl. 6, figs. 14-17), 1883.

Celtis sp. TAKAHASHI. Mem. Fac. Sci. Kyushu Univ., ser. D, vol. 5, no. 1, p. 57, pl. 5, fig. 7, 1954.

Celtis nathorstii, TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 32, pl. 10, fig. 1, 1961.

Celtis aizuensis K. SUZUKI. Sci. Rep. Fukushima Univ., no. 10, p. 63, pl. 14, figs. 8-10, 1961.

Remarks: Two well-preserved leaves and many fragmentary specimens from the Shanabuchi flora are identified by their secondary venation and marginal serration as *C. miobungeana* HU and CHANEY from the Miocene Shanwang flora of China; they closely resemble the modern *C. bungeana* BL. of China and *C. jessoensis* KOIDZUMI of Japan, especially the latter. Our specimens vary from obliquely obtuse to truncately rounded, or sometimes slightly cordate in basal form, but these variable shapes of foliage well match those of the modern equivalent species. The leaves referred to *C. nathorstii* TANAI and ONOE by the senior author (TANAI, 1961) merely represent leaves of our species with a cuneate base, and they are included in our species. *C. aizuensis* SUZUKI recently established on the basis of several leaves from the Upper Miocene Fujitoge flora is indistinguishable from our species in all characters of foliage. The most close living species, *C. jessoensis*, is widely distributed from Hokkaido to Kyushu.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25663.

Celtis nordenskioldii NATHORST

Pl. 14, fig. 3

Celtis nordenskioldii NATHOST. Kgl. Svensk. Vet. Akad. Handl., vol. 20, p. 47, pl. 6, figs. 14-17, (not pl. 15, fig. 2), 1883.

TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 36, pl. 10, fig. 7, 1961.

Remarks: Many leaf impressions from the Shanabuchi and Rubeshibe floras are identified as this species by their rounded base, marginal serration with acute teeth, and 4 to 6 pairs of stout secondary veins, though they somewhat vary from prolongly cordate to oblong-ovate in shape. *C. nordenskioldii* is distinguished from *C. miobungeana* by its coarser serration and by more numerous secondaries. Our specimens resemble the leaves of the modern *C. occidentalis* LINNE., which is widely distributed in the eastern and central United States, extending across the Rocky Mountains into Washington and Oregon.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25666 (Shanabuchi).

Ulmus miopumila HU and CHANEY

Pl. 14, fig. 1; pl. 18, fig. 6

Ulmus miopumila HU and CHANEY. Pal. Sin., New Ser. A., no. 1, p. 39, pl. 14, figs. 2, 3, 1938.

Remarks: A single complete leaf impression and 3 fragmentary specimens of elm from the Shanabuchi are referred to *U. miopumila* from the Miocene Shawang flora of China by their size and regularly doubly serrate margin. This species is closely similar in general appearance to *U. subparvifolia* NATHORST from the Pliocene Mogi flora of Kyushu (NATHORST, 1883) and *U. protoparvifolia* HU and CHANEY, but it differs distinctly in its marginal serration and larger size.

The leaves of *U. miopumila* closely resemble those of the modern *U. pumila* LINNE. living in northern and western China, Manchuria, and Korea, extending northward into Mongolia, and southward into India.

Occurrence: Shanabuchi.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25627a, 25669.

Ulmus protojaponica TANAI and ONOE

Pl. 2, figs. 1b, 2; pl. 4, fig. 4b; pl. 9, fig. 1; pl. 13, fig. 2; pl. 14, fig. 4

Ulmus protojaponica TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 38, pl. 10, figs. 3, 8, 1961.
Ulmus aizuana SUZUKI. Sci. Rep. Fukushima Univ., no 10, p. 60, pl. 14, figs. 4, 5, 1961.

Supplementary description: Leaves variable in size and shape, ovate to oblong-ovate, somewhat asymmetric, 4 to 19 cm. (estimated) long and 3 to 11 cm. wide; apex acute to abruptly acuminate; base variable, cuneate or obtuse to rounded, frequently inequilaterally cordate; midrib stout, slightly curving or nearly straight; secondary veins slender, 15 to 20 pairs, opposite to subopposite, diverging at angles of 25 to 40 degrees at one side and 40 to 60 degrees at other side in middle portion of blade, sometimes forking near marginal border, ending in teeth; in the cordate part 3 or 4 abaxial branches extending from a pair of secondary; tertiaries among intersecondary spaces thin, percurrent; nervilles obscure, fine; margin doubly serrate, with slightly incurved and acute teeth; petiole stout, 1 to 3 cm. long; texture thin.

Remarks: The above description is based mainly on many well-preserved leaf impressions from the Shanabuchi and Rubeshibe flora and several fossil winged seeds from the Rubeshibe. Our specimens, though variable in size, shape and basal form, are referred to *U. protojaponica* TANAI and ONOE by their secondary venation and margin, and are closely similar to leaves produced by the modern *U. davidiana* PLANCH. of China, and *U. davidiana* var. *japonica* NAKAI of Japan. They are more similar to the Chinese species than to its Japanese variety in having frequently leaves with a round and cordate base. It is also close to the modern *U. pubscens* WALT.

of the eastern United States and adjacent Canada.

U. protojaponica is inseparable from *U. aizuana* K. SUZUKI lately established on the basis of 3 leaves from the Upper Miocene Fujitoge flora of Fukushima Prefecture. Another similar species is *U. sekiensis* HUZIOKA and NISHIDA from the Middle Miocene Seki flora of Sado island (HUZIOKA and NISHIDA, 1960); but its single leaf is incomplete at the base, and accurate comparison is difficult. Resemblance may be noted to *U. appendiculata* HEER and *U. pseudolongifolia* OISHI and HUZIOKA, which are common in the Middle Miocene floras of Hokkaido and Saghalien (OISHI and HUZIOKA, 1954), but it is apparently distinguishable from the former in not having an obliquely cordate base, and from the latter by its broader leaves.

Occurrence: Shanabuchi, Rubeshibe, and Samakesaroma.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25621b, 25670a, 25672, 25673 (Shanabuchi), 25803a, b (Rubeshibe).

Zelkova ungeri KOVATS

Pl. 14, fig. 2

Zelkova ungeri KOVATS. Jahrb. dam. K. K. geol. Reichsanst., p. 178, 1851.
KONNO. Geol. Central Shinano, pl. 9, figs. 4, 5, 1931.
TANAI. Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, p. 322, pl. 18, figs. 1-4, 6-9, 11 (see synonymy), 1961.

Remarks: This species, widely distributed in the Tertiary of Eurasia, is of rare occurrence, and was probably not common near sites of deposition. *Z. ungeri* is closely similar to the modern *Z. serrata* MAKINO living in hilly areas or lower slopes of Honshu, Shikoku, and Kyushu.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. no. 25671.

Family POLYGONACEAE

Polygonum megalophyllum new species

Pl. 9, fig. 6

Description: Leaves oblong-ovate, 27 cm. long and 15.5 cm. wide; apex acute; base inequilaterally cordate; margin nearly entire, irregularly undulate; midrib stout, slightly arcuate; secondary veins stout, 12 subalternate pairs, irregularly spaced, diverging at angles of 60 to 70 degrees, slightly arched, near marginal border abruptly curving up, camptodrome; a few slender subsecondary veins diverging from the midrib, parallel to secondaries; 4 or 5 abaxial branches extending from a pair of basal secondaries; tertiary veins among the intersecondary spaces forming a large and irregularly quadrangular network; nervilles forming a fine areolation; texture rather firm; petiole missing.

Remarks: Our large leaf impressions, though incomplete, are closely similar to leaves produced by the modern *P. sachalinensis* FR. SCHM. of northern Japan. But there is a minor difference in its slightly undulate margin, for the modern leaves usually have entire margins. The modern species is a perennial herb with a comparatively hardy stem, and in common on plains and in hilly areas of northern Japan; it is widely distributed in Hokkaido, Saghalien and Kurile islands, extending southward into the coastal area along the Japan Sea in northern and central Honshu.

The leaves of *P. miosinicum* HU and CHANEY from the Miocene Shanwang flora of China resemble our specimens in shape, margin, and secondary venation, but they differ in their smaller size. A large leaf of *P. cuspidatum* SIEB. and ZUCC. from a Neogene flora in Ushigatani, Fukui Prefecture (NATHORST, 1888) is distinguishable in its shape and venation.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25676 (Shanabuchi).

Rumex ezoensis new species

Pl. 9, figs. 2, 5

Description: Leaves oblong in shape, 17 to 28 cm. long and 6.5 to 11 cm. wide; base cordate, or somewhat auriculate; apex gradually narrowed, with acute tip; margin serrulate with acute teeth; midrib stout, straight; secondary veins stout, 19 to 24 subalternate pairs, diverging at angles of about 60 degrees on middle part of blade, 70 to 100 degrees at lower part, slightly arched, near margin curving up along marginal border, forming loops; one or two slender subsecondary veins extending from midrib, parallel to secondaries; tertiary nerves distinct, irregularly percurrent; nervilles indistinct, forming an irregulary fine mesh; texture thin; petiole stout, grooved, more than 2 cm. long.

Remarks: The impressions of 6 large leaves, 3 each in the Shanabuchi and Rubeshibe floras, are assigned to the genus *Rumex* by their characteristic features of base, venation and petiole. Our specimens are closely similar to leaves produced by the modern *R. longifolius* DC., through the modern leaves have obtuse teeth. *R. longifolius* is widely distributed in the temperate regions of Europe and Asia; in Japan it grows on moist grassy plains in Hokkaido and northern Honshu. The occurrence of this fossil suggests that there was a similar habitat near sites of deposition in this region during Late Tertiary time.

This is the first record of *Rumex* in the Tertiary of Japan and adjacent regions. There are no fossils comparable to our species in the world, except the above-described *Polygonum megalophyllum*. *R. ezoensis* somewhat resembles *P. megalophyllum* in general appearance, but it differs distinctly in having more numerous secondaries and serrulate margin.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25677 (Shanabuchi); paratype No. 25805 (Rubeshibe).

Family CERCIDIPHYLLACEAE

Cercidiphyllum crenatum (UNGER) BROWN

Pl. 12, fig. 4; pl. 19, fig. 2

Cercidiphyllum crenatum (UNGER) BROWN. Jour. Paleont., vol. 13, p. 488, pl. 68, figs. 1, 6, 8-10, 1935.

TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, no. 2, p. 325, pl. 19, figs. 1, 2, (see synoymy). 1961.

Remarks: This species is common in the Shanabuchi flora, and closely resembles leaves of the modern *C. japonicum* SIEB. and ZUCC. of Hokkaido and northern Honshu.

Occurrence: Shanabuchi, Samakesaroma and Ikutawara.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25680, 25681 (Shanabuchi).

Family MAGNOLIACEAE

Magnolia elliptica TANAI and ONOE

Pl. 11, fig. 2

Magnoia elliptica TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 40, pl. 12, figs. 1, 5, 1961.

Remarks: This species is represented by 4 well-preserved leaf impressions from the Shanabuchi flora and another from the Rubeshibe. Our specimens are referable to *Magnolia* by their shape, secondary venation and thick petiole. Among modern *Magnolias* our specimens are closely similar to leaves produced by the living *M. denudata* DESROUSS. and *M. liliflora* DESROUSS. These living trees are native in central China, and are widely cultivated in Japan. Our specimens are also similar to leaves of the living *M. kobus* DC. of Japan. Leaves figured as *M. miocenica* by HU and CHANEY (1938) are too imcomplete to make adequate comparison possible. A leaf figured by BERRY as *Anona ampla* from the Wilcox flora of the southern United States (BERRY, 1961) shows some resemblance to our specimens.

Occurrence: Shanabuchi, Rubeshibe, and Samakesaroma.

Collection: Hypotype U. H. M. P. Reg. No. 25684 (Shanabuchi).

Family LAURACEAE

Cinnamomum sp.

Pl. 18, fig. 2

Description: Leaf incomplete, probably elongate-elliptical in shape, triplinerved, rounded at base, upper part of blade missing, about 6 cm. long (estimated) and 2 cm. wide; midrib stout, straight; lateral primaries leaving slightly above the base, gently curving up along margin, extending upward beyond middle part of blade, giving off 3 or 4 slender tertiaries which make marginal loops within marginal border; more than 2 pairs of secondaries in intersecondary spaces; nervilles distinct, forming fine polygonal network; texture thick; margin entire; petiole stout, 2.5 cm. long.

Remarks: A single incomplete impression from the Shanabuchi flora surely belongs to the Lauraceae as judged by its triplinervation and thick texture. It closely resembles leaves produced by the modern *C. camphora* NEES and EBERM., which is living in Honshu, Shikoku and Kyushu, extending southward into Loochoo islands and Formosa. It somewhat resembles *C. oguniense* MORITA from the Miocene Oguni flora of northeastern Honshu (MORITA, 1931) in general outline, but differs in mode of triplinervation.

Occurrence: Shanabuchi.

Collection: A representative specimen is U. H. M. P. Reg. No. 25688.

Family HAMAMELIDACEAE

Hamamelis protojaponica new species

Pl. 5, fig. 3b; pl. 17, fig. 4

Hamamelis sp. TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 42, pl. 12, fig. 3, 1961.

Description: Leaves rhomboidal-elliptical or -oval in shape, 6.8 to 12 cm. long (estimated) and 4.5 (estimated) to 8 cm. wide; base asymmetrically rounded, slightly cordate; apex obtuse; midrib rather stout, somewhat flexuous; secondary veins 7 or 8 pairs, subalternate, diverging at angles of 50 to 70 degrees in the case of proximad pair, 20 to 40 degrees in the upper part of blade, slightly curving up, ending in short teeth, a few branches from secondaries given off near the margin, entering marginal teeth; tertiaries percurrent in interscondary spaces; nervilles indistinct; margin irregularly undulate-dentate, with small and obtuse teeth; texture firm; petiole stout, more than 8 mm. long.

Remarks: Two incomplete leaf impressions, one each from the Shanabuchi and Rubeshibe floras are closely similar to typical leaves of the modern *Hamamelis japonica* SIEB. and ZUCC. which is widely distributed from Hokkaido to Kyushu. An incomplete leaf of *Hamamelis* sp. from the Mio-Pliocene Onbara florule of western Honshu, is essentially similar to our specimens, and is included in this new species. The leaves of *H. miomollis* HU and CHANEY from the Miocene Shanwang flora of China resemble our specimens in general appearance, but differ distinctly in venation. The basal pair of secondaries of *H. miomollis* extends up along the margin, and reach the middle margin of the leaf; while the basal secondaries of our species reach only one third of the way. Another allied species is *H. merriami* CHANEY and AXELROD from the Miocene flora of the Columbia Plateau (CHANEY and AXELROD, 1959).

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25644b (Shanabuchi); paratype No. 25807 (Rubeshibe).

Liquidambar miosinica HU and CHANEY

Pl. 21, fig. 9

Liquidambar miosinica HU and CHANEY. Pal. Sin. New Ser. A. no. 1, p. 46, pl. 23, figs. 1, 2, 1938. TANAI and N. SUZUKI. Tertiary Flora of Japan I. p. 128, pl. 23, figs. 6, 8, 11 (see synonymy and discussion), 1963.

Remarks: Two fragmentary leaf impressions from the Shanabuchi and Samakesaroma floras resemble *Liquidambar* in having glands on the marginal teeth and are identical with *L. miosinica*, one of the common species in the Middle Miocene of Japan. It appears to have been rare near sites of deposition during Upper Miocene time. This species closely resembles the modern *L. formosana* HANCE living in Formosa, and central and southern China.

Occurrence: Shanabuchi and Samakesaroma.

Collection: Hypotype U. H. M. P. Reg. No. 25689 (Shanabuchi).

Family ROSACEAE

Crataegus sugiyamae HUZIOKA and NISHIDA

Pl. 3, fig. 4

Crataegus sugiyamae HUZIOKA and NISHIDA. Publ. Sado Mus., no. 3 p. 16, pl. 5, fig. 1, 1960.

Remarks: A well-preserved impression of the lower half of a hawthorn leaf appears to have all the typical characters of *C. sugiyamae*. The modern *Crataegus* of Japan is living only in Hokkaido, though widely distributed in the northern hemisphere. *C. sugiyamae* resembles *C. maximowiczii* C. K. SCHN. of Hokkaido, which extends into Saghalien, Manchuria, Korea, and eastern Siberia. Our fossil species is more similar to the modern *C. douglassi* LINDL. of eastern Canada, and *C. holmesiana* ASHE of the northeastern United States. There is no comparable fossil species of *Crataegus* in Japan. *C. sugiyamae* is closely similar to *C. nupata* (COKER.) MACG. from the Oligocene Florissant flora (MACGINITIE, 1953), and *C. gracilens* MACG. from the Miocene flora of the Columbia Plateau (CHANEY and AXELROD, 1959).

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25690.

Prunus ishidai new species

Pl. 3, fig. 5; pl. 13, fig. 7

Description: Leaves ovate to obovate in shape, 7 to 7.5 cm. long and 4 cm. wide; apex abruptly acuminate, with a prolonged tip; base roundly obtuse; midrib stout, nearly straight; secondary veins thin but distinct, 10 to 13 pairs, opposite to subalternate, diverging at angles of 30 to 40 degrees, nearly straight or slightly curving up, near margin forming distinct loops; tertiary veins branching from secondaries, ending in marginal teeth; tertiaries in intersecondary spaces irregularly percurrent; nervilles forming a fine polygonal mesh; margin incised and doubly serrate, with acute teeth; texture thin; petiole stout, 1.5 cm. long.

Remarks: This new species is based on 2 nearly complete impressions from the Shanabuchi flora and an incomplete but well-preserved specimen from the Rubeshibe. They are closely similar in their shape and characteristic margin to the modern *P. nipponicum* MATSUMURA growing in montane areas of Hokkaido, and northern and central Honshu. Our specimens resemble also leaves produced by the modern *P. apetala* (SIEB. and ZUCC.) FRANCH. and SAVAT. of Honshu and Kyushu, but those of this living species usually have a shorter petiole.

It is a pleasure to name this species for Mr. Masao ISHIDA of the Geological Survey of Japan, who discovered the Rubeshibe flora, and who has assisted materially in collecting it.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25691 (Shanabuchi); paratypes Nos. 25692 (Shanabuchi), 25809 (Rubeshibe).

Prunus protossiori TANAI and ONOE

Pl. 12, fig. 8; pl. 18, fig. 3

Prunus protossiori TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 44, pl. 13, figs. 6, 7 (see synonymy), 1961.

Remarks: These leaf impressions of cherry are identical to *P. protossiori* TANAI and ONOE in their venation and finely serrate margins with nearly equal-sized teeth. Our specimens are closely similar to the modern *P. ssiori* FR. SCHN. when grows on mountain slopes in Hokkaido, and central and northern Honshu, extending northward into Saghalien, Kurile islands, Manchuria, and Ussurri region. One of our specimens (Pl. 12, fig. 8) has teeth more than twice as coarse as the more common leaves of this species. Such coarse-margined leaves are not uncommon in the similar living species, *P. ssiori*.

P. protossiori somewhat resembles *P. matsumaensis* TANAI and N. SUZUKI from the Middle Miocene Yoshioka flora of southwestern Hokkaido (TANAI and N. SUZUKI, 1963), but differs distinctly in secondary venation. There is no fossil leaf of cherry comparable to our species in East Asia.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25693, 25694 (Shanabuchi).

Prunus rubeshibensis new species

Pl. 5, fig. 1; pl. 17, fig. 2

Description: Leaves oval to obovately oval in shape, 8 to 12 cm. long and 5 to 7.5 cm. wide; apex abruptly acuminate, with prolonged tip; base rounded or broadly rounded, slightly cordate; midrib stout, nearly straightly arched; secondary veins about 12 opposite pairs, 1 or 2 basal pairs rather slender, somewhat flexuous, other secondaries stout, diverging at angles of 40 to 45 degrees at middle of blade, at lower angles above, and at 70 to 90 degrees at the base, gently curving up, looping well within margin; tertiaries branching from secondaries, also forming loops or entering marginal teeth; other tertiaries in intersecondary spaces irregularly percurrent; nervilles distinct, forming a fine polygonal network; margin coarsely double-serrate, with acute teeth; texture rather thin; petiole stout, not completely preserved.

Remarks: This new species is represented by several well-preserved and nearly complete leaf impressions which have the typical characters of cherry. These specimens are somewhat similar to the above-described *P. ishidai*, but differ distinctly in basal shape and secondary venation of lower pairs. Excluding it, no fossil cherries are similar to our species.

Among the living cherries, the leaves of *P. rubeshibensis* are closely similar to those of the modern *P. nigra* AIT. of northeastern North America, but these modern leaves have somewhat obtuse marginal teeth. This new species is somewhat similar to the modern *P. sargentii* REHD. of northern Japan, Korea, and Saghalien, though they differ in marginal serration.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25812 (Rubeshibe); paratypes Nos. 25813 (Rubeshibe), 25700 (Shanabuchi).

Prunus subserotina new species

Pl. 7, fig. 6

Description: Leaves oval to oblong or elliptical, 5 to 7.5 cm. long and 2 to 3 cm. wide; apex acute or acuminate, with a long, slender tip; base rounded to obtuse; midrib stout, nearly straight; secondary veins slender, thin 14 to 16 pairs, irregularly spaced, leaving midrib at somewhat irregular angles from 30 to 60 degrees, gently curving up, near marginal area forming loops; 1 or 2 subsecondaries leaving midrib irregularly; tertiary veins in intersecondary spaces thin and indistinct, forming a coarse network; nervilles indistinct; margin finely crenato-serrate; texture probably glabrous, thin; petiole 0.7 to 1 cm. long.

Remarks: This new species is based on a twig bearing 4 well-preserved leaves and many single leaves, all of which are closely similar to those of the modern *P. serotina* EHRH. of North America in their characteristic margin and secondary venation. This modern species is distributed in the eastern half of the United States and adjacent Canada; it is one of the chief elements of many tracts of forest of the Appalachian region. Our specimens are also similar to the modern *P. davidiana* FRANCH. of the northern and central China, and *P. pennsylvanica* LINNE. of North America.

P. subserotina is closely similar to *P. serrulata* HEER from the Oligocene flora of Saghalien (HEER, 1878), and *P. scottii* HEER from the Oligocene Mormon Creek Flora of southwestern Montana, the western United States (BECKER, 1960). *P. miodavidiana* HU and CHANEY from the Miocene Shanwang flora of China (HU and CHANEY, 1938) somewhat resembles our specis, but differs distinctly in its more numerous secondary veins. Another allied species is *P. treasheri* CHANEY from the Lower Pliocene Troutdale flora of Oregon, the western United States (CHANEY, 1944).

Occurrence: Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25814; paratypes Nos. 25815, 25816.

Rubus sp.

Pl. 12, fig. 9

Description: Leaf incomplete, oval, shallowly trilobed, 4.5 cm. long and 3.4 cm. wide; base cordate; apex missing; midrib stout, nearly straight; a pair of lateral primaries making angles of 60 degrees with midrib; secondary veins from the midrib 5 opposite pairs, diverging at angles of 45 to 50 degrees, gently curving up, ending in marginal teeth; secondaries from the laterals 4 or 5, abaxially extending, diverging at angles of 40 to 60 degrees, margin doubly serrate, with acute teeth; texture thin; petiole missing.

Remarks: A single leaf from the Shanabuchi locality is referred to *Rubus* in its shape and venation, but is too ill-preserved to give new specific name. This leaf is closely similar to that of the modern *R. crataegifolius* BUNGE, which is widely distributed from Hokkaido to Kyushu, Japan, extending into northern China.

Occurrence: Shanabuchi.

Collection: A representative specimen is U. H. M. P. Reg. No. 25701.

Sorbus lanceolata new species

Pl. 13, fig. 3

Description: Leaflets lanceolate, 8.5 to 9.7 cm. long and 1.3 to 2.1 cm. wide; apex gradually narrowed, acuminate; base obtuse or rounded, slightly inequilateral; midrib rather slender, nearly straight; secondary veins weak, alternate to subalternat, 12 to 16 pairs, at angles of 30 to 50 degrees, curving up along marginal border, ending in marginal teeth; tertiary veins very thin, indistinct; margin entire in lower half, serrate with very small, incurved and acute teeth above; texture thin; petiolule short, 2 or 3 mm. long.

Remarks: Our collection from the Shanabuchi and Rubeshibe localities includes 2 twigs bearing 5 lateral leaflets and 2 single leaflets, all with the typical characters of mountain-ash. These leaflets are closely similar to those produced by the modern *S. matsumurana* (MAKINO) KOEHNE, which grows on high mountains of Hokkaido, and northern and central Honshu. No fossil leaflets of *Sorbus* in the world are closely similar. Two leaflets of *S. nipponica* TANAI and ONOE from the Miocene Yoshioka flora of southwestern Hokkaido (TANAI, 1961) somewhat resemble our specimens, but differ distinctly in smaller size and more prominent secondary veins.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25702 (Shanabuchi).

Sorbus protoalnifolia new species

Pl. 21, fig. 3

Description: Leaf oval in shape, 6 cm. and 4 cm. wide, obtuse at base, bluntly pointed at apex; midrib stout, straight; secondary veins stout, regularly spaced, diverging at angles of 40 to 50 degrees, slightly curving up, ending in large teeth; tertiaries and nervilles indistinct; margin coarsely double-serrate; texture rather firm; petiole incomplete, more than 5 mm. long.

Remarks: This new species is based on a well-preserved, nearly complete impression from the Shanabuchi flora. It closely matches the leaf variation displayed by the modern *S. alnifolia* (SIEB. and ZUCC.) C. KOCH. This modern species is commonly found in slope forest of Japan, and is widely distributed from Hokkaido to Kyushu, extending into Korea, China, Manchuria, and Ussuri region.

Our specimen is closely similar to fossil leaves of *Micromeles alnifolia* (S. and Z.) KOENE. from the Pleistocene Shiobara flora of Tochigi Prefecture Honshu (ENDO, 1940).

Occurrence; Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25703.

Sorbus uzenensis HUZIOKA

Pl. 10, fig. 4; pl. 18, fig. 1

Sorbus uzenensis HUZIOKA, HUZIOKA and NISHIDA. Publ. Sado Mus., no. 3, p. 17, pl. 4, fig. 8, 1960.

Remarks: Five incomplete leaflets in the Shanabuchi flora have the typical venation and serration of mountain-ash, and are referred to this species. They closely resemble *S. nipponica* TANAI and ONOE from the Upper Miocene Mitoku flora of western Honshu (TANAI and ONOE, 1961), but are distinguishable by their larger size and doubly serrate margin with unequal teeth.

S. uzenensis is closely similar to the modern *S. commixta* HEDL. which is widely distributed from Hokkaido to Kyushu.

Occurrence: Shanabuchi.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25705, 25706.

Spiraea protothunbergii new species

Pl. 2, fig. 7

Description: Leaf oblanceolate, 2 cm. long and 0.6 cm. wide; acute at both apex and base; midrib stout, straight; secondary veins slender, about 11 alternate pairs, leaving midrib at angles of about 30 degrees, gently curving up, ending in marginal teeth; tertiaries indistinct; margin entire in lower part, and finely serrulate above, texture thin; petiole short and stout.

Remarks: This species is based on a well-preserved, complete leaf impression which is closely similar to the living *S. thunbergii* SIEB. of China, a modern shrub widely cultivated in Honshu, Shikoku and Kyushu. No fossil leaves resemble our species in Japan.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25704.

Family LEGUMINOSAE

Cladrastis chaneyi new species

Pl. 10, fig. 1; pl. 21, fig. 1

Description: Detached leaflets variable in size and shape, ovate or oblong-ovate to oval, sometimes obovate, 5.8 to 12 cm. long and 3.3 to 7.5 cm. wide; apex abruptly acute, with shortly acuminate tip; base rounded to broadly rounded, rarely cuneate; midrib stout, straight, thick below, thin distad; secondary veins rather stout, distinct, prominent on under side of blade, 9 to 12 pairs, opposite to subopposite, at angles of 40 to 50 degrees at middle of leaf, more spreading below, gently arched, near margin abruptly curving up, forming distinct loops; sometimes one or two subsecondaries leaving midrib, nearly parallel to secondaries, forming loops with secondaries; tertiaries thin, irregularly percurrent, nearly at right angles to secondaries; nervilles fine, indistinct, making a fine polygonal mesh; margin entire; texture rather firm; petiolules stout and thick, with cross ridges, sometimes twisted, 0.5 to 0.6 cm. long and 1.5 to 3 cm. wide.

Remarks: This new species is based on two well-preserved foliage specimens which are clearly leguminous, including short, thick petiolules with cross ridge. These leaflets closely resemble those produced by the modern *C. lutea* (MICHX.) KOCH. of the eastern United States, though most of them are somewhat larger than the average of the modern leaves. Our leaflets with obovate bases well match the terminal leaflets of *C. lutea*.

C. chaneyi is somewhat similar to *C. aniensis* HUZIOKA from the Miocene Yoshioka flora of southwestern Hokkaido (TANAI and N. SUZUKI, 1963), but is distinguishable in shape and has more secondaries. There are no other similar fossil leaflets known from Japan. This new species is named in honor of Dr. Ralph W. CHANEY, who has rendered valuable assistance during our study of the Late Tertiary flora of northeastern Hokkaido.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Holotype U. H. M. P. Reg. No. 25708 (Shanabuchi); paratype No. 25723 (Shanabuchi).

Gleditsia miosinensis HU and CHANEY

Pl. 2, fig. 4

Gleditsia miosinensis HU and CHANEY. Pal. Sin. New. Ser. A., no. 1, 52, pl. 26, figs. 6, 7, 1938. TANAI and N. SUZUKI. Tertiary Floras of Japan I., p. 132, pl. 15, fig. 9; pl. 23, figs. 2, 10, 1963.

Remarks: Four poorly preserved impressions of small oblong leaflets in our collections appear to represent this species. All the preserved characters are typically leguminous, including a short petiolules. These leaflets are closely similar to those produced by the living *G. sinensis* LAMARCK of northern and central China, and the living *G. japonica* MIQ. of Honshu, Shikoku, and Kyushu.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25712 (Shanabuchi).

Robinia nipponica TANAI

Pl. 5, fig. 6

Robinia nipponica TANAI. Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 11, no. 2, p. 346, pl. 24, figs. 10, 11, 16; pl. 25, fig. 3, 1961.

Remarks: An incomplete impression of an oval leaflet from the Samakesaroma flora is referred to this species by its shape, secondary venation, and petiole. *R. nipponica* is compared with the modern *R. viscosa* VENT. living on the high slopes of the Alleghany Mountains in the eastern United States.

Occurrence: Samakesaroma.

Collection: Hypotype U. H. M. P. Reg. No. 25841.

Wisteria fallax (NATHORST) TANAI and ONOE

Pl. 9, fig. 4

Wisteria fallax (NATHORST) TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 45, pl. 10, fig. 6; pl. 14, figs. 2-4, 1961.

Sophora fallax NATHORST. Kgl. Svensk. Vet. Akad. Handl., vol. 20, p. 58, pl. 10, figs. 11, 12; pl. 12, figs. 1, 2, 1883.

Remarks: Several complete impressions of well-preserved leaflets in the Rubeshibe collection, with oblong-ovate shape and entire margin, are similar to leaflets produced by the living *W. floribunda* DC. This modern vine grows in Honshu, Shikoku, and Kyushu, and extends into China. Our leaflets resemble those of *Cladrastis aniensis* HUZIOKA from the Mioccne Utto flora of Akita Prefecture (HUZIOKA, 1963), but are distinguishable by their more slender secondary venation and narrower shape.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25713.

Family RUTACEAE

Phellodendron mioamurense TANAI and N. SUZUKI

Pl. 8, figs. 1, 3; pl. 19, fig. 4

Phellodendron mioamurense TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 134, pl. 22, fig. 10, 1963.

Phellodendron amurense RUPR., FLORIN. Kgl. Svendk. Vet. Akad. Handl., vol. 61, p. 23, pl. 6, fig. 17, 1920.

Remarks: This species is presented by a terminal and a lateral leaflet attached to the rachis, and several detached leaflets, from the Shanabuchi flora. Some of our specimens are coarsely serrate with small, blunt teeth. These leaflets resemble those produced by the living *P. amurense* RUPR. widely distributed in northeastern Asia.

A single fossil leaflet of *P. amurense* from the Pliocene Mogi flora of Nagasaki Prefecture, falls within the range of variation represented by *P. mioamurense*. Our species is closely similar to *P. grandifolium* ILJINSKAYA from the Oligocene flora of Ashutas province, western Siberia (ILJINSKAYA in KRYSHTOFOVICH, 1956).

Occurrence: Shanabuchi.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25679b, 25680b, 25716.

Family SIMAROUBACEAE

Ailanthus yezoense OISHI and HUZIOKA

Pl. 10, figs. 6, 7, 11

Ailanthus yezoense OISHI and HUZIOKA. Jour. Geol. Soc. Jap., vol. 49, p. 181, figs. 2-4, 1942.
TANAI and N. SUZUKI. Trans. Proc. Palaeont. Soc. Jap., N.S., no. 52, pl. 21, figs. 1, 3-6, 12, 13, 1963.

Remarks: Several well-preserved leaflets in the Shanabuchi flora closely resemble those of *Ailanthus*, and their occurrence here with 4 winged seeds strengthens the identification. These leaflets have a few glands on lower margin, and their characteristic winged seeds well match those produced by the living *A. altissima* (MILL.) SWINGLE of central and southern China. This modern species may originally have been a warm-temperate trees for it is luxuriantly naturalized in Malaysia, New Zealand and Australia; but it is also a hardy plant which grows well even in cool-temperate regions of North America, Europe and Japan. Accordingly, the occurrence of *A. yezoense* does not necessarily suggest that the Shanabuchi climate was warm-temperate.

As discussed in detail by the authors (TANAI and N. SUZUKI 1963b), winged seeds of *A. yezoense* are closely similar to those of *A. confucii* UNGER from the Tertiary flora of Europe and *A. indiana* (MACG.) BROWN from the Miocene floras of the western United States, but no fossil leaflets closely similar to our specimens have been reported. Foliage figured as *A. youngi* by HU and CHANEY from the Miocene Shanwang flora of China (HU and CHANEY, 1938) seems doubtfully referable to this genus, though the seed appears to represent *Ailanthus*. The seeds figured by CHANEY and AXELROD from the Columbia Plateau of Oregon are clearly referable to *Ailanthus*, but the leaflets cited (*Apocynum indiana* MACGINITIE, 1933, and *Sapindus oregoninum* KNOWLTON, LAMOTTE, 1935) on page 189 do not look to us like those of *Alianthus*.

Occurrence: Shanabuchi.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25750, 25752, 25757.

Family ANACARDIACEAE

Rhus miosuccedanea HU and CHANEY

Pl. 20, fig. 4

Rhus miosuccedanea HU and CHANEY. Pal. Sin., New Ser. A., no. 1, p. 63, pl. 35, fig. 3b; pl. 36, figs. 6, 8; pl. 38, figs. 1-3, 1938.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 350, pl. 24, fig. 18, 1961.

Remarks: These incomplete leaflets show well preserved secondary venation, and have the typical characters of sumac. They are much like leaflets of the living *R. succedanea* LINNE. which is growing in central and southern Honshu, Shikoku and

Kyushu, extending southward into Loochoo island, Formosa, southern China, Malaysia and India. Our leaflets are also similar to those of the living *R. sylvestris* SIEB. and ZUCC. of southwestern Japan, Formosa and others.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25717 (Shanabuchi).

Rhus protoambigua K. SUZUKI

Pl. 5, fig. 2; pl. 8, fig. 5; pl. 17, fig. 3

Rhus protoambigua K. SUZUKI. Monog. Assoc. Geol. Coll. Jap., no., 9, p. 39, pl. 5, fig. 8, 1959.
Lindera sp. TANAI. Jour. Fac. Sci. Hokkaido Univ., Ser. 4, vol. 11, no. 2, pl. 22, fig. 2, 1961.

Remarks: This species is represented by many well-preserved impressions of detached leaflets which are closely similar to those of the living *R. ambigua* LAV. and DIP. *R. protoambigua* was established on the basis of only one lateral leaflet from Upper Miocene Tennoji flora of Honshu, but our collection includes both terminal and lateral leaflets. These specimens are variable in shape and size, much like leaflets of the modern equivalent; some leaflets, apparently abnormal (see pl. 5, fig. 2; pl. 17, fig. 3) show emarginate apices, but the tip are characteristically acuminate. A single specimen of *Lindera* sp. from the Miocene Ouchi flora of Honshu (TANAI, 1961) represents a terminal leaflets of *R. protoambigua*.

The living equivalent species, *R. ambigua*, is one of the common vines in the deciduous forests from Hokkaido to Kyushu, extending northward into Saghalien and southern Kurile islands.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25719, 25721 (Shanabuchi), 25820 (Rubeshibe).

Family ACERACEAE

Acer palaeodiabolicum ENDO

Pl. 10, fig. 3

Acer palaeodiabolicum ENDO. Short papers I. G. P. S., no. 1, p. 12, pl. 3, fig. 3, 1950.
N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 687, pl. 2, figs. 1, 2, 1963.

Remarks: *A. palaeodiabolicum* is represented by a number of well-preserved impressions of leaves and samaras from the Rubeshibe flora. These specimens are variable in size, but fall within the variation displayed by the living equivalent, *A. diabolicum* BLUME of Japan.

Occurrence: Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25897.

Acer palaeorufinerve TANAI and ONOE

Acer palaeorufinerve TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 49, pl. 5, fig. 4, 1961.
N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 688, pl. 3, fig. 5, 1963.

Remarks: This species is represented by a nearly complete leaf and a few fragmentary specimens from the Rubeshibe and Samakesaroma floras, which match those produced by the modern *A. rufinerve* SIEB. and ZUCC., commonly growing in Honshu, Shikoku and Kyushu.

Occurrence: Rubeshibe and Samakesaroma.

Acer protojaponicum TANAI and ONOE

Acer protojaponicum TANAI and ONOE. Bull. Geol. Surv. Jap. vol. 10, p. 281., pl. 6, figs. 5-7, 1959.
N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 688, pl. 4, fig. 5; pl. 5, fig. 4, 1963.

Remarks: A number of well-preserved impressions from the Shanabuchi and other 3 localities, are referable to *A. protojaponicum*. They are variable in size and shape, but resemble those produced by the living *A. japonicum* THUNB., which is growing in Hokkaido and Honshu.

Occurrence: Shanabuchi, Rubeshibe, Samakesaroma, and Ikutawara.

Acer pseudocarpinifolium ENDO

Pl. 10, fig. 8; pl. 11, fig. 1

Acer pseudocarpinifolium ENDO. Short Papers I.G.P.S., no. 1, p. 14, pl. 3, fig. 6, 1950.
N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 689, pl. 3, figs. 2, 3 (see synonymy), 1963.

Remarks: This species was originally described by ENDO (1950) on the basis of a samara from the Upper Miocene flora near Sendai; lately it has been redesignated by the junior author (SUZUKI, 1963) on the basis of both leaves and samaras, which are excellently preserved. Our specimens are closely similar to leaves and samaras, which are excellently preserved. Our specimens are closely similar to leaves and samaras produced by the living *A. carpinifolium* SIEB. and ZUCC., which is widely distributed in Honshu, Shikoku, and Kyushu.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25766 (Shanabuchi), 25910 (Rubeshibe).

Acer pseudoginnala TANAI and ONOE

Pl. 10, fig. 9

Acer pseudoginnala TANAI and ONOE. Bull. Geol. Surv. Jap., vol. 10, p. 282, pl. 6, fig. 2, 1959.
N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 689, pl. 3, fig. 4, 1963.

Remarks: This species is represented by only one samara from the Rubeshibe locality; it is closely similar to samaras produced by the modern *A. ginnala* MAXIM. widely distributed in East Asia.

Occurrence: Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25908.

Acer subpictum SAPORTA

Pl. 2, fig. 1a

Acer subpictum SAPORTA. Bull. Soc. Géol. France, ser, 3, vol. 1, 1873.

OISHI and HUZIOKA. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 7, p. 93, pl. 13, figs. 1-4; pl. 14, figs. 1-4, 1943.

N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 690, pl. 5, figs. 1-3, 1963.

Remarks: Numerous leaves and several samaras from the Shanabuchi and other localities are referred to *A. subpictum*, which is one of most common maples in the Neogene of Eurasia. These specimens are highly variable in size and shape, and resemble those produced by the living *A. mono* MAXIM., widely distributed in temperate East Asia.

Occurrence: Shanabuchi, Rubeshibe, Samakesaroma, and Ikutawara.

Collection: Hypotypes U. H. M. P. Reg. No. 25803c (Rubeshibe).

Acer subukurunduense N. SUZUKI

Acer subukurunduense N. SUZUKI. Jour. Fac Sci. Hokkaido Univ., ser. 4, vol. 11, p. 690, pl. 1, fig. 1, 1963.

Remarks: This species was established by the junior author (SUZUKI, 1963) on the basis of a well-preserved leaf and 2 fragmentary leaves from the Rubeshibe locality. It is closely similar to the modern *A. ukurunduense* TRAUTVETTER, which is living in the subalpine forest of Japan, extending northward into Saghalien, Korea and Manchuria.

Occurrence: Rubeshibe.

Acer yabei ENDO

Pl. 10, figs. 2, 10; pl. 13, fig. 4

Acer yabei ENDO. Short Papers I. G. P. S., no. 1, p. 13, pl 3, fig. 7, 1950.

N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 691, pl. 4, figs. 3, 4, 6 (see synonymy and discussion), 1963.

Remarks: This species has been redesignated by the junior author (N. SUZUKI, 1963) on the basis of both leaves and samaras from the Shanabuchi and Rubeshibe floras, which specimens are closely similar to those of the living *A. saccharinum* LINNE. This living equivalent species is growing in the United States, extending into northeastern Canada.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. No. 25906, 25916 (Rubeshibe), 25767 (Shanabubhi).

Acer sp.

Acer sp. N. SUZUKI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 692, pl. 2, fig. 4, 1963.

Remarks: An incomplete impression of large leaf from the Rubeshibe locality closely resembles leaves of the modern *A. tschonoskii* MAXIM., which is growing in mountains of Honshu, Shikoku and Kyushu, extending into China. No fossil maple leaves in Japan are comparable to our specimen.

Occurrence: Rubeshibe.

Family HIPPOCASTANACEAE

Aesculus majus (NATHORST) TANAI

Aesculus majus (NATHORST) TANAI. Jap. Jour. Geol. Geogr. vol. 22, p. 131, 1952.
TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 367, pl. 28, fig. 1; pl. 29, figs. 4, 5; pl. 30, fig. 3, 1961.
Aesculiphyllum majus NATHORST. Palaeont. Abhandl., vol. 4, no. 3, p. 6, pl. 1, fig. 3, 1888.

Remarks: A single incomplete impression of an oblong leaf in our collection is referred to this species, which is closely similar to the modern *A. turbinata* BLUME. This modern species is one of the most common trees in the deciduous broad-leafed forest from southwestern Hokkaido to northern Kyushu.

Occurrence: Shanabuchi.

Family RHMANACEAE

Zizyphus miojujuba HU and CHANEY

Pl. 21, figs. 2, 6

Zizyphus miojujuba HU and CHANEY. Pal. Sin., New Ser. A., no. 1, p. 66, pl. 41, figs. 1, 4, 1938.
TANAI and N. SUZUKI. Tertiary Flora of Japan I., p. 143, pl. 16, fig. 6, 1963.
Paliurus nipponicus MIKI, TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 370, pl. 32, figs. 11, 12 (not pl. 31, fig. 2), 1961.

Remarks: Five well-preserved leaf impressions from the Shanabuchi flora have the shape, secondary venation and areolation of this species. They closely resemble *Paliurus miosinicus* HU and CHANEY from the Miocene Shanwang flora of China, but differ in venation. Two leaves previously assigned to *P. nipponicus* MIKI from the Shanabuchi flora (TANAI, 1961) are here included in *Z. miojujuba* on the basis of their shape and venation. This fossil species is closely similar to the modern *Z. jujuba* MILLER, widely distributed over most of China.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25724a, b.

Family VITACEAE

Vitis naumanni (NATHORST) TANAI

Pl. 11, fig. 3

Vitis naumanni (NATHORST) TANAI. Geol. Surv. Jap. Rep., no. 163. pl 15, fig. 11, 1955.
Vitiphyllum naumanni NATHOST. Palaeont. Abhandl., vol. 4, p. 17, pl. 6, fig. 2 1888.
Vitis labrusca LINNE, NATHORST. Kongl. Svensk. Vet. Akad. Handl., vol. 20, p. 61, pl. 7, fig. 9, 1883.

Description: Leaves variable in size and shape, orbiculate-cordate to orbicularly pentagonal-cordate in general outline, 10 to 18 cm. long (estimated) and asymmetrically deeply-cordate; central lobe trigonal in shape, acute at apex; leaf palmately 5-ribbed from base, lowest pair of primaries slender, nearly at right angles to midrib, with 4 or more branching secondaries from lower side, craspedodrome; inner pairs of primaries well-defined, leaving midrib at angles of 30 to 45 degrees, craspedodrome, with 6 or 7 secondaries on under side also ending in marginal teeth; midrib stout, slightly arcuate; about 6 pairs of secondaries, opposite, nearly parallel to inner primaries, craspedodrome; tertiaries irregularly percurrent, nearly at right angles to secondaries; nervilles forming coarse, polygonal network; margin coarsely double-dentate, with small, acute teeth; petiole missing; texture thin.

Remarks: This species is based on a nearly complete leaf impression and several fragmentary specimens, which are referred to *Vitis* by their shape, well-defined venation and dentate margin. These leaves resembles those of the living *V. coignetiae* PULL. which is common in Hokkaido, Honshu, and Shikoku. An incomplete leaf of *Vitiphyllum naumanni* NATHORST from the Miocene Kitaaigi flora of Honshu is inseparable form our specimens. A fragmentary leaf of *V. labrusca* LINNE. from the Pliocene Mogi flora of Kyushu, though lacking its upper part, is closely similar to our leaves in its well-defined venation, cordate base, and dentate margin, and is included in *V. naumanni*.

V. naumanni resembles *V. olriki* HEER from the Paleogene flora of arctic regions (HEER, 1868; HOLLICK, 1936), but differs in maginal serration. Fossil seeds of *V. coignetiae* have been reported from Pleistocene floras in various areas of Honshu by MIKI (1956), and fossil seeds of *V. labruscoides* MIKI, considered to be an ancestral species of *V. coignetiae*, have been described by MIKI (1956) from the Upper Miocene or the Mio-Pliocene of Honshu. Our species, based on leaves, may be placed in synonymy with *V. labruscoides* after further study.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. 25824 (Rubeshibe).

Family THEACEAE

Stewartia okutsui TANAI

Pl. 14, figs. 7, 8; pl. 20, fig. 7

Stewartia okutsui TANAI. Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11, p. 374, pl. 25, figs. 7, 10, 1961.
Stewartia pseudo-camellia MAXIM., MIKI. Jap. Jour. Bot., vol. 8, p. 324, fig. 8, I-J, 1937.
MIKI. Jap. Jour. Bot., vol. 11, p. 289, fig. 18, E, 1941.
OKUTSU. Sci. Rep. Tohoku Univ., ser. 2, vol. 26, p. 107, pl. 5, figs. 2, 3, 1955.

Supplementary description: Capsules oval in shape, acuminate at apex, rounded at base, 1.8 to 2 cm. long and 1.2 to 1.5 cm. wide, probably splitting into 5 valves; each valve ovate in shape, acuminate at apex, 2 cm. long and 7 mm. wide; peduncle stout, more than 1.5 cm. long.

Remarks: Two well-preserved, nearly complete leaves in the Rubeshibe flora closely resemble those of *Stewartia*, and their occurrence here with a well-preserved capsule of *Stewartia* strengthens the identification. An incomplete capsule was also found at Shanabuchi. These leaves and capsules are closely similar to those of the modern *S. pseudo-camellia* MAXIM. of Honshu, Shikoku, and Honshu.

Fossil capsules of *S. pseudo-camellia* described from the Pliocene in various localities of Honshu by MIKI (1937, 1941) are essentially inseparable from those of our species, and are included in *S. okutsuii*. Our capsule specimens are similar to those of *S. monadelpha* SIEB. and ZUCC. described from the Pliocene of Honshu (MIKI, 1941; K. SUZUKI, 1962), but differ distinctly in their large size.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotypes U. H. M. P. Reg. Nos. 25825, 25826, 25827 (all from Rubeshibe).

Family ARALIACEAE

Aralia subelata new species

Pl. 2, fig. 9

Description: Leaflet small, ovate in shape, rounded at base, acute at apex, 3 cm. long and 1.9 cm. wide; midrib stout, somewhat flexuous; secondary veins slender, 5 opposite pairs, diverging at angles of 35 to 40 degrees, slightly curving up, ending in marginal teeth; tertiary veins forming a coarse polygonal network which includes a fine areolation; margin serrate with large and triangular teeth; texture thin; petiolule slender, more than 2 mm. long.

Remarks: A single well-preserved, complete leaflet from the Shanabuchi flora resembles the terminal leaflets produced by the living *A. elata* (MIQ.) SEEM. This modern species is one of the common shrubs widely distributed from Hokkaido to

Kyushu; it extends northward into Saghalien, Manchuria, and Ussurri region. Fossil seeds of *A. elata* were reported by MIKI from the Upper Pliocene Akashi flora of Hyogo Prefecture (MIKI, 1937). No fossil leaflets of *Aralia* in Japan are similar to this new species.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25725.

Kalopanax acerifolius (NATHORST) HU and CHANEY

Pl. 20, fig. 2

Kalopanax acerfolium (NATHORST) HU and CHANEY. Pal. Sin., New Ser. A., no. 1, p. 70, pl. 47, figs. 3, 5, 1938.

TANAI. Jour. Fac Sci. Hokkaido Univ., ser. 4, vol. 11, p. 377 (see synoymy), 1961.

Acanthopanax acerifolium NATHORST. Kgl. Svenk. Vet. Akad. Handl., vol. 20, p. 54, pl. 8, fig. 5; pl. 9, figs. 1, 2, 1883.

Remarks: This species is based on a nearly complete leaf impression and many well-preserved, incomplete specimens from the Shanabuchi flora. Though these leaves are variable in foliage and lobe shapes, they closely resemble leaves of the modern *K. septemlobus* (THUNB.) KOIDZ. This species is common in the slope forests of Hokkaido, Honshu, Shikoku, and Kyushu, and extends northward into Saghalien and southern Kurile islands, westward into Korea and China, and northwestward into Manchuria.

Occurrence: Shanabuchi.

Collection: Hypotype U. H. M. P. Reg. No. 25727.

Family CORNACEAE

Cornus megaphylla HU and CHANEY

Pl. 12, fig. 5

Cornus megaphylla HU and CHANEY. Pal. Sin., New. Ser. A., no. 1, p. 71, pl. 48, figs. 3-5; pl. 49, fig. 2, 1938.

TANAI and ONOE. Geol. Surv. Jap. Rep., no 187, p. 54, pl. 17, fig. 9, 1961.

Remarks: Many fragmentary leaf impressions in the Rubeshibe flora are identical with this species in their shape and secondary venation. *C. megaphylla* is closely similar to the modern *C. macrophylla* WALL. of China and Korea, and also to the living *C. controversa* HEMSL. of Japan.

Occurrence: Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25828.

Cornus subkousa TANAI and ONOE

Cornus subkousa TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 53, pl. 17, figs. 6, 7, 1961.

Remarks: A single specimen of a poorly preserved ovate leaf from Shanabuchi is referred to *C. subkousa*. This specimen adds information regarding the base, which is broadly rounded; its tip is incomplete. It is closely similar to the modern *C. kousa* BUERG, which grows in Honshu, Shikoku, and Kyushu, extending to Korea and China. *C. subkousa* resembles the above-described *C. megaphylla*, but differs distinctly in its smaller size and fewer secondary veins.

Occurrence: Shanabuchi.

Clethra maximowiczii NATHORST

Pl. 6, fig. 1

Clethra maximowiczii NATHORST. Kgl. Svensk. Vet. Akad. Handl., vol. 20, p. 51, pl. 11, figs. 18–20, 1883.

Clethra barbinervis SIEB. and ZUCC. OKUTSU. Saito-Ho-On Kai Mus. Res. Bull., no. 19, p. 164, pl. 13, fig. 2; pl. 14, figs. 1, 2, 1940.

Cf. *Clethra barbinervis* SIEB and ZUCC., K. SUZUKI. Monog. Assoc. Geol. Collab. Jap., no. 9, p. 42, pl. 5, fig. 4, 1959.

Clethra sp., TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 54, pl. 17, fig. 10, 1961.

Supplementary description: Leaves oblanceolate to obovate, 15 to 18 cm. long and 7 to 7.5 cm. wide; apex obtuse to acute; base acute or cuneate; midrib stout, straight; secondary veins rather slender but distinct, subalternate, 13 to 15 pairs diverging at angles of 45 to 55 degrees, curving upward near margin, thence forming bows by dichotomous branches, camptodrome; tertiaries branching from secondaries entering marginal teeth, tertiaries in intersecondary spaces thin, irregularly percurrent; nervilles obscure, forming a fine mesh; margin finely dentate-serrate except basal entire portion; teeth small, acute, unequal-sized; texture thin; petiole stout and thick.

Remarks: Four well-preserved leaf impression with 2 complete specimens in our collection are referred to *Clethra maximowiczii* NATHORST, originally described from the Pliocene Mogi flora of Kyushu. Our leaves are closely similar to those of the living *C. barbinervis* SIEB. and ZUCC., which is a common tree in slope forests from Hokkaido to Kyushu, and also lives on Quelpart Island, Korea.

Foliage specimens previously described as *C. barbinervis* from the Upper Miocene of Honshu (OKUTSU, 1940; K. SUZUKI, 1959) are inseparable in all characters from our specimens, and are included in *C. maximowiczii*. An incomplete leaf figured as *Clethra* sp. from the Pliocene Ningyo-toge flora of western Honshu (TANAI and ONOE, 1961) is also referable to this species, as indicated by characteristic secondary venation and marginal serration.

Occurrence: Shanabuchi and Rubeshibe.

Collection: Hypotype U. H. M. P. Reg. No. 25729 (Shanabuchi).

Family ERICACEAE

Rhododendron tatewakii new species

Pl. 5, fig. 7; pl. 19, fig. 6

Description: Leaves obovate to oblanceolate, 8 to 8.5 cm. long and 4 to 5.5 cm. wide; apex acute with a cuspidate tip; base gradually narrowed, acute; midrib stout, nearly straight, or slightly curved; secondary veins thin, 7 to 9 pairs, opposite to subopposite, at angles of 45 to 65 degrees, near marginal border curving upward, forming loops; sometimes a slender subsecondary vein; tertiary veins branching from secondaries, camptodrome; intersecondary tertiaries indistinct, forming irregularly polygonal network, in which fine areolation is included; margin entire; texture firm; petiole stout and short, about 4 mm. long.

Remarks: This new species is based on 2 well-preserved, nearly complete leaf impressions from the Shanabuchi flora. These specimens resemble leaves of *Lindera* in shape and venation, but they are definitely referable to *Rhododendron* in having a cuspidate apex. Our foliage is closely similar to that of the modern *R. albrechti* MAXIM., a shrub growing in the subalpine forest in Hokkaido, and in central and northern Honshu. The modern leaves appear to be finely serrate with hard hairs on the margin, whereas the fossils seem to be entire. Since these firm marginal hairs would probably not be preserved, their absence on the fossils is not serious bar to the suggested relationships.

No fossil species of *Rhododendron* are similar to our new species. A leaf figured as *Lindera gaudini* (NATHORST) TANAI from the Miocene Ouchi flora of Honshu (TANAI, 1961) is somewhat similar, but differs distinctly in shape.

Occurrence: Shanabuchi.

Collection: Holotype U. H. M. P. Reg. No. 25731; paratype No. 25732.

Family EBENACEAE

Diospyros sublotus new species

Pl. 12, fig. 7; pl. 13, fig. 1; pl. 18, fig. 5

Diospyros miokaki HU and CHANEY. Pal. Sin., New. Ser. A., no. 1, p. 72, pl. 42, fig. 3 (not figs. 1, 2), 1883.

Description: Leaves ovate or elliptic ovate to oblong, 7 to 14.2 cm. long and 3.3 to 6.2 cm. wide; apex abruptly acute with shortly acuminate tip; base broadly cuneate to rounded; midrib stout, thick, nearly straight; secondary veins rather stout, prominent on under side of blade, 8 to 10 pairs, leaving midrib at irregular intervals and at angles of 40 to 55 degrees, gently curving up, forming loops near margin; a few branches from secondaries extending to abaxial side, forming small loops; 1 or

2 veins in intersecondary spaces leaving midrib; tertiaries irregularly percurrent, trending transversely to secondaries; nervilles thin, indistinct, forming fine polygonal network; margin entire, sometimes undulate; texture rather thin; petiole stout and thick, slightly grooved, 3 to 5 mm. long.

Remarks: This new species, based on a number of well-preserved leaf impressions, is common at Shanabuchi and Rubeshibe, but is represented by only one specimen at Samakesaroma. Though somewhat variable in size and shape, these leaves are closely similar to those of the living *Diospyros lotus* LINNE., which is widely distributed in China, Korea, and western Asia, and is cultivated in Japan. But most of our leaves are larger in size, and have more numerous secondary veins. The shoots of one year's growth in *D. lotus* generally have leaves as large as our specimens. The venation feature and grooved, short petiole of our fossils show a close similarity to *D. lotus*.

One of the larger leaves figured by HU and CHANEY (1938, pl. 46, fig. 3) as *D. miokaki* differs in its secondary venation and oblong shape from the other 2 leaves figured (pl. 46, figs. 1, 2), and seems identical to *D. sublotus*. Leaves of our species are somewhat similar to those of *D. nordquisti* NATHORST from the Pliocene Mogi flora of Kyushu (NATHORST, 1883), but differ in secondary venation. A single leaf figured by ANDERANSZKY (1959) as *D.* cf. *lotus* L. from the Oligocene Sarmatian flora of Hungary is also similar.

Occurrence: Shanabuchi, Rubeshibe and Samakesaroma.

Collection: Holotype U. H. M. P. Reg. No. 25831 (Rubeshibe); paratypes Nos. 25735, 25736 (Rubeshibe).

Family OLEACEAE

Forsythia kitamiensis (OISHI and HUZIOKA) new comb.

Pl. 11, fig. 4

Celts kitamiensis OISHI and HUZIOKA. Jap. Jour. Geol. Geogr., vol. 24, p. 139, pl. 15, fig. 7, 1954.

Remarks: A single well-preserved leaf impression and its counterpart in the Shanabuchi collection appears to have all the typical features of *Forsythia*. Close relationship to *F. suspensa* (THUNB.) VAHL is shown by the oval leaf, rather thin texture, the irregularity of secondary venation, and acute marginal serration. Its leaves are highly variable in shape, and our specimen well matches some of them. This living shrub grows in northern and central China, and is widely cultivated as one of the common garden plants of Japan.

A leaf impression from Shanabuchi, referred to *Celtis kitamiensis* OISHI and HUZIOKA, differs distinctly from hackberry in its secondary venation; it is essentially the same as our specimen, though it has a short lobe on one side. Such a slightly lobate leaf falls within the variation represented by leaves of *F. suspensa*.

Occurrence: Shanabuchi.
Collection: Hypotype U. H. M. P. Reg. No. 25737.

Fraxinus honshuensis TANAI and ONOE

pl. 12, figs. 1, 2

Fraxinus honshuensis TANAI and ONOE. Geol. Surv. Jap. Rep., no. 187, p. 57, pl. 18, fig. 7, 1961.

Remarks: A rather poorly preserved winged seed shows an emarginate wing tip which slightly clasps the seed, thus resembling *F. honshuensis*. This species is closely similar to the modern *F. longicuspis* SIEB. and ZUCC. of Honshu, Shikoku, and Kyushu.

Occurrence: Samakesaroma.
Collection: Hypotypes U. H. M. P. Reg. Nos. 25843a, b.

Fraxinus k-yamadai new species

Pl. 13, fig. 6

Description: Samara 4.3 cm. long and 0.9 cm. long wide, wing oblanceolate, thin, with numerous subparallel veins, emarginate at apex, clasping the seed; seeds linear-lanceolate, compressed, 2.8 cm. long and 4 mm. wide.

Remarks: This new species is based on a completely preserved winged seed from the Shanabuchi locality. No fossil or living samaras of *Fraxinus* in Japan are similar to our specimen. It closely resembles the samara of *F. coulteri* DORF from the Miocene of the western United States (DORF, 1936: AXELROD, 1956). These winged seeds are closely similar to those of the living *F. americana* LINNE. of the eastern United States and *F. oregona* NUTT. of the Pacific coast.

This species is named in honour of Dr. Keiichi YAMADA of Geological Survey of Japan, who directed us to the fossil localities of the Shanabuchi flora.

Occurrence: Shanabuchi.
Collection: Holotype U. H. M. P. Reg. No. 25738.

Lonicera sp.

Pl. 12, figs. 3, 6

Description: Leaf incomplete, ovate, 6.3 cm. long and 3.7 cm. wide; base obtusely cuneate; apex rounded, with a small acute tip; midrib stout and straight; secondaries rather thick, about 8 pairs, opposite to subopposite, leaving midrib at angles of 45 to 55 degrees, at lower angles in basal part, slightly arched, near margin curving up, then forming a distinct loops; tertiaries in intersecondary spaces thin, forming a coarse and irregular network, a few branches from secondaries forming small loops at marginal border; nervilles thin but distinct, finely reticulate; margin nearly entire in lower half, irregularly crenate in upper half; texture thin, probably pubesent; petiole thick, 2.5 mm. long.

Remarks: A single incomplete leaf and its counterpart from the Rubeshibe locality are closely similar to leaves of the modern *L. gracilipes* MIQ. which is widely distributed from southern Hokkaido to Kyushu. But these specimens are too fragmentary to establish as a new species. No fossil leaves in Japan are similar to our specimens.

Occurrence: Rubeshibe.

Collection: Representative specimens are U. H. M. P. Reg. Nos. 25834a, b.

A SUMMARY OF SYSTEMATIC REVISIONS

In the preceding pages we have changed to a large extent the taxonomic disposition of certain species in the Neogene flora of Japan. The revisions are summarized below; the original names are given first with the reference concerned, followed by the revised name or revised combination in this paper; the pages in which reasons for making these changes are described are indicated at the right.

Pages

Betula honmashinichii HUZIOKA and NISHIDA. HUZIOKA and NISHIDA, 1960, pl. 2, figs. 8-10. =*Betula protoermani* ENDO 17

Betula onbaraensis TANAI and ONOE. TANAI, 1961a, pl. 11, fig. 9. =*Carpinus subcordata* NATHORST 18

Betula oobae K. SUZUKI. K. SUZUKI, 1961. pl. 7, figs. 5, 6. =*Betula protoermani* ENDO.... 17

Betula protoglobispica TANAI and ONOE. TANAI and ONOE, 1961, pl. 3, figs. 1, 2. =*Betula protoermani* ENDO 17

Celtis aizuensis K. SUZUKI. K. SUZUKI, 1961, pl. 14, figs. 8-10. =*Celtis miobungeana* HU and CHANEY 22

Celtis kitamiensis OISHI and HUZIOKA. OISHI and HUZIOKA, 1954, pl. 15, fig. 4. =*Forsythia kitamiensis* (OISHI and HUZIOKA) TANAI and N. SUZUKI 46

Celtis nathorsti TANAI and ONOE. TANAI and ONOE, 1961, pl. 10, fig. 1. =*Celtis miobungeana* HU and CHANEY 22

Celtis nordenskioldii NATHORST. (in part) NATHORST, 1883, pl. 15, fig. 2 (not pl. 6, figs. 14-17) =*Celtis miobungeana* HU and CHANEY 22

Celtis sp. TAKAHASHI, 1954, pl. 5, fig. 7 =*Celtis miobungeana* HU and CHANEY 22

Clethra barbinervis SIEB. and ZUCC. OKUTSU, 1940, pl. 13, fig. 2; pl. 14, figs. 1, 2. =*Clethra maximowiczii* NATHORST 44

Clethra cf. *barvinervis* SIEB. and ZUCC. K. SUZUKI, 1959, pl. 5, fig. 4. =*Clethra maximowiczii* NATHORST 44

Clethra sp. TANAI and ONOE. 1961, pl. 17, fig. 10. =*Clethra maximowiczii* NATHORST 44

Diospyros miokaki HU and CHANEY. (in part) HU and CHANEY, 1938, pl. 42, fig. 3 (not figs. 1, 2) =*Diospyros sublotus* TANAI and N. SUZUKI 46

Fagus crenata BLUME. K. SUZUKI, 1961, pl 11, figs. 8-15. =*Fagas palaeocrenata* OKUTSU 20

Hamamelis sp. TANAI and ONOE, 1961, pl. 12, fig. 3. =*Hamamelis protojaponica* TANAI and N. SUZUKI 27

Lindera sp. TANAI, 1961a, pl. 22, fig. 2. =*Rhus protoambigua* K. SUZUKI 37

Paliurus nipponicus MIKI. (in part) TANAI, 1961a, pl. 32, figs. 11, 12 (not pl. 31, fig. 2) =*Zizyphus miojujuda* HU and CHANEY 40
Phellodendron amurense RUPR. FLORIN, 1920, pl. 6, fig. 17. =*Phellodendron mioamurense* TANAI and N. SUZUKI 35
Picea magna MACGINITIE. TANAI, 1961a, pl. 1, figs. 5-7. =*Picea kaneharai* TANAI and ONOE 3
Picea magna MACGINITIE. TANAI and N. SUZUKI, 1963, pl. 2, figs. 13, 14, 16, 17, 20, 21, 39. =*Picea kaneharai* TANAI and ONOE 3
Picea magna MACGINITIE. HUZIOKA, 1963, pl. 2, fig. 2. =*Picea kaneharai* TANAI and ONOE 3
Picea miocenica TANAI. TANAI 1961a, pl. 1, figs. 12, 15. =*Picea kaneharai* TANAI and ONOE 3
Populus balsamoides GOEPPERT. K. SUZUKI, 1961, pl. 2, fig. 8,; pl. 3, figs. 1, 2. =rejected 7
Populus balsamoides GOEPPERT. (in part) TANAI, 1961a, pl. 4, fig. 9 (not fig. 8) =rejected.. 7
Salix lavateri HEER. KONNO, 1931, pl. 8, fig. 5. =*Salix hokkaidoensis* TANAI and N. SUZUKI 10
Salix sp. KONNO, 1931, pl. 8, fig. 6. *Salix parasachalinensis* TANAI and N. SUZUKI 12
Stewartia pseudo-camellia MAXIM. MIKI, 1937, fig. 8, I-J. =*Stewartia okutsui* TANAI 42
Stewartia pseudo-camellia MAXIM. MIKI, 1941, fig. 18, E. =*Stewartia okutsui* TANAI 42
Ulmus aizuana K. SUZUKI. K. SUZUKI, 1961, pl. 14, figs. 4, 5. =*Ulmus protojaponica* TANAI and ONOE 24
Vitiphyllum naumanni NATHORST. NATHORST, 1888, pl. 6, fig. 2. =*Vitis naumanni* (NATHORST) TANAI 41
Vitis labrusca LINNE. NATHORST, 1883, pl. 7, fig. 9. =*Vitis naumanni* (NATHORST) TANAI 41

PART II. COMPOSITION AND INTERPRETATION

By

Toshimasa TANAI

PRESENT PHYSICAL SETTING

PHYSICAL CONDITIONS

The four localities from which the fossil plants were obtained are situated in the Kitami and Abashiri Provinces, northeastern Hokkaido as shown in Figure 1. Two major localities are known in the neighbourhood of Engaru and Rubeshibe towns respectively; two minor localities are known at Ikutawara town. This region is made up largely of hills of 200-500 meters elevation and their adjacent alluvial plains. These hills extend southward with gradual increase in height, and connect with the Kitami mountain range of NNW-SSE trend, which forms partially the northern backbone range of Hokkaido. The major drainage develops toward the east or north-east from the Kitami range, and enters the Okhotsk Sea. Along the Sea coast there are widespread plains which are largely low moor.

This region is bordered westward by the Kitami range including the Mt. Teshio-dake, and southward by the Chishima volcanic range including Mt. Daisetsu, Mt. Oakan and Mt. Meakan. Since this area is bounded by these mountain ranges west- and southward, climate is mainly influenced by that of the Okhotsk Sea. Summer temperatures average from 16° to 20°C. (from July to August), and winter temperatures (from December to February) are from −6° to −12°C. on the average; monthly precipitation is from 100 to 150 mm. in summer, and 50 to 70 mm. in winter. The annual precipitation is about 800 mm. on the average; this is one of the regions of lowest precipitation in Japan. Snowfall is comparatively heavy, though rather lighter than in other parts of Hokkaido, and totals 1.5 to 2 meters in average annual maximum. In summer sea fog occurs frequently along the coast; in winter the coast is usually closed by sea ice. Exact climatic data are not available for the immediate fossil localities, but general climatic conditions are known from a nearby meteorological station at Abashiri City on the sea coast. Climatic data given by WADACHI (1958) from this station are shown in Table 1.

WOODY VEGETATION

The forest of this region show a mixed type of subarctic and temperate forests. They are closely related to the forest of southern Kurile and southern Saghalien;

Table 1. Climatic Data for Abashiri (1921-1950).

Month.	Temp.	Precip.
Jan.	−6.8	70
Feb.	−7.3	44
Mar.	−3.2	50
Apr.	3.3	53
May	8.3	65
June	12.5	59
July	17.5	86
Aug.	19.9	98
Sept.	15.9	126
Oct.	10.1	84
Nov.	3.2	80
Dec.	−3.3	52
Annual Average	5.8	867

(Temperature in degrees Centigrade; precipitation in millimeters).

many members of the temperate forest of Honshu extend into this region, though such characteristic trees as *Fagus crenate*, *Castanea crenata*, *Pinus densiflora*, *Pterocaya rhoifolia*, *Carpinus laxiflora*, *Quercus serrata* and *Aesculus turbinata* are not found. On lowlands and hillsides of region a deciduous broad-leafed forest is developed, composed mainly of *Acanthopanax sciadophylloides*, *Acer mayrii*, *A. mono* var. *glabrum*, *A. palmatum* var. *matsumurae*, *Carpinus cordata*, *Cercidiphyllum japonicum*, *Hydrangea paniculata*, *Juglans ailanthifolia*, *Morus bombycis*, *Prunus sargentii*, *P. ssiori*, *Quercus grosseserrata* var. *mongolica*, *Sambucus sieboldianus*, *Sorbus alnifolia*, *Tilia maximowicziana*, and *Ulmus davidiana* var. *japonica*. The conifer forest on mountains of 800 to 1500 meters elevation resembles those of the subarctic zone, and consists of *Abies sachalinensis*, *A. sachalinensis* var. *mayriana*, *Picea glehni*, and *P. jezoensis*. At middle altitudes these conifers form a mixed forest with many deciduous broad-leafed trees such as *Acer mono*, *A. ukurunduense*, *Betula ermani*, *B. maximowicziana*, *B. platyphylla* var., *Kalopanax pictus*, *Magnolia kobus* var. *borealis*, *M. obovata*, *Phellodendron amurense* var. *sachalinense*, *Populs maximowiczii*, *Prunus maximowiczii*, *Quercus grosseserrata*, *Rhododendron dauricum*, *Sorbaria stellpila*, *Tilia japonica*, *T. maximowicziana*, and *Ulmus laciniata*. This mixed forest is shown on Plate 1.

The forests around the fossil localities have been disturbed by man, and are probably secondary. They consist mainly of the above-noted lowland trees such as *Acer mono* var., *Betula maximowicziana*, *B. platyphylla* var. *japonica*, *Hydrangea paniculata* var., *Kalopanax pictus*, *Magnolia obovata*, *Morus bombycis*, *Prunus sargentii*, *Quercus grosseserrata* var. *mongolica*, and *Sambucus sieboldianus* var. *miquelii*.

THE SHANABUCHI FLORA

INTRODUCTION

Fossil plants have long been known to occur in thin-bedded tuffaceous shale exposed in Kamishanabuchi Village and along the upper course of Fumi river, about 10 kilometers west or northwest of Engaru-machi, Monbetsu-gun. The plant fossils studied here came from the former locality as shown in Figure 1. They are now so numerous that they can be regarded as representing the fossil flora, which is called here the Shanabuchi Flora. The area around the fossil localities is an important mining field in which metallic ore deposits are abundantly distributed; it contains Konomai gold-silver mine situated about 10 kilometers northwest of Kamishanabuchi, and the Kitami copper-zinc mine about 8 kilometers southwestward. The ore deposits and ore-bearing formations have been investigated in detail by various geologists since 1913, but the plant-bearing formation and its flora have received little attention until recently.

The first mention of the occurrence of plant fossils this area was by T. TAKAHASHI et al. (1936, p. 37); they listed only 9 species, which were collected when they investigated mineral resources of this region. S. OISHI and K. HUZIOKA (1954) described only *Celtis kitamiensis* from the Kamishanabuchi locality. Thereafter many mining geologists (Y. URASHIMA, 1953, p. 4-7, 1957, p. 599; T. OTAGAKI, 1951) discussed the geology and reported the occurrence of plant fossils, but no floral list has been

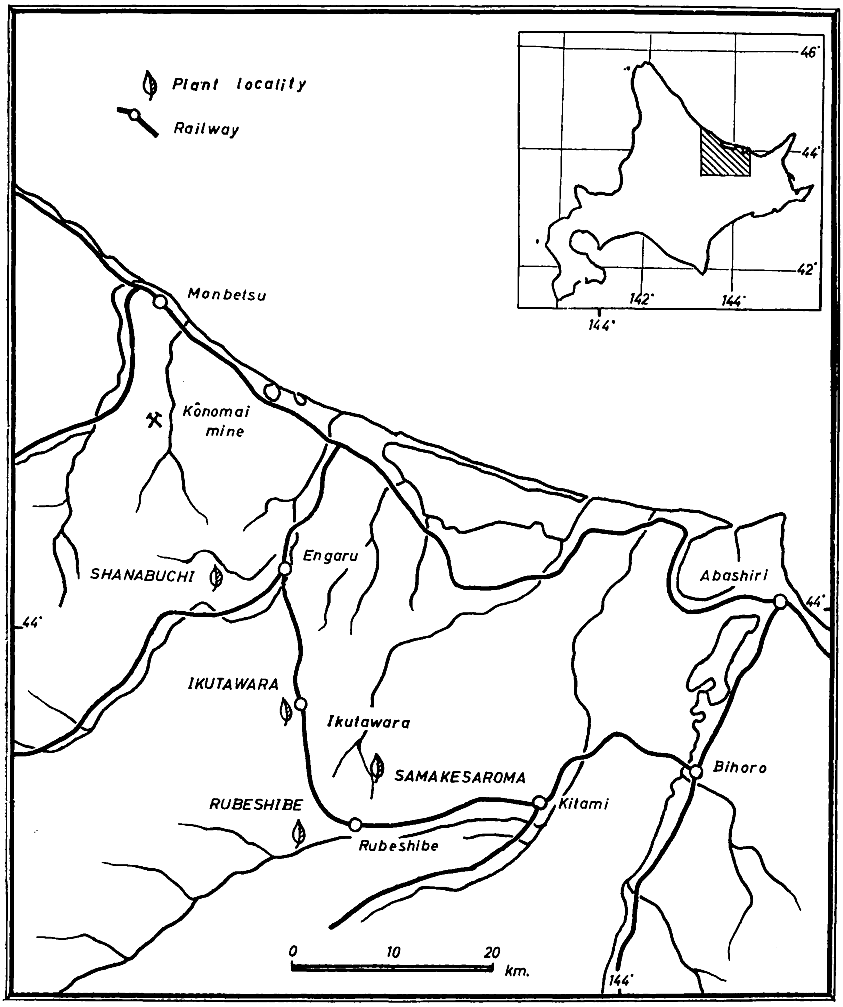


Figure 1. Localities of Late Tertiary Plants in Northeastern Hokkaido.

known. For several years past the author has studied the Shanabuchi flora, and has made a brief report with descriptions of several species (TANAI, 1961, p. 184, Table 6). With the additional material collected in 1960 and 1961, there are now on hand enough plant fossils to make possible our consideration of the floral composition and paleoecology of the Shanabuchi forest, although the collection is not as large as might be desired. Most of the geologists who have investigated this area have referred the plant-bearing formation to the Lower Pliocene on the basis of general stratigraphy and lithology. However, on the basis of plant fossils and stratigraphic relationships, the author has concluded that the Shanabuchi plant-bearing formation is Late Miocene age as discussed in detail in a later chapter.

GEOLOGIC OCCURRENCE

In the central Kitami district including the fossil localities, the Neogene Tertiary sediments are widely distributed on Mesozoic sediments and granite of probable Mesozoic time. The Tertiary was first divided into three groups by TAKAHASHI et al. (1936) and K. TAKEUCHI (1942): the Konomai, Monbetsu and Shanabuchi in asending order. Thereafter URASHIMA et al. (1953, p. 5) concluded that the two lower groups were contemporaneous, and included the Monbetsu group in the Konomai. The Konomai group is made up mainly of shale, tuffaceous siltstone and tuff; its lower part consists principally of black and gray shale with well-developed bedding; its upper half is made up largely of pyroclastic materials, and consists mainly of tuff, tuff-breccia, and alternating layers of tuff and yellowish-gray tuffaceous siltstone contains a few molluscs such as *Crenella* sp., *Fusus* sp., *Lucinoma acutilineata*, *Propeammusium tateiwai*, and *Thracia* sp. at several localities. This group is largely of marine origin, but in its upper part several fragmentary plant fossils such as *Fagus antipofi*, *Carpinus subcordata* and *Fraxinus* sp. have been found.

The Shanabuchi group is of lacustrine origin. It is distributed widely in the area along the Shanabuchi and Fumi rivers, and lies unconformably upon the Konomai group to the west and Mesozoic rocks to the south and east. This group is divided into two formations, the Shanabuchi and Humi in ascending order. The lower part of the Shanabuchi formation is made up mainly of conglomerate and sandstone, and contains of the Konomai rocks and of basalt. The upper part is composed mainly of siltstone, tuffaceous sandstone and tuff, commonly with thin alternation. Siltstone at the middle of these upper beds includes many well-preserved plant fossils at several localities, especially at the Kamishanabuchi locality. Rhyolitic tuff-breccia and its flow overlie the sediments of Shanabuchi formation in some sections, and are widely distributed to the west and northwest; they are considered to be a marginal facies of the Shanabuchi formation. The Humi formation is made up mainly of rhyolitic tuff and tuff-breccia, and is distributed in the center of Shanabuchi depositional basin. The Konomai group has been referred to the Middle Miocene on the basis of marine molluscs and lithology. The Shanabuchi formation was originally assigned to the Lower Pliocene, but the author has recently assigned it to the Upper Miocene (TANAI, 1961; TANAI and SUZUKI, 1961).

The Kamishanabuchi locality is located along the Minamizawa, about 3 kilometers southwest of the Kamishanabuchi bus stop. Along the road cut there are exposures of alternating tuffaceous gray siltstone and fine-grained sandstone, which are well banded with thicknesses of 0.5 to 3 cm. (pl. 1, fig. 1). These sediments dip northwestward about 20 degrees. The tuffaceous siltsone includes numerous leaves and winged seeds, most of which are well preserved. Cones, cone-scales, and other organs are of rare occurrence.

COMPOSITION

The Shanabuchi flora is distributed in 30 families, 51 genera and 70 species, of which 18 are described as new, and one as a new combination. There are 7 conifers, 2 monocotyledons, and the remainder are dicotyledons. The largest family is the Rosaceae with 5 genera and 9 species; next come the Betulaceae with 3 genera and 8 species, the Ulmaceae with 3 genera and 5 species, and the Pinaceae, Salicaceae, and Aceraceae with 4 species each. The remaining families have 3 species or less, and most of them are represented by only one. The following genera are predominant in number of species; *Alnus* and *Acer* with 4 species each, and *Carpinus, Prunus,* and *Sorbus* with 3 each. *Populus, Salix, Pterocarya, Fagus, Celtis, Ulmus,* and *Rhus* have 2 species each, and remainder are represented by single species. Thus, the Shanabuchi flora consists mainly of temperate plant families such as Pinaceae, Salicaceae, Juglandaceae, Betulaceae, Fagaceae, Ulmaceae, Rosaceae, and Aceraceae, most of which are now widely distributed in the northern hemisphere; they account for more than the half of total species. There are few representatives of the Lauraceae and other tropical families, and the Fagaceae includes no evergreen oaks whose living equivalents are tropical or subtropical in distribution.

Systematic List of Families and Species

Pinaceae
- *Abies protofirma* TANAI
- *Picea kaneharai* TANAI and ONOE
- *Pinus* sp.
- *Tsuga oblonga* MIKI

Taxodiaceae
- *Taiwania japonica* TANAI and ONOE

Cupressaceae
- *Juniperus honshuensis* TANI and ONOE
- *Thuja nipponica* TANAI and ONOE

Liliaceae
- *Disporum ezoanum* new species

Smilax trinervis MORITA

Salicaceae

Populus kitamiana new species
Populus kobayashii K. SUZUKI
Salix hokkaidoensis new species
Salix parasachalinensis new species

Juglandaceae

Juglans japonica TANAI and ONOE
Pterocarya asymmetrosa KONNO
Pterocarya protostenoptera TANAI

Betulaceae

Alnus miojaponica TANAI
Alnus protohirsuta ENDO
Alnus protomaximowiczii TANAI
Alnus subfirma new species
Betula protoermani ENDO
Carpinus stenophylla NATHORST
Carpinus subcordata NATHORST
Carpinus subyedoensis KONNO

Fagaceae

Fagus palaeocrenata OKUTSU
Fagus protojaponica K. SUZUKI

Ulmaceae

Celtis miobungeana HU and CHANEY
Celtis nordenskioldii NATHORST
Ulmus miopumila HU and CHANEY
Ulmus protojaponica TANAI and ONOE
Zelkova ungeri KOVATS

Polygonaceae

Polygonum megalophyllum new species
Rumex ezoensis new species

Cercidiphyllaceae

Cercidiphyllum crenatum (UNGER) BROWN

Magnoliaceae

Magnolia elliptica TANAI and ONOE

Lauraceae

Cinnamomum sp.

Hamamelidaceae

Hamamelis protojaponica new species
Liquidambar miosinica HU and CHANEY

Rosaceae

Crataegus sugiyamae HUZIOKA and NISHIDA
Prunus ishidai new species
Prunus protossiori TANAI and ONOE
Prunus rubeshibensis new species
Rubus sp.
Sorbus lanceolata new species
Sorbus protoalnifolia new species

Sorbus uzenensis HUZIOKA
Spiraea protothunbergi new species

Leguminosae
Cladrastis chaneyi new species
Gleditsia miosinensis HU and CHANEY
Wisteria fallax (NATHORST) TANAI and ONOE

Rutaceae
Phellodendron mioamurense TANAI and N. SUZUKI

Simaroubaceae
Ailanthus yezoense OISHI and HUZIOKA

Anacardiaceae
Rhus miosuccedanea HU and CHANEY
Rhus protoambigua K. SUZUKI

Aceraceae
Acer protojaponicum TANAI and ONOE
Acer pseudocarpinifolium ENDO
Acer subpictum SAPORTA
Acer yabei ENDO

Hippocastanaceae
Aesculus majus (NATHORST) TANAI

Rhamnaceae
Zizyphus miojujuba HU and CHANEY

Vitaceae
Vitis naumanni (NATHORST) TANAI

Theaceae
Stewartia okutsui TANAI

Araliaceae
Aralia subelata new species
Kalopanax acerifolius (NATHORST) HU and CHANEY

Cornaceae
Cornus subkousa TANI and ONOE

Clethraceae
Clethra maximowiczii NATHORST

Ericaceae
Rhododendron tatewakii new species

Ebenaceae
Diospyros sublotus new species

Oleaceae
Forsythia kitamiensis (OISHI and HUZIOKA) new combination
Fraxinus k-yamadai new species

Assumed Growth Habit

The size and habit of a plant are of importance in determining the number of its foliar and fruiting units which may be available for scattering and deposition in the sedimentary record. As a preliminary to considering the numerical representation of the Shanabuchi species, the author is listing in Table 2 their probable growth habit as judged from their most similar living equivalents.

The data in Table 2 show that 45 trees make up 64 per cent, 18 shrubs and small trees make up 26 per cent, 4 vines comprise 6 per cent, and 3 herbs 4 per cent. Judging from these percentage, trees were predominant in the Shanabuchi vegetation, like most Japanese Tertiary floras, but the ratio of trees to shrubs is somewhat lower than that of the Middle Miocene fioras of southwestern Hokkaido, which were recently reported by the senior author (TANAI, 1963).

Numerical Representation

The following quantative appraisal of the Shanabuchi flora is based on a count of 1000 specimens from one locality, as shown in Table 3. This count is not sufficiently large to preclude the possibility that certain species, especially the rare ones, may have been more numerous in the Shanabuchi forest than is suggested by these figures. They represent, however, the totals for each of several collections during the years of 1960 to 1961, and with respect to the dominant species their proportional representations have not greatly changed during several leaf counts in the field.

Of the 70 Shanabuchi plants, 19 are among the numerous, making up more than one per cent each, and combined to constitute nearly 84 per cent of the total. Excluding only one species, *Salix hokkaidoensis*, all of them are included in trees listed in Table 2. *Fagus protojaponica* is the most predominant species, making up 25 per cent of specimens counted. It is followed by *Cladrastis chaneyi*, *Ulmus protojaponica*, *Betula protoermani*, *Cercidiphyllum crenatum*, *Juglans japonica*, *Carpinus subcordata*, *Acer protojaponicum* and *Magnolia elliptica*, and these 8 species make up 41 per cent of the total specimens. The next 5 species, *Celtis miobugeana*, *Celtis nordenskioldii*, *Picea kaneharai*, *Salix parasachalinensis*, and *Salix hokkaidoensis*, make up nearly 11 per cent. Each of the remaining species comprises less than 2 per cent of the total; most of them are represented by only 0.4 per cent. With the exception of *Salix hokkaidoensis*, the 24 species listed in the category of shrubs, vines and herbs, reach a combined total of only 5 per cent. Although they are not as well suited for scattering their leaves and fruits as trees, it may be assumed that they must have been subordinate members of the Shanabuchi forest, or that they lived on forest borders at a distance. *Salix hokkaidoensis* has a higher frequency of leaf occurrence than those of other shrubs, making up 2 per cent of the total. As judged from the habitat of its living equivalent it was a riverside shrub, and it seems to have been well situated for shedding leaves in site of deposition.

It may be concluded that deciduous trees, notably beech, yellow-wood, elm, birch, katsura-tree, hornbeam, maple, walnut, willows and hackberries, were dominant members of the forest near the site of deposition; they are represented largely by heavy organs such as foliages. It is noteworthy that two conifers, *Picea kaneharai* and *Thuja nipponica*, show comparatively high percentages in their frequency. *Picea kaneharai* is represented only by winged seeds which could have been widely dispersed from its upland habitat. *Thuja nipponica*, represented only by foliage shoots, may be supposed to have occupied slopes not far distant from basin of deposition, and its

Table 2. Assumed Growth Habit of the Shanabuchi Plants.

Trees	
Abies protofirma	*Zelkova ungeri*
Picea kaneharai	*Cercidiphyllum crenatum*
Pinus sp.	*Magnolia elliptica*
Tsuga oblonga	*Cinnamomum* sp.
Taiwania japonica	*Liquidambar miosinica*
Thuja nipponica	*Prunus protossiori*
Populus kitamiana	*Sorbus protoalnifolia*
Populus kobayashii	*Cladrastis chaneyi*
Salix parasachalinensis	*Gleditsia miosinensis*
Juglans japonica	*Phellodendron mioamurense*
Pterocarya asymmetrosa	*Ailanthus yezoense*
Pterocarya protostenoptera	*Acer protojaponicum*
Alnus miojaponica	*Acer pseudocarpinifolium*
Alnus protohirsuta	*Acer subpictum*
Betula protoermani	*Acer yabei*
Carpinus stenophylla	*Aesculus majus*
Carpinus subcordata	*Stewartia okutsui*
Carpinus subyedoensis	*Kalopanax acerifolius*
Fagus palaeocrenata	*Cornus subkousa*
Fagus protojaponica	*Clethra maximowiczii*
Celtis miobungeana	*Diospyros sublotus*
Celtis nordenskioldii	*Fraxinus k-yamadai*
Ulmus protojaponica	
Small trees or shrubs	
Juniperus honshuensis	*Rubus* sp.
Salix hokkaidoensis	*Sorbus lanceolata*
Alnus protomaximowiczii	*Sorbus uzenensis*
Alnus subfirma	*Spiraea protothunbergi*
Ulmus miopumila	*Rhus miosuccedanea*
Hamamelis protojaponica	*Zizyphus miojujuba*
Crataegus sugiyamae	*Aralia subelata*
Prunus ishidai	*Rhododendron tatewakii*
Prunus rubeshibensis	*Forsythia kitamiensis*
Vines	
Smilax trinervis	*Rhus protoambigua*
Wisteria fallax	*Vitis naumanni*
Herbs	
Disporum ezoanum	*Rumex ezoensis*
Polygonum megalophyllum	

Table 3. Numerical Representation of the Shanabuchi Species.

Species	Number of specimens	Percentage
Fagus protojaponica (total)	254	25.4
(bracts)	(3)	
(leaves)	(251)	
Cladrastis chaneyi (leaflets)	73	7.3
Ulmus protojaponica (leaves)	71	7.1
Betula protoermani (leaves)	69	6.9
Cercidiphyllum crenatum (leaves)	56	5.6
Juglans japonica (leaflets)	52	5.2
Carpinus subcordata (leaves)	42	4.2
Acer protojaponicum (leaves)	35	3.5
Magnolia elliptica (leaves)	34	3.4
Celtis miobungeana (leaves)	22	2.2
Celtis nordenskioldii (leaves)	21	2.1
Picea kaneharai (winged seeds)	21	2.1
Salix parasachalinensis (leaves)	21	2.1
Salix hokkaidoensis (leaves)	20	2.0
Pterocarya asymmetrosa (total)	16	1.6
(winged seeds)	(4)	
(leaflets)	(12)	
Thuja nipponica (foliage shoots)	16	1.6
Kalopanax acerifolius (leaves)	15	1.5
Carpinus stenophylla (leaves)	13	1.3
Ailanthus yezoense (total)	11	1.1
(winged seeds)	(4)	
(leaflets)	(7)	
Carpinus subyedoensis (leaves)	9	0.9
Alnus protohirsuta (leaves)	7	0.7
Diospyros sublotus (leaves)	6	0.6
Phellodendron mioamurense (leaflets)	6	0.6
Abies protofirma (cone scales)	5	0.5
Zizyphus miojujuba (leaves)	5	0.5
Zelkova ungeri (leaves)	5	0.5
Rhododendron tatewakii (leaves)	5	0.5
Acer subpictum (total)	4	0.4
(samara)	(1)	
(leaves)	(3)	
Alnus miojaponica (leaves)	4	0.4
Clethra maximowiczii (leaves)	4	0.4
Populus kitamiana (leaves)	4	0.4
Prunus ishidai (leaves)	4	0.4
Prunus protossiori (leaves)	4	0.4
Wisteria fallax (leaflets)	4	0.4
Pterocarya protostenoptera (total)	4	0.4
(winged nut)	(1)	
(leaflets)	(3)	
Gleditsia miosinensis (leaflets)	3	0.3
Rhus protoambigua (leaflets)	3	0.3
Rumex ezoensis (leaves)	3	0.3
Ulmus miopumila (leaves)	3	0.3

Table 3—(*Continued*)

Species	Number of specimens	Percentage
Acer yabei (samaras)	3	0.3
Alnus protomaximowiczii (leaves)	3	0.3
Fagus palaeocrenata (leaves)	3	0.3
Acer pseudocarpinifolium (total)	2	0.2
(samara)	(1)	
(leaf)	(1)	
Alnus subfirma (leaves)	2	0.2
Forsythia kitamiensis (leaves)	2	0.2
Polygonum megalophyllum (leaves)	2	0.2
Populus kobayashii (leaves)	2	0.2
Smilax trinervis (leaves)	2	0.2
Sorbus uzenensis (leaflets)	2	0.2
Taiwania japonica (foliage shoots)	2	0.2
Tsuga oblonga (total)	2	0.2
(cone)	(1)	
(winged seed)	(1)	
Aesculus majus (leaflet)	1	0.1
Aralia subelata (leaflet)	1	0.1
Cinnamomum sp. (leaf)	1	0.1
Cornus subkousa (leaf)	1	0.1
Crataegus sugiyamae (leaf)	1	0.1
Disporum ezoanum (leaf)	1	0.1
Fraxinus k-yamadai (winged seed)	1	0.1
Hamamelis protojaponica (leaf)	1	0.1
Juniperus honshuensis (foliage shoot)	1	0.1
Liquidambar miosinica (leaf)	1	0.1
Pinus sp. (needled leaf)	1	0.1
Prunus rubeshibensis (leaf)	1	0.1
Rubus sp. (leaf)	1	0.1
Rhus miosuccedanea (leaflet)	1	0.1
Sorbus lanceolata (leaflet)	1	0.1
Sorbus protoalnifolia (leaf)	1	0.1
Spiraea protothunbergi (leaf)	1	0.1
Stewartia okutsui (capsule)	1	0.1
Vitis naumanni (leaf)	1	0.1
Total specimens	1000	100.0

shoots probably did not have far to travel. Other conifers are rare, and should probably be considered subordinate members or upland trees in the Shanabuchi forest.

PALEOECOLOGY

In attempting to reconstruct the environments occupied by Tertiary floras, it is necessary first to determine which modern communities show the closest relationships to them. Since most of the plants making up the Shanabuchi flora have similar species living in China and Japan, our attention will be turned largely to the modern forests of eastern Asia.

Distributional Considerations

The Shanabuchi flora consists mostly of temperate genera which are largely confined to middle latitudes. Although several Shanabuchi genera now live at low latitudes, none of them are confined to subtropical or tropical forests. Such angiosperms as *Cinnamomum*, *Clethra*, *Diospyros*, *Liquidambar*, and *Smilax* range well to the south, but they regularly extend into temperate latitudes and altitudes. *Zelkova* and *Ailanthus* are living in both temperate and subtropical forests in Asia. A conifer, *Taiwania*, lives in subtropical regions of southern China and Formosa, but it occupies high altitudes.

Table 4 shows the modern distribution of Shanabuchi genera in four regions of abundance: in Japan from Hokkaido to Kyushu; in East Asia, including mainly China proper and Formosa, but excluding Japan; in North America east of the Rocky Mountains; and in North America westward to the Pacific Coast. All of the 51 genera now live in East Asia, but 4 genera, *Ailanthus*, *Liquidambar*, *Taiwania*, and *Zizyphus*, are not native in Japan. It is noteworthy that the Shanabuchi flora has fewer such genera than the Middle Miocene floras of southwestern Hokkaido; the Yoshioka flora, with 51 genera, has 17 no longer living in Japan (TANAI, 1963, Table 4). Representation of Shanabuchi genera in the living forests of North America is lower than in those of Asia; and it is lower in western than in eastern America because of the summer-dry climate which has eliminated several broad-leafed deciduous members of the Tertiary forests there.

The Elements of the Shanabuchi Flora

In common with most Neogene floras from middle latitudes of the northern hemisphere, the Shanabuchi flora can be divided into three elements on the basis of the distribution of living plants which appear to be most closely related to its fossil species. Of these the East Asian Element is the largest, since 62 of the Shanabuchi species have their living equivalents in eastern Asia; not only do they make up 86 per cent of the total, but included in them are nearly 90 per cent of the specimens recorded. The East American Element, with only 8 species, and the West American Element with three, together include only about 10 per cent of the specimens recorded. This representation is in marked contrast to that of a well-known Neogene flora, the Mascall of Oregon, in which the East American Element makes up 64 per cent, the East Asian 49 per cent, and the West American 43 per cent. In both these Miocene floras the closest modern relationships are with plants which live in regions of summer rainfall. But already these summer-wet forest on the eastern sides of the two continents appear to have been well-differentiated so far as their species content was concerned; over 85 per cent of the Mascall specimens collected fall in species assigned to the East American Element, as compared to the 90 per cent above noted for the East

Table 4. Present-day Distribution of the Shanabuchi Genera.

Genus \ Region	East Asia		North America	
	Japan	China & Formosa	Western	Eastern
Abies	×	×	×	×
Picea	×	×	×	×
Pinus	×	×	×	×
Tsuga	×	×	×	×
Taiwania	...	×	...	...
Juniperus	×	×	×	×
Thuja	×	×	×	×
Disporum	×	×	×	×
Smilax	×	×	×	×
Populus	×	×	×	×
Salix	×	×	×	×
Juglans	×	×	×	×
Pterocarya	×	×	...	...
Alnus	×	×	×	×
Betula	×	×	×	×
Carpinus	×	×	...	×
Fagus	×	×	...	×
Celtis	×	×	×	×
Ulmus	×	×	...	×
Zalkova	×	×	...	...
Polygonum	×	×	×	×
Rumex	×	×	×	×
Cercidiphyllum	×	×	...	...
Magnolia	×	×	...	×
Cinnamomum	×	×	...	...
Hamamelis	×	×	...	×
Liquidambar	...	×	...	×
Crataegus	×	×	×	×
Prunus	×	×	×	×
Rubus	×	×	×	×
Sorbus	×	×	×	×
Spiraea	×	×	×	×
Cladrastis	×	×	...	×
Gleditsia	×	×	...	×
Wisteria	×	×	...	×
Phellodendron	×	×	...	...
Ailanthus	...	×	...	...
Rhus	×	×	×	×
Acer	×	×	×	×
Aesculus	×	×	×	×
Zizyphus	...	×	...	...
Vitis	×	×	×	×
Stewartia	×	×	...	×
Aralia	×	×	×	×
Kalopanax	×	×	...	...
Cornus	×	×	×	×
Clethra	×	×	...	×
Rhododendron	×	×	×	×
Diospyros	×	×	...	×
Forsythia	×	×	...	...
Fraxinus	×	×	×	×
Totals	47	51	29	41

Table 5. The Modern Equivalents of the Shanabuchi Plants and their Distribution in eastern Asia and North America.

Fossil species	Modern equivalent	East Asia													North Amer.	
			Japan					China								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Abies protofirma	*A. firma*			×	×	×	×									
Picea kaneharai	*P. polita*				×	×	×									
Pinus sp.	*P. densiflora*		×*	×	×	×	×									
Tsuga oblonga	*T. diversifolia*			×	×	×	×									
Taiwania japonica	*T. cryptomeroides*							×				×	×			
Juniperus honshuensis	*J. chinensis*			×	×	×	×									
Thuja nipponica	*T. standishii*			×	×		×		×							
Disporum ezoanum	*C. smilacinum*		×	×	×	×	×		×							
Smilax trinervis	*S. china*		×	×	×	×	×		×	×	×	×				
Populus kitamiana	*P. grandidentata*															×
Populus kobayashii	*P. tremuloides*														×	×
	(*P. sieboldi*)		(×)	(×)	(×)	(×)	(×)		(×)							
Salix hokkaidoensis	*S. koriyanagi*								×							
	(*S. gilgiana*)		(×)	(×)	(×)	(×)	(×)		(×)							
Salix parasachalinensis	*S. sachalinensis*	×	×	×	×	×										
Juglans japonica	*J. ailanthifolia*	×	×	×	×	×	×									
Pterocarya asymmetrosa	*P. rhoifolia*		×	×	×	×	×			×						
Pterocarya protostenoptera	*P. stenoptera*									×	×	×	×			
Alnus miojaponica	*A. japonica*		×	×	×	×	×		×					×		
Alnus protohirsuta	*A. hirsuta*	×	×	×	×	×	×							×		
Alnus protomaximowiczii	*A. maximowiczii*	×	×	×	×				×					×		
Alnus subfirma	*A. firma*			×	×	×	×									
Betula protoermani	*B. ermani*	×	×	×	×				×							
Carpinus stenophylla	*C. japonica*			×	×	×	×									
Carpinus subcordata	*C. cordata*		×	×	×	×	×		×	×	×			×		
Carpinus subyedoensis	*C. tschonoskii*			×	×	×	×		×		×					
Fagus palaeocrenata	*F. crenata*		×	×	×	×	×									
Fagus protojaponica	*F. japonica*			×	×	×	×									
Celtis miobungeana	*C. jessoensis*		×	×	×	×	×		×							

	(*C. bungeana*)										(×)					
Celtis nordenskioldii	*C. occidentalis*														×	×
Ulmus miopumila	*U. pumila*										×					
Ulmus protojaponica	*U. davidiana* var. *japonica*	×	×	×	×	×			×	×				×		
Zelkova ungeri	*Z. serrata*			×	×	×	×		×		×		×	×		
Polygonum megalophyllum	*P. sachalinensis*	×	×	×	×											
Rumex ezoensis	*R. longifolius*		×	×	×	×	×		×							
Cercidiphyllum crenatum	*C. japonicum*		×	×	×	×	×			×	×		×			
Magnolia elliptica	*M. liliflora*										×					
Cinnamomum sp.	*C. camphora*				×	×	×	×			×	×				
Hamamelis protojaponica	*H. japonica*		×	×	×	×	×									
Liquidambar miosinica	*L. formosana*							×			×	×	×			
Crataegus sugiyamae	*C. douglasii*														×	×
	(*C. maximowiczii*)	(×)	(×)						(×)							
Prunus ishidai	*P. nipponica*		×	×	×											
	(*P. apetala*)			(×)	(×)	(×)	(×)									
Prunus protossiori	*P. ssiori*	×	×	×	×									×		
Prunus rubeshibensis	*P. nigra*															×
	(*P. sargenti*)	(×)	(×)	(×)	(×)				(×)							
Rubus sp.	*R. crataegifolius*		×	×	×	×	×			×						
Sorbus lanceolata	*S. matsumurana*		×	×	×											
Sorbus protoalnifolia	*S. alnifolia*		×	×	×	×	×		×	×	×	×		×		
Sorbus uzenensis	*S. commixta*		×	×	×	×	×									
Spiraea protothunbergi	*S. thunbergi*										×					
Cladrastis chaneyi	*C. lutea*															×
	(*C. platycarpa*)				(×)	(×)	(×)				(×)		(×)			
Gleditsia miosinensis	*G. sinensis*									×	×					
	(*G. japonica*)			×	(×)	(×)	(×)									
Wisteria fallax	*W. floribunda*			×	×	×	×									
Phellodendron mioamurense	*P. amurense*		×	×	×	×	×		×	×			×			
Ailanthus yezoense	*A. altissima*			×	×	×	×			×	×	×	×			
Rhus miosuccedanea	*R. succedanea*			×	×	×	×	×			×	×	×			
Rhus protoambigua	*R. ambigua*	×	×	×	×	×	×			×	×					
Acer protojaponicum	*A. japonicum*		×	×	×	×	×									
Acer pseudocarpinifolium	*A. carpinifolium*			×	×	×	×									

Table 5—(*Continued*)

Fossil species	Modern equivalent	East Asia													North Amer.	
			Japan					China								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Acer subpictum	*A. mono*	×	×	×	×	×	×		×	×			×	×		
Acer yabei	*A. saccharium*															×
Aesculus majus	*A. turbinata*		×	×	×	×	×									
Zizyphus miojujuba	*Z. jujuba*							×	×	×	×	×	×			
Vitis naumanni	*V. coignetiae*		×	×	×	×	×									
Stewartia okutsui	*S. pseudo-camellia*			×	×	×	×									
Aralia subelata	*A. elata*	×	×	×	×	×	×		×					×		
Kalopanax acerifolius	*K. septemlobus*	×	×	×	×	×	×		×	×	×	×	×	×		
Cornus subkousa	*C. kousa*			×	×	×	×		×	×	×					
Clethra maximowiczii	*C. barbinervis*		×	×	×	×	×		×		×	×	×			
Rhododendron tatewakii	*R. albrechtii*		×	×	×											
Diospyros sublotus	*D. lotus*								×				×			
Forsythia kitamiensis	*F. suspensa*									×	×		×			
Fraxinus k-yamadai	*F. americana*															×
Nearest species		12	35	48	49	42	41	5	22	18	20	12	13	11	3	8
Closely similar but not nearest species		(2)	(4)	(4)	(6)	(5)	(5)	(0)	(4)	(0)	(2)	(0)	(1)	(0)	(0)	(0)

MODERN DISTRIBUTION

1. Saghalien and Kurile Islands.
2. Hokkaido, Japan.
3. Northeastern Honshu, Japan.
4. Central Honshu, Japan.
5. Southern Honshu, Japan.
6. Kyushu and Shikoku, Japan.
7. Formosa and Loochoo Islands.
8. Korea, including Quelpart Island.
9. Northern China including Shantung Province.
10. Central China.
11. Southeastern China.
12. Southwestern China.
13. Manchuria.
14. Western North America.
15. Eastern North America.

* Hokkaido species with an asterik are confined to the southwestern part of the island.

Asian Element of the Shanabuchi.

Table 5 shows the nearest living equivalents of the Shanabuchi plants and their modern distribution. In some cases a second living species is included in parenthesis, to show somewhat less close similarity in another geographic area. Eastern Asia has been classified in various way with respect to phytogeographic divisions. For simplicity the author is designating only 5 regions each in Japan and China, with columns also for Saghalien, Korea and Formosa; all of these fall into the East Asian Element. In addition there are columns for the West American Element and the East American Element, as indicated at the bottom of Table 5.

The East Asian Element

No effort has yet been made to classify the various parts of the East Asian Element into components, in the way that CHANEY has set up these subdivisions for the East American, the West American, and other elements represented in the Tertiary floras of North America (CHANEY, 1944, p. 9). The author has presented a large body of distributional material regarding the species of the Daijima-type and Aniai-type floras which will provide a basis for defining some of the components of these and other Neogene floras of Japan. In this paper the author designates for convenience' sake a Central and Northern Honshu Component, and Central China Upland Component, to include those portions of the Shanabuchi flora which are most abundantly represented by living related species in the modern forests of Japan and China. These components, here only tentatively set up, include much of what CHANEY has designated as the Northern temperate highland Component in his subdivisions of the Asiastic Element.

The Central and Northern Honshu Component

When one turns to the detailed distribution of the species of conifers and angiosperms which represent the nearest living equivalents of the Shanabuchi plants, it is readily apparent that most of them are concentrated in Japan from central to northern Honshu, where typically temperate forests show luxuriant growth at middle elevations. Over 78 per cent of the Shanabuchi species are represented by closely similar living species in this region. Southward and northward there is a gradual reduction in the number of living species which show this close relationship to the Shanabuchi plants.

The abundance of *Fagus protojaponica* in the fossil record turns our attention first to the deciduous broad-leafed forests of northern Kwanto and central Honshu. These forests have been divided into communities by HONDA (1928), NAKANO (1942), TAKAHASHI (1948), and HARA (1959). HARA (1959, pp. 44-45) has designated the forests of central Honshu as the *Castanea* zone from 600-700 meters up to 1200-1300 meters and as the *Fagus* zone from 1200-1300 meters up to 1500-1700 meters. In the upper zone,

Table 6. Slope Plants of Honshu and Shanabuchi Equivalents.

Shanabuchi flora	Slope forest, Mt. Ontake (600-1300 m.)	Slope forest, Chichibu Mountains. (800-1400 m.)	Sadankyo ravine forest, Hiroshima Prefecture. (500-930 m.)	Oirase ravine forest, Towada National Park. (240-360 m.)
Tsuga oblonga	**T. sieboldii*	**T sieboldii*	*T. sieboldii*	....
Pinus sp.	*P. densiflora*	....	*P. densiflora*	....
Disporum ezoanum	*D. smilacinum*	*D. smilacinum*	*D. smilacinum*	**D. sessile*
Smilax trinervis	*S. china*	*S. china*	*S. china*	....
Populus kobayashii	*P. sieboldii*	....	....	**P. maximowiczii*
Salix parasachalinensis	....	....	....	*S. sachalinensis*
Juglans nipponica	*J. ailanthifolia*	*J. ailanthifolia*	....	....
Pterocarya asymmetrosa	*P. rhoifolia*	*P. rhoifolia*	*P. rhoifolia*	*P. rhoifolia*
Alnus protohirsuta	....	(*A. firma*)	....	**A. pendula*
Alnus subfirma	*A. hirsuta* var.	*A. hirsuta* var.	....	*A. hirsuta* var.
Carpinus stenophylla	*C. carpinoides*	*C. carpinoides*	*C. carpinoides*	*C. carpinoides*
Carpinus subcordata	*C. cordata*	*C. cordata*	*C. cordata*	*C. cordata*
Carpinus subyedoensis	*C. tschonoskii*	*C. tschonoskii*	*C. tschonoskii*	....
Fagus palaeocrenata	*F. crenata*	*F. crenata*	*F. crenata*	*F. crenata*
Fagus protojaponica	*F. japonica*	*F. japonica*	*F. japonica*	....
Celtis miobungeana	**C. sinensis* var.	**C. sinensis* var.	**C. sinensis* var.	....
Ulmus protojaponica	....	*U. davidiana* var.	....	*U. davidiana* var.
Zelkova ungeri	*Z. serrata*	*Z. serrata*	*Z. serrata*	*Z. serrata*
Polygonum megalophyllum	....	....	**P. falcatum*	....
Cercidiphyllum crenatum	*C. japonicum*	*C. japonicum*	*C. japonicum*	*C. japonicum*
Magnolia elliptica	....	**M. kobus*	**M. salicifolia*	**M. kobus*
Hamamelis protojaponica	*H. japonica*	*H. japonica*	*H. japonica*	....
Prunus protossiori	*P. ssiori*	*P. ssiori*	....	....
Prunus rubeshibensis	*P. sargentii*	*P. sargentii*	....	....
Rubus sp.	*Rubus* sp.	**R. wrightii*	**P. palmatus*	....
Sorbus protoalnifolia	*S. alnifolia*	*S. alnifolia*	*S. alnifolia*	*S. alnifolia*
Sorbus uzenensis	....	....	*S. commixta*	....
Wisteria fallax	*W. floribunda*	*W. floribunda*	*W. floribunda*	....
Phellodendron mioamurense	....	*P. amurense*	*P. amurense*	....
Rhus miosuccedanea	**R. silvestris*	....	**R. silvestris*	....
Rhus protoambigua	*R. ambigua*	*R. ambigua*	*R. ambigua*	*R. ambigua*

Acer protojaponicum	*A. japonicum*	*A. japonicum*	*A. japonicum*	*A. japonicum*
Acer pseudocarpinifolium	*A. carpinifolium*	*A. carpinifolium*	*A. carpinifolium*	…………
Acer subpictum	*A. mono*	*A. mono*	*A. mono*	*A. mono*
Aesculus majus	*A. turbinata*	*A. turbinata*	*A. turbinata*	*A. turbinata*
Vitis naumanni	…………	…………	…………	*V. coignetiae*
Stewartia okutsui	*S. pseudo-camellia*	*S. pseudo-camellia*	*S. pseudo-camellia*	…………
Aralia subelata	*A. elata*	…………	*A. elata*	…………
Kalopanax acerifolius	*K. septemlobus*	…………	*K. septemlobus*	*K. septemlobus*
Cornus subkousa	*C. kousa*	**C. controversa*	*C. kousa*	…………
Clethra maximowiczii	*C. barbinervis*	*C. barbinervis*	*C. barbinervis*	…………
Fraxinus k-yamadai	**F. sieboldiana*	**F. sieboldiana* var.	**F. sieboldiana* var.	**F. sieboldiana* var.
42 species in 34 genera	34 species in 28 genera	21 species in 18 genera	33 species in 26 genera	33 species in 25 genera

* The most similar species found here.

Fagus crenata is, in general, predominant, accompanied by other deciduous trees such as *Acanthopanax sciadophylloides, Acer carpinifolium, A. diabolicum, A. micranthum, Acer mono, A. rufinerve, Aesculus turbinata, Betula grossa, Carpinus carpinoides, C. cordata, Cercidiphyllum japonicum, Fagus japonica, Hydrangea hirda, H. paniculata, Ilex geniculata, Kalopanax septemlobus, Magnolia obovata, Prunus ssiori, Pterocarya rhoifolia, Quercus crispula, Sorbus alnifolia, Tilia japonica, Ulmus laciniata,* and *Viburnum furcatum.* Associated conifers are *Chamaecyparis obtusa, Pinus parviflora,* and *Thuja standishii.* Among the above-noted trees, *Fagus japonica,* which is the nearest equivalent of *F. protojaponica,* is dominant in the lower zone, especially in its upper part; *F. crenata* is more numerous at higher altitudes. In the lower zone, *Castanea crenata, Fagus japonica, Quercus serrata* grow luxuriantly, accompanied by *Acer mayrii, Acer mono, Aesculus turbinata, Alnus hirsutu* var. *sibirica, Carpinus laxiflora, Cercidiphyllum japonicum, Kalopanax septemlobus, Magnolia obovata, Pterocarya rhoifolia,* and *Zelkova serrata.* Many of the Shanabuchi species have living equivalents in this zone, but the absence of chestnuts and deciduous oaks from the fossil record is noteworthy. The vegetation on Mt. Ontake, as investigated by KOIDZUMI (1914), TAKAHASHI (1943) and TATEWAKI (1954) shows well developed broad-leafed deciduous forests; Shanabuchi species find their closest equivalents on the slope forests at elevations of 600-1400 meters, as shown in Table 6.

The Kwanto district has been extensively cultivated and disturbed by man. The vegetation covering the wide Kwanto Plain around Tokyo and the adjacent hills is secondary forest belonging to the *Castanea* zone. It consists mainly of *Acer crataegifolium, Alnus hirsuta* var., *A. japonica, Broussonetia kazinoki* var., *Carpinus laxiflora, C. tchonoskii, Castanea crenata, Celtis sinensis* var., *Euonymus alatus, Fraxinus sieboldiana, Lonicera japonica, Magnolia kobus, Mallotus japonica, Quercus acutissima, Q. serrata, Rhododendron* spp. *Rubus wrightii, Styrax japonica, Wisteria floribunda, Zelkova serrata.* Many of the Shanabuchi plants have related modern species in the *Castanea* zone, especially at its upper levels, and in the lower half of the beech zone. In mountain districts of the Kwanto region, the *Castanea* zone gradually passes into the *Fagus* zone at elevation between 800-1200 meters. The forest of the *Fagus* zone consists principally of *Acer carpinifolium, A. micranthum, A mono, A. palmatum, A. rufinerve, Actinidia arguta, Betula grossa, Carpinus carpinoides, C. cordata, Cericidiphyllum japonicum, Corylus sieboldiana, Fagus crenata, F. japonica, Fraxinus lanuginosa* var., *Hydrangea paniculata, Ilex geniculata, Juglans ailanthifolia, Magnolia obovata, Prunus apetala, P. grayana, P. sargentii, P. ssiori, Quercus mongolica* var., *Rhamnus costata, Rhododendron quinquefolium, Rhus ambigua, Sorbus alnifolia, S. japonica, Syringa reticulata, Tilia japonica, Ulmus davidiana* var., *U. laciniata,* and *Viburnum furcatum.* A natural forest of this kind is also found on the slopes of the Chichibu mountains, northwestern Kwanto, as investigated by MAEDA and YOSHIOKA (1952).

When we turn our attention to the *Castanea* zone in western Honshu, we find living vegetation still more similar to the Shanabuchi flora. In the Chugoku mountain range, at elevations above 600-700 meters, the dominant trees are *Quercus crispula* and *Fagus crenata.* In the lower zone of this forest there are many broad-leafed deciduous trees such as *Acer carpinifolium, A. palamatum* var., *A. rufinerve, Aesculus turbinata, Betula grossa, Castanea crenata, Carpinus carpinoides, C. cordata, C. laxiflora, Cercidiphyllum japonicum, Platycarya strobilacea, Pterocarya rhoifolia, Quercus acutissima, Q. mongolica, Q. serrata, Stewartia pseudocamellia* and *Zelkova serrata.*

This typical forest below the beech zone has been described by HORIKAWA and SASAKI (1959) in the district at the Sandankyo Gorge, southwestern Hiroshima Prefecture. On the river borders and alluvial fans (500 to 900 meters elevation) the deciduous forest has many related species of the Shanabuchi plants as shown in Table 6, and it also has many southern trees which are included in the Shanabuchi flora.

In northern Honshu, another extensively cultivated region, the deciduous forest of the *Castanea* zone covers hills below 100-200 meters elevation at the south and below the *Fagus* zone. It includes *Acer palmatum* var., *Castanea crenata, Corylus sieboldiana, Fagus japonica, Quercus dentata, Q. mongolica* var., *Quercus serrata, Viburnum dilatatum, Wisteria floribunda,* and *Zalkova serrata.* Along the valleys in the lower part of the *Fagus* zone, the deciduous forest is made up of *Alnus hirsuta* var., *Aesculus turbinata, Carpinus cordata, Cercidiphyllum japonicum, Populus maximowiczii, Pterocarya rhoifolia, Quercus mongolica* var., and *Rhus ambigua.* This typical natural forest ranges up the slopes of Mt. Hakkoda and its neighbors as already pointed out

Table 7. Plants of the Mixed and Subalpine Forests of Central and Northern Honshu, and Shanabuchi Equivalents.

Shanabuchi flora	Mt. Hakkoda	Ozegahara and its surrounding mountains	Mt. Hotaka	Mt. Ontake
Picea kaneharai	....	**P. jessoensis*	*P. polita*	*P. polita*
Tsuga oblonga	*T. diversifolia*	*T. diversifolia*	*T. diversifolia*	*T. diversifolia*
Juniperus honshuensis	*J. chinensis*	*J. chinensis* var.	....	*J. chinensis* var.
Thuja nipponica	....	*T. standishii*	*T. standishii*	*T. standishii*
Disporum ezoanum	*D. smilicinum*	*D. smilacinum*	....	....
Salix parasachalinensis	*S. sachalinensis*	*S. sachalinensis*	....	....
Pterocarya asymmetrosa	....	*P. rhoifolia*	*P. rhoifolia*	*P. rhoifolia*
Alnus protohirsuta	....	*A. hirsuta*	*A. hirsuta*	*A. hirsuta*
Alnus protomaximowiczii	*A. maximowiczii*	*A. maximowiczii*	*A. maximowiczii*	*A. maximowiczii*
Betula protoermani	*B. ermani*	*B. ermani*	*B. ermani*	*B. ermani*
Fagus palaeocrenata	*F. crenata*	*F. crenata*	....	*F. crenata*
Ulmus protojaponica	....	*U. davidiana* var.	*U. davidiana* var.	*U. davidiana* var.
Polygonum megalophyllum	*P. sachalinensis*	*P. sachalinensis*	**P. cuspidatum*	....
Cercidiphyllum crenatum	....	*C. japonicum*	*C. japonicum*	*C. japonicum*
Hamamelis protojaponica	....	*H. japonica*	....	....
Prunus ishidai	....	*P. nipponica*	*P. nipponica*	*P. nipponica*
Prunus protossiori	....	*P. ssiori*	....	*P. ssiori*
Sorbus uzenensis	*S. commixta*	*S. commixta*	*S. commixta*	*S. commixta*
Sorbus lanceolata	....	....	*S. matsumurana*	*S. matsumurana*
Phellodendron mioamurense	....	*P. amurense*	....	....
Rhus protoambigua	*R. ambigua*	*R. ambigua*	....	*R. ambigua*
Acer protojaponicum	*A. japonicum*	*A. japonicum*	....	*A. japonicum*
Acer subpictum	*A. mono*	*A. mono*	*A. mono*	*A. mono*
Aesculus majus	....	*A. turbinata*	*A. turbinata*	*A. turbinata*
Vitis naumanni	*V. coignetiae*	*V. coignetiae*	....	*V. coignetiae*
Aralia subelata	*A. elata*	*A. elata*	....	....
Kalopanax acerifolius	....	*K. pictus*	....	*K. pictus*
Clethra maximowiczii	....	*C. barbinervis*	*C. barbinervis*	*C. barbinervis*
Rhododendron tatewakii	....	*R. albrechtii*	*R. albrechtii*	....
23 species in 25 genera	14 species in 13 genera	28 species in 24 genera	17 species in 14 genera	22 species in 17 genera

* The most similar species found here.

by many botanists. The forest along the Oirase river in Towada National Park has been described in detail by TATEWAKI et al. (1961). The Shanabuchi flora has equivalent living species here, but they are less numerous than in other regions of Honshu cited in Table 6. The floral lists in this table demonstrate the similarity of the Shanabuchi flora to the slope forests of central Honshu and the northern Kwanto region.

In central and northern Honshu, vegetation above the beech zone is subalpine in character, a mixed forest of conifers and deciduous trees occurring from altitudes of 1500-1800 up to 2200-2600 meters in central Honshu, and from 1000-1400 up to 1700-2200 meters in northern Honshu. In central Honshu it consists mainly of *Abies homolepsis, A. mariesii, A. veitchii, Larix leptolepis, Picea bicolor, P. jessoensis* var. *hondoensis, P. polita, Pinus parviflora, Tsuga diversifolia,* and *Thuja standishii,* associated with *Alnus matsumurae, Betula corylifolia, Cercidiphyllum magnificum, Ilex rugosa, Populus maximowiczii* and *Viburnum furcatum.* At higher levels associated with the above-noted conifers, a shrubby forest of *Acer ukurunduense, Alnus maximowiczii, Betula ermani, Lonicera brandtii, Prunus nipponica* and *Sorbus matsumurana* is generally present. Table 7 shows the relationships of the Shanabuchi flora to this mixed, subalpine forest at four localities in Honshu: on the slopes (800 to 1450 meters elevation) of Mt. Hakkoda, northern Honshu (HORIKAWA, 1930; YOSHIOKA, 1938); on the Ozegahara moor (about 1500 meters elevation) and the slopes of its surrounding mountains, up to 2200 meters elevation, northern Kwanto region (HARA, 1954; SUZUKI, T., 1954; HORIKAWA and SASAKI, 1954); on slopes (1500 to 2200 meters elevation) of Mt. Hotaka, central Honshu (NAKAI, 1928); and on slopes (1700 to 2600 meters elevation) of Mt. Ontake, central Honshu (KOIDZUMI, 1914; TAKAHASHI, 1943). Twenty-nine of the Shanabuchi species have living equivalents in these upland forests; more than half of them also range up into montane levels.

The Shanabuchi equivalents of such montane species as *Alnus maximowiczii* (*A. protomaximowiczii*), *Betula ermani* (*B. protoermani*), *Juniperus chinensis* (*J. honshuensis*), *Picea polita* (*P. kaneharai*), *Prunus nipponica* (*P. ishidai*), *Rhododendron albrechtii* (*R. tatewakii*), and *Sorbus matsumurana* (*S. lanceolata*) are, with one exception, sparsely represented in the fossil record, and may be supposed to have lived in the mountains, at some distance from the Shanabuchi sites of deposition. The abundance of this exception, *Betula protoermani,* in the fossil record is difficult to explain in terms of the distribution of its living equivalent, which has its most common occurrence at high altitudes.

From this discussion of the distribution in Japan of modern trees and shrubs which resemble the Shanabuchi species, and which may be supposed to have occupied similar environments, it may be concluded that the Central and Northern Honshu Component makes up a significant part of the Shanabuchi flora, both in number of species and in specimens recorded. The modern forests which show greatest similarity occupy valleys and slopes in central Honshu and northern Kwanto. The montane forests of these regions have relatively low representation in the fossil record.

The Central China Upland Component

As discussed above, the temperate forest of Honshu is closely similar in its composition and components to the Shanabuchi vegetation, but several genera are unrepresented, such as *Ailanthus*, *Liquidambar*, *Taiwania*, and *Zizyphus* as shown in Table 4. These four genera have survived in the slope forests of central China,

Table 8. Living Equivalents in the Uplands of Central China.

Shanabuchi flora	Mountains of Central China
Pinus sp.	*P. massoniana*
Thuja nipponica	*T. sutchuensis*
Smilax trinervis	*S. china*
Populus kobayashii	*P. adenopoda*
Populus kitamiana	*P. tremula* var. *davidiana*
Pterocarya asymmetrosa	**P. paliurus*
Alnus protomaximowiczii	*A. lanata*
Betula protoermani	**B. luminifera*
Carpinus subcordata	*C. cordata*
Carpinus subyedoensis	*C. tchonoskii*
Fagus palaeocrenata	*F. longipetiolata*
Fagus protojaponica	*F. engleriana*
Celtis miobungeana	**C. bungeana*
Ulmus miopumila	*U. pumila*
Ulmus protojaponica	**U. wilsoniana*
Zelkova ungeri	*Z. serrata*
Cercidiphyllum crenatum	*C. japonicum* var. *sinicum*
Magnolia elliptica	*M. liliflora*
Cinnamomum sp.	*C. pedunculata*
Hamamelis protojaponica	*H. mollis*
Liquidambar miosinica	*L. formosana*
Prunus ishidai; *P. rubeshibensis*	*P.* spp.
Rubus sp.	*R. setchuenensis*
Sorbus protoalnifolia	*S. alnifolia*
Cladrastis chaneyi	*C. wilsonii*
Gleditsia miosinensis	*G. sinensis*
Ailanthus yezoense	*A. altissima*
Acer pseudocarpinifolium	*A. davidii*
Acer subpictum	*A. mono*
Acer protojaponicum	*A. flabellatum*
Aesculus majus	*A. wilsonii*
Vitis naumanni	**V. sinensis*
Stewartia okutsui	*S. sinensis*
Aralia subelata	*A. elata*
Kalopanax acerifolius	*A. septemlobus*
Clethra maximowiczii	*C. barbinervis*
Diospyros sublotus	*D. lotus*
Forsythia kitamiensis	*F. suspensa*

* The most similar species found here.

where all of the arborescent genera of the Shanabuchi flora are represented, where there are many species similar to our fossils. Unfortunately the writer has little detailed knowledge of the deciduous broad-leafed forests of China, and have had to depend mainly on YOUNG's Illustrated Manual of Chinese trees and shrubs (1957).

A forest at Shui-hsa-pa in central China has been discussed with reference to its Tertiary relationships by CHANEY (1948, 1952, 1959), and has been more fully studied by CHU and COOPER (1950), who have greatly extended our knowledge of the vegetation in which *Metasequoia* has survived. There are doubtless forests in adjacent areas which might also be compared to the Shanabuchi flora, in which *Metasequoia* is not represented. The *Metasequoia* forest of the Shui-hsa-pa district in western Hupeh contains the following species closely similar to Shanabucni plants (fossil species in parenthesis): *Acer davidii* (*A. pseudocarpinifolium*), *Ailanthus altissima* (*A. yezoense*), *Betula luminifera* (*B. mioluminifera*), *Carpinus fargesiana* (*C. subyedo-*

Table 9. Eastern North American Plants and Shanabuchi Equivalents.

Shanabuchi Flora	Appalachian Mountain region	Southern Atlantic Coastal Plain
Pinus sp.	*P. echinata*	....
Tsuga oblonga	*T. canadensis*	....
Juniperus honshuensis	*J. virginiana*	*J. virginiana*
Thuja nipponica	*T. occidentalis*	....
Salix parasachalinensis	**S. nigra*	**S. nigra*
Salix hokkaidoensis	**S. fluviatilis*	....
Populus kobayashii	*P. tremuloides*	*P. heterophylla*
Populus kitamiana	*P. grandidentata*	....
Juglans japonica	*J. nigra*	....
Alnus protomaximowiczii	*A. rugosa*	*A. rugosa*
Betula protoermani	*B. lutea*	**B. nigra*
Fagus protojaponica	*F. grandifolia*	*F. grandifolia*
Celtis nordenskioldii	*C. occidentalis*	*C. occidentalis*
Ulmus protojaponica	*U. americana*	*U. americana*
Ulmus miopumila	....	*U. crassifolia*
Magnolia elliptica	*M. acuminata*	*M. acuminata*
Hamamelis protojaponica	*H. virginiana*	*H. virginiana*
Liquidambar miosinica	*L. straciflua*	*L. styraciflua*
Crataegus sugiyamae	*C. holmesiana*	....
Prunus rubeshibensis	*P. nigra*	....
Sorbus uzenensis	*S. americana*	....
Cladrastis chaneyi	*C. lutea*	....
Gleditsia miosinensis	*G. triancanthus*	....
Rhus miosuccedanea	**R. vernix*	....
Acer yabei	*A. saccharinum*	*A. saccharinum*
Aesculus majus	*A. octandra*	....
Cornus subkousa	*C. florida*	*C. florida*
Diospyros sublotus	*D. virginiana*	*D. virginiana*
Fraxinus k-yamadai	*F. americana*	*F. americana*

* The most similar species found here.

ensis), *Celtis labilia* (*C. miobungeana*), *Cercidiphyllum japonicum* var. *sinicum* (*C. crenatum*), *Fagus longipetiolata* (*F. palaeocrenata*), *Kalopanax septemlobus* (*K. acerifolius*), *Liquidambar formosana* (*L. miosinica*), *Populus adenopoda* (*P. kobayashii*), *Pterocarya paliurus* (*P. asymmetrosa*), *Rubus setchuenensis* (*Rubus* sp.), and *Salix wilsonii* (*S. parasachalinensis*). Comparison between the upland forests of western Hupeh and Szechuan provinces and the Shanabuchi floras shows a close resemblance to their slope and upland members, as shown in Table 8. Many of the trees listed range down into the lowlands, such as *Celtis bungeana*, *Cinnamomum pedunculata*, *Diospyros lotus*, *Liquidambar formosana*, *Pinus massoniana*, *Smilax china*, and *Zelkova serrata*, but none of the typically lowland trees has an equivalent in the Shanabuchi flora. *Pterocarya stenoptera*, which is closely similar to the Shanabuchi species, lives usually on river borders in central and southern China, but also inhabits dry slopes.

The montane conifers of the Shanabuchi flora, represented largely by winged seeds and cone scales, are *Picea kaneharai* (*P. neovetichii*), *Tsuga oblonga* (*T. yunnanensis*), and *Taiwania japonica* (*T. cryptomeroides*). *Picea neoveitchii* inhabits the highlands at 1800 to 2000 meters elevation in Shansi, Shensi and Hupeh provinces. *Tsuga yunnanensis* lives on the mountains at altitudes of 2000-3500 meters in Yunnan and southwestern Szechuan provinces. *Taiwania cryptomeroides* occupies elevations at 1800 to 2600 meters in the central mountain range of Formosa, and also lives in the uplands of Yunnan and Fukien provinces in southern China. *Picea kanehraai*, represented only by winged seeds, is one of the common members in the Shanabuchi flora, having representation of 2 per cent; the other conifers are rare. It seems apparent that specimens of these montane species came from trees living at so great a distance from the site of deposition that few organs other than winged seed were carried down to the sites of deposition.

North American Relationships

The plants assigned to the North American Elements in Table 5 include 8 dicotyledons which make up about 10 per cent of the total fossil record. There are additional species which show suggestive relationships to the Shanabuchi plants. Table 9 indicates the resemblance of 29 Shanabuchi species to members of the modern forests in the Appalachian Mountains and in the southern Atlantic Coastal Plain. Sixteen similar species are distributed from the Appalachian region sowthward along the Atlantic Coastal Plain, and some of them are chracteristic members of the swamp cypress forests and its borders. These include *Diospyros virginiana*, *Liquidambar styraciflua* and *Salix nigra*; however, the Shanabuchi flora contains no remains of *Taxodium*, lobed oaks, or *Nyssa*. Thirteen similar species extend northward into Canada from the Appalachian region; they include *Betula lutea*, *Celtis occidentalis*, *Fraxinus americana*, *Populus tremuloides*, *Prunus nigra*, *Sorbus americana*, *Thuja occidentalis* and *Tsuga canadensis*, most of which are common members of the slope forest. *Crataegus holmesiana, Cladrastis lutea, Gleditsia triacanthus,* and *Aesculus octandra* are distributed from the Appalachians westward into Interior.

The Shanabuchi flora contains only a few assigned to the West American Element, and they are poorly represented by specimens in our collections. *Abies concolor* (*A. protofirma*), *Alnus tenuifolia* (*A. protohirsuta*), *Celtis occidentalis* (*C. nordenskioldii*), *Crataegus douglasii* (*C. sugiyamae*), *Populus tremuloides* (*P. kobayashii*), *Salix fluviatilis* (*S. hokkaidoensis*), all occupy the Pacific slope of North America.

Comparison of the Shanabuchi flora with forests living in North America appears to indicate that it is more similar to the vegetation of the Appalachian Mountain slope than to that of the lowlands of the southern Atlantic Coastal Plain. This conclusion is similar to those involving comparison with the forest of eastern Asia, in which slope forest resemblance are most pronounced.

The Shanabuchi Plant Associations

The areas and environments described in the preceding pages are occupied by modern forests which show marked resemblance to the Shanabuchi flora; most similar is the forest covering mainly the Lower beech zone of Honshu, Japan; the mountain slope forest of Szechuan and Hupeh provinces in China also has much in common; resemblance to the forest of the Appalachian region in eastern North America involves fewer species. No one of these forests contain all the trees and shrubs that lived in northeastern Hokkaido during Late Miocene time, for the plant associations of the Upper Tertiary in Japan were more diverse than those now living in the northern hemisphere. The habitats occupied by modern equivalents of the Shanabuchi plants provide the most reliable evidence for estimates of physical conditions during Late Miocene time. Combining the evidence derived from the distribution of its modern equivalents in East Asia and North America, and the frequency records of its members, the Shanabuchi flora may be further subdivided as shown in the following lists.

1) Abundant fossil species with living equivalents on slopes

Species	Per cent of specimens collected	Organs represented
Fagus protojaponica	25.4	Largely leaves
Cladrastis chaneyi	7.3	Leaflets only
Ulmus protojaponica	7.1	Leaves only
Betula protermani	6.9	Leaves only

Excluding *Betula protoermani*, all three of these species are represented by living equivalents which are of typical slope habitat in the deciduous broad-leafed forests, though not all of them are found in slope forests at the same latitudes. Their abundance in the fossil record, and their representation by heavy organs such as foliage and, in the case of *Fagus protojaponica*, heavy bracts, is interpreted as indicating that they lived on adjacent slopes near sites of deposition. *Ulmus davidiana* var. *japonica*, similar to *U. protojaponica*, occupies most lowlands in Hokkaido, but grows on slopes and in montane areas of northern and central Honshu. *Betula ermani*, the living equivalent of *B. protoermani*, is one of the typical species of the subalpine forest of Japan, and ranges down into the upper part of the *Fagus* zone, mixed with beech and other many deciduous broad-leafed trees. This abundance and representation by such heavy organs as leaves suggest that *B. protoermani* was mainly a member of the slope rather than of montane forest, although its living equivanlent is subalpine.

2) Common fossil species with living equivalents on slopes

Species	Per cent	Organs represented
Cercidiphyllum crenatum	5.6	Leaves only
Juglans japonica	5.2	Leaflets only
Carpinus subcordata	4.2	Leaves only
Acer protojaponicum	3.5	Leaves only
Magnolia elliptica	3.4	Leaves only
Celtis miobungeana	2.2	Leaves only
Celtis nordenskioldii	2.1	Leaves only
Picea kaneharai	2.1	Winged seeds only
Salix parasachalinensis	2.1	Leaves only
Salix hokkaidoensis	2.0	Leaves only
Thuja nipponica	1.6	Foliage shoots only
Pterocarya asymmetrosa	1.6	Leaflets and winged nuts
Kalopanax acerifolius	1.5	Leaves only
Carpinus stenophylla	1.3	Leaves only
Ailanthus yezoense	1.1	Leaflets and winged seeds

The common occurrence of these 15 species, the predominance of heavy organs in the record of most of them, and the typical slope habitat of their living equivalents, all suggest that they lived on valley slopes adjacent to sites of deposition. Two species, *Cercidiphyllum crenatum* and *Acer protojaponicum*, may have had wide distribution from lower slopes to montane areas, judging from the habitats of their living equivalents. Two conifers, *Picea kaneharai* and *Thuja nipponica*, seem to have ranged from upper slopes to mountains.

3) Uncommon fossil species with living equivalents on slopes

Species	Per cent	Organs represented
Carpinus subyedoensis	0.9	Leaves only
Alnus protohirsuta	0.7	Leaves only
Diospyros sublotus	0.6	Leaves only
Phellodendron mioamurense	0.6	Leaflets only
Abies protofirma	0.5	Cone scales only

Zizyphus miojujuba	0.5	Leaves only
Zelkova ungeri	0.5	Leaves only
Acer subpictum	0.4	Leaves and winged seeds
Alnus miojaponica	0.4	Leaves only
Clethra maximowiczii	0.4	Leaves only
Populus kitamiana	0.4	Leaves only
Wisteria fallax	0.4	Leaflets only
Acer yabei	0.3	Winged seeds only
Gleditsia miosinensis	0.3	Leaflets only
Rumex ezoensis	0.3	Leaves only
Ulmus miopumila	0.3	Leaves only

With a few exceptions, all the species of this group have modern equivalents which are common on slopes; their small representation suggests that they were not common members of the Shanabuchi forest. *Abies protofirma* is closely similar to the modern *A. firma*, which ranges from lowlands to slopes in Honshu, Shikoku, and Kyushu, associated with broad-leafed trees; its small percentage and its representation only by cone scales may indicate that it was restricted to upper slopes. *Zelkova ungeri*, one of the most common species in the Neogene of Eurasia, is recorded by only 5 leaves. Its living equivalent, *Z. serrata*, ranges from lowlands to lower slopes in Honshu; *Z. ungeri* seems to have been abundant on lowlands during the Middle Miocene, as already suggested (TANAI, 1963, p. 37). The scant representation of *Z. ungeri* may indicate that it was largely restricted to lowland habitats at some distance from the basins of Shanabuchi deposition. *Zizyphus jujuba*, the living equivalent of *Z. miojujuba*, is widely distributed in lowlands and hilly areas along the Hwang Ho river in China, ranging up slopes to altitudes of 700 meters. As shrubs, neither it nor *Z. miojujuba* would be large producers of leaves. The herb, *Rumex ezoensis*, also seems not to have been well suited to preservation.

4) Rare fossil species with living equivalents on slopes

Species	Per cent	Organs represented
Acer pseudocarpinifolium	0.2	Leaf and winged seed
Alnus subfirma	0.2	Leaves only
Forsythia kitamiensis	0.2	Leaves only
Polygonum megalophyllum	0.2	Leaves only
Populus kobayashii	0.2	Leaves only
Smilax trinervis	0.2	Leaves only
Sorbus uzenensis	0.2	Leaves only
Aesculus majus	0.1	Leaf
Aralia subelata	0.1	Leaflet
Cinnamomum sp.	0.1	Leaflet

Cornus subkousa	0.1	Leaf
Crataegus sugiyamae	0.1	Leaf
Disporum ezoanum	0.1	Leaf
Fraxinus k-yamadai	0.1	Winged seed
Hamamelis protojaponica	0.1	Leaf
Liquidambar miosinica	0.1	Leaf
Pinus sp.	0.1	Leaf
Prunus rubeshibensis	0.1	Leaf
Rubus sp.	0.1	Leaf
Rhus miosuccedanea	0.1	Leaflet
Sorbus protoalnifolia	0.1	Leaf
Spiraea protothunbergi	0.1	Leaf
Stewartia okutsui	0.1	Capsule
Vitis naumanni	0.1	Leaf
Juniperus honshuensis	0.1	Foliage shoot

Nearly all of these species were typical slope trees as judged from the habitats of their living equivalents, although several may also have ranged into the lowlands. Their small representation is in agreement with this suggestion, and it is probable that many of them were rare members of the Shanabuchi forest. Several species such as *Smilax trinervis*, *Cinnamomum* sp., *Pinus* sp., *Rhus miosuccedanea*, and *Juniperus honshuensis* may have been rather of lowland habitat, as judged from their living equivalents, but they seem to have ranged up onto slopes in Shanabuchi time. Two herbs, *Polygonum megalophyllum* and *Disporum ezoanum*, were not large producers of leaves, and furthermore they may have been not suitable to preserve their leaves, due to their fragile leaf texture. Though its living equivalent ranges from lowlands to slopes, *Liquidambar miosinica*, represented only by one leaf, is presumed to have been rather a slope tree, or to have been actually one of rare members which have survived in the Upper Miocene forest of northeastern Hokkaido since Middle Miocene time. As already reported (TANAI, 1963, p. 23), *L. miosinica* was found commonly in the Middle Miocene slope forest of southwestern Hokkaido. Thirteen species on this list appear to have been small trees, shrubs or vine as already shown in Table 2, and the consequent low leaf production may have been a factor of the low representation.

5) Abundant fossil species with living equivalents in mountains

Species	Per cent	Organs represented
Betula protoermani	6.9	Leaves only

Betula protermani seems to have ranged from upper slopes to mountains as discussed in 1), though its living equivalent is a common member of the subalpine forest of Japan.

6) Common fossil species with living equivalents in mountains

Species	Per cent	Organs represented
Cercidiphyllum crenatum	5.6	Leaves only
Acer protojaponicum	3.5	Leaves only
Picea kaneharai	2.1	Winged seeds only
Thuja nipponica	1.6	Foliage shoots only

All these species seem to have been distributed from slopes to montane areas as already discussed in 2). Judging from their common occurrence and the habitats of their living equivalents, *Cercidiphyllum crenatum* and *Acer protojaponicum* may have lived mainly on slopes. *Picea kaneharai* is represented only by winged seeds, and so it is presumed to have been rather a montane tree.

7) Uncommon fossil species with living equivalents in mountains

Species	Per cent	Organs represented
Rhododendron tatewakii	0.5	Leaves only
Prunus ishidai	0.4	Leaves only
Alnus protomaximowiczii	0.3	Leaves only
Acer subpictum	0.3	Leaves and winged seed
Fagus palaeocrenata	0.3	Leaves

Rhododendron tatewakii, *Prunus ishidai* and *Alnus protomaximowiczii* seem to have been exclusively montane, for their living equivalents are common members of the subalpine forest of Honshu. Their scant representation agrees with this suggestion, though it may be due partly to their small tree habit. *Acer subpictum* may have ranged from slopes to montane areas, judging from the habitat of its living equivalent. *Fagus crenata*, the living equivalent of *F. palaeocrenata*, is a representative of slope forest in Honshu, and frequently ranges up into the mixed forest. Though the Shanabuchi flora is made up mainly of slope plants, it is difficult to explain the scant representation of *F. palaeocrenata*. It is probable that *F. palaeocrenata* lived only in a montane habitat or that it was a rare member in the slope forest. As already noted in comparison with the modern forests of Japan, in central Honshu on the Pacific slope of mountains of central and southern parts, *F. crenata* is not a dominat species in the temperate-deciduous broad-leafed forest; the *Castanea* zone passes into the subalpine coniferous forest through the mixed forest. Accordingly, the rarity of *F. palaeocrenata* may suggest that physical conditions were similar to those in central Honshu.

8) Rare fossil species with living equivalents in mountains

Species	Per cent	Organs represented
Tsuga oblonga	0.2	Cone and winged seed
Taiwania japonica	0.2	Foliage shoots only

Sorbus uzenensis	0.2	Leaflets only
Sorbus lanceolata	0.1	Leaf

All these species, excluding *Sorbus uzenensis*, were typically montane species as judged from the habitats of their living equivalents; *Tsuga diversifolia* (*T. oblonga*) and *Sorbus matsumurana* (*S. lanceolata*) are common members of the subalpine forest of Honshu; *Taiwania cryptomeroides* (*T. japonica*) inhabits the montane or uplands forest of Formosa and China. *Sorbus uzenensis* seems to have been ranged from slopes to montane areas as judged from its living equivalent.

On the basis of these altitudinal records and inference, the author assigns the Shanabuchi species to plant associations as follows:

Slope Association

Abies protofirma
Acer protojaponicum
Acer pseudocarpinifolium
Acer subpictum
Acer yabei
Aesculus majus
Ailanthus yezoense
Alnus miojaponica
Alnus protohirsuta
Alnus subfirma
Aralia subelata
Betula protoermani
Carpinus stenophylla
Carpinus subcordata
Carpinus subyedoensis
Celtis miobungeana
Celts nordenskioldii
Cercidiphyllum crenatum
Cinnamomum sp.
Cladrastis chaneyi
Clethra maximowiczii
Cornus subkousa
Crataegus sugiyamae
Diospyros sublotus
Disporum ezoanum
Fagus palaeocrenata
Fagus protojaponica
Forsythia kitamiensis
Fraxinus k-yamadai
Gleditsia miosinensis
Hamamelis protojaponica
Jnglans japonica
Juniperus honshuensis
Kalopanax acerifolius
Liquidambar miosinica
Magnolia elliptica
Phellodendron mioamurense
Picea kaneharai
Pinus sp.
Polygonum megalophyllum
Populus kitamiana
Populus kobayashii
Prunus protossiori
Prunus rubeshibensis
Pterocarya asymmetrosa
Pterocarya protostenoptera
Rhus miosuccedanea
Rhus protoambigus
Rubus sp.
Rumex nipponicus
Salix hokkaidoensis
Salix parasachalinensis
Smilax trinervis
Sorbus protoalnifolia
Sorbus uzenensis
Spiraea protothunbergi
Stewartia okutsui
Thuja nipponica
Ulmus miopumila
Vitis naumanni
Zelkova ungeri
Zizyphus miojujuba
Wisteria fallax

Montane Association

Acer protojaponicum
Acer subpictum
Alnus protomaximowiczii
Betula protoermani
Cercidiphyllum crenatum
Fagus palaeocrenata
Picea kaneharai
Prunus ishidai
Rhododendron tatewakii
Sorbus lanceolata
Sorbus uzenensis
Taiwania japonica
Thuja nipponica
Tsuga oblonga

The 63 members of the Slope Association make up 90 per cent of the total Shanabuchi species; their specimens make up 97.8 per cent of the total recorded. It may be concluded that the Shanabuchi forest represents mainly the slope vegetation during Late Miocene time. On the other hand, specimens of the 14 members of the Montane Association show a total of 22.3 per cent; but if we omit the more typically slope species and consider only those limited to high elevations, the montane species have a far lower representation. On this basis there are only 6 species, *Taiwania japonica, Tsuga oblonga, Alnus protomaximowiczii, Pruns ishidai, Sorbus lanceolata,* and *Rhododendron tatewakii,* confined to the montane areas, with total specimens making 1.7 per cent on the total.

Climate

Our first approach to an appraisal of the Shanabuchi climate will be to determine the conditions under which similar forests of the slope and uplands are living today. The Shanabuchi forest, as discussed above is closely similar to the lower part of the modern beech forest in Honshu, Japan; it also resembles slope forest of Central China and the Appalachian Mountain of eastern North America. Table 10 gives climatic records at localities situated near the regions where these modern forests occur. The Shanabuchi forest is most similar to the slope forest of northern Kwanto region, Honshu; here (for instance, at Utsunomiya and Chichibu) there is a mean annual precipitation of about 1500 mm. The Miocene slopes under consideration may have extended to higher elevations than those two localities, with minor differences in temperature and precipitation. As shown in Table 10, there is a decrease in mean temperature and precipitation toward northern Honshu, where several southern genera gradually disappear from slope forests. The Shanabuchi forest is also closely similar to the forest of central Honshu; at middle altitudes (for instance, at Iida, Matsumoto and Takayama) there is mean annual temperature of 10° to 12°C. and annual precipitation of 1013 to 1738 mm. The modern slope forests here have more southern trees there have been recorded in the Shanabuchi flora; so it may be assumed that the Shanabuchi climate was more similar to that of middle altitudes to the north. In the northern Kwanto region and in northern Honshu, temperatures range from $-4°$ to 2°C. in winter and from 16° to 25°C. in summer; monthly precipitation varies from 50 to 200 mm. in winter, and from 150 to 250 mm. in summer.

There are no reliable climatic data for slopes and uplands of Szechuan, and Hupeh provinces, central China, where forests resembling the Shanabuchi flora are known to occur. Chungking and Tingakwan, at lower altitude, have mean temperatures of 18.7° and 13.8°C. and mean annual precipitation of 1057 and 527 mm. respectively. At higher elevations temperature is doubtless lower than at the above-noted places, and precipitation is probably higher. In the slope forests of central China a number of warm-temperate trees are mixed with temperate broad-leafed trees, and many relict plants have survived from the Tertiary. Climate in the interior regions of central China is more mild than that of the same latitudes of Japan. This is probably due to the sheltering effects of high surrounding mountains, as indicated by the environment of the modern *Metasequoia* forest. There is no reason to suppose that the climate was similarly mild with sheltering topography during Ṣhanabuchi time.

Records from several localities in the eastern United States are shown in Table 10: mean annual precipitation is not greatly different from the same latitude

Table 10. Climatic Data for several localities in Japan, China, and the United States (after WADACHI, 1958).

	Altitudes	Latitudes	Mean ann. Precip.	Rainiest season	Lowest average precip. in any month	Mean ann. temp.	Lowest record temp.
Morioka, Aomori Pref.	155	39.6	1,205	summer	54	9.3	−20.6
Yamagata, Yamagata Pref.	151	38.2	1,250	summer	75	10.7	−20.0
Sendai, Miyagi Pref.	38	38.2	1,216	summer	35	11.1	−11.7
Karuizawa, Nagano Pref.	934	36.3	1,364	summer	23	7.7	−18.6
Utsunomiya, Tochige Pref.	120	36.5	1,506	summer	28	12.4	−14.8
Shirakawa, Fukushima Pref.	354	37.2	1,418	summer	30	10.8	—
Chichibu, Saitama Pref.	218	36.0	1,448	summer	22	12.3	−15.8
Iida, Nagano Pref.	482	35.3	1,553	summer	56	11.9	−16.5
Takayama, Gifu Pref.	560	36.1	1,738	summer	95	9.9	−25.5
Matsumoto, Nagano Pref.	611	36.1	1,013	summer	31	60.1	−24.8
Chung-king, China	217	29.3	1,054	summer	19	18.7	1.6
Hankow, China	36	30.3	1,160	summer	38	16.9	—
Tingkswan, China	395	34.2	527	summer	4	13.8	—
Kai-feng, China	100	34.5	582	summer	8	14.1	—
Pittsburgh, U.S.A.	351	40.3	938	summer	60	10.3	—
Cincinatti, U.S.A.	232	39.1	999	spring	56	12.7	—
Knoxville, U.S.A.	290	35.5	1,156	winter	64	15.2	—
Mountain City, U.S.A.	740	36.0	1,175	summer	55	11.6	—

(Latitude to nearest degree; altitude in meters; precipitation in mm.; temperature in degree Centigrade).

in Japan, with 1000 to 1250 mm.; mean annual temperatures are generally higher, from 10° to 17°C., but would be less at stations at high altitudes if they were available for comparison. The climate of the Appalachian slopes seems generally similar to that described in central Honshu and northern Kwanto, although there is a somewhat less precipitation.

A few living equivalents of the warm-temperate members of the Shanabuchi flora are living in Japan. *Cinnamomum camphora* is distributed westward from Kwanto region; *Rhus succedanea* is distributed from southwestern Japan northward to coastal area of northern Honshu. Though *Liquidambar formosana* is native in central and southern China and Formosa, it does not occur except under cultivation in Japan. The southern genera of the Shanabuchi flora are represented by only few specimens, and appear to have been relicts of the Middle Miocene warm-temperate flora.

The preceding analysis of the modern distribution and habitats of Shanabuchi equivalents in East Asia and North America, and of the quantitative significance of the fossil records, suggests that this Late Miocene forest occupied mainly slope environments. Discussion of the climatic setting of the Slope Association has shown similarities to the climate under which the lower forest of the beech zone is growing in northern Kwanto region and central Honshu. It is concluded that Shanabuchi climate had a mean annual temperature from 8° to 12°C. with winter mean temperature falling −4°C. and with a mean annual precipitation of 1000 to 1500 mm. with summer the rainiest season. Absence of any record of *Metsasequoia* is in accord with the conclusion.

THE RUBESHIBE FLORA

INTRODUCTION

The discovery of a rich fossil plants at Rubeshibe-machi, situated about 26 kilometers south of Engaru-machi, is particularly welcome because it adds materially to our understanding of Late Tertiary vegetation in Hokkaido. The Rubeshibe flora throws significant light on the distribution and local differentiation of Late Tertiary floras in northeastern Hokkaido, since it marks the first known occurrence of a Pliocene flora there. Fossil plants have been collected in diatomaceous rocks exposed along the Muka River, near Ootomi Village of Rubeshibe-machi, about 3 kilometers west of the Rubeshibe Station of the Sekihoku Railway Line. These diatomaceous rocks have previously been considered to be of Pleistocene age.

The author knows of no mention of fossil plants here before 1959, when M. ISHIDA brought in specimens collected during his geological mapping of the Rubeshibe sheet (scale 1:50,000). During 1960 and 1961 the author and N. SUZUKI collected a number of well-preserved plant fossils. Our collection is sufficiently large to date the flora reliably. It also provides paleoecological evidence which makes possible inferences regarding the topographic and climatic setting during the Pliocene.

There are few published reports on the geology of this area. A compiled geologic map (scale 1 : 200,000) was published by the Hokkaido Geological Survey in 1957; in this map the diatomaceous rocks are treated as Pleistocene. T. ISHIKAWA et al., (1962, p. 59) reported on the area along the Muka River, when they surveyed the Onneyu hot spring which is situated about 6 kilometers west of the plant locality; they also concluded that the plant-bearing rocks are of Pleistocene age. K. SAWAMURA and M. HATA (1962, p. 18) reported only on the general stratigraphy of the Rubeshibe area, describing stratigraphic relations of several formations and their age, but has left a geologic map unpublished.

GEOLOGIC OCCURRENCE

The area including the fossil locality is hilly with relief of 360 to 400 meters, and with a bordering alluvial plain at an altitude of about 200 meters. The Muka river crosses the region from west-southwest to east-northeast; along the river, cliffs 20 to 30 meters high are developed.

In this area Neogene Tertiary sediments and associated volcanics are widely distributed on Mesozoic beds composed schalstein, chert, slate and graywacke sandstone. The Tertiary is composed mainly of pyroclastic materials, and according to SAWAMURA and HATA (1962, p. 18) it is divided into four parts, the Onne volcanics, the Okedo, the Komatsuzawa and Rubeshibe formations is ascending order. The Onne volcanics are composed of rhyolite and its tuff breccia, and are correlated with the Konomai group which is described above in the Shanabuchi flora. The Onne volcanics are intruded by pyroxene-andesite, and are overlain unconformably by the Okedo formation which is composed mainly of dacitic tuff, sandstone, siltstone and volcanic conglomerate. The Okedo formation is of lacustrine origin, with many fragmentray plant fossils. Its contemporaneous equivalent to the east of Rubeshibe-machi contains several molluscan fossils such as *Patinopecten matsumoriensis* (NAKAMURA), *Chlamys kaneharai* (YOKOYAMA), and *Macoma* sp., and is of marine origin. Overlying the Okedo formation with disconformity, the Komatsuzawa formation consists mainly of diatomaceous siltstone, tuffaceous sandstone and siltstone, and glassy tuff; the diatomaceous siltstone contains numerous fossil plants and terrestrial diatoms. The Rubeshibe formation covering the Komatsuzawa has only a local distribution, and consists mainly of loose gravel, sand and clay. Pleistocene river terraces at 3 levels are developed along the Muka River, and are covered by andestic pumice flows.

The plant-bearing Komatsuzawa formation is well exposed along the Muka River, and especially near Ootomi Village where many plant fossils were collected. Here the formation consists of tuffaceous siltstone and pumiceous sandstone, in alternating layers, with a diatomaceous siltstone about 1 meter thick (Pl. 1, fig. 2). This is white, finely laminated, and includes a number of well-preserved leaves, winged seeds, and cone scales.

COMPOSITION

The Rubeshibe flora consists of 50 species belonging to 31 genera of 19 families, of which 13 species are described as new and 9 have been recorded from the adjacent, somewhat older Shanabuchi flora. There are 4 genera and 4 species of conifers, and the remainder are dicotyledons. The largest family is the Aceraceae with 9 species; next come the Betulaceae with 8 species of 5 genera, the Saliaceae and Rosaceae with 5 species each, and the Pinaceae and Fagaceae with 3 species each. The remaining families are represented by only one or two species. The following genera are predominant in number of species; *Acer* with 8 species, *Prunus* with 4 species, *Salix* and *Betula* with 3 species; *Populus, Alnus, Fagus* and *Rhus* with 2 species each; and remainder are represented by single species.

Like the Shanabuchi flora, which it closely resembles, the Rubeshibe flora consists largely of typically temperate plants such as Pinaceae, Salicaceae, Betulaceae, Fagaceae, Rosaceae, and Aceraceae, which are now widely distributed in the northern hemisphere. Most of the Rubeshibe species have also been found in the Shanabuchi flora, and there is a similarity in the high representation of beech, birch, alder, hornbeam, maple and yellow-wood. However the Rubeshibe flora shows a marked differences in having no exotic genera such as *Taiwania, Liquidambar, Ailanthus* and *Zizyphus.* This difference is interpreted as due to age discrepancy rather than to variations in local environment.

Systematic List of the Rubeshibe Flora

Pinaceae
- *Abies protofirma* TANAI
- *Picea kaneharai* TANAI and ONOE
- *Tsuga oblonga* MIKI

Cupressaceae
- *Thuja nipponica* TANAI and ONOE

Salicaceae
- *Populus balsamoides* GOEPPERT
- *Populus kitamiana* new species
- *Salix crenatoserrulata* new species
- *Salix kitamiensis* new species
- *Salix misaotatewakii* new species

Betulaceae
- *Alnus protohirsuta* ENDO
- *Alnus protomaximowiczii* TANAI
- *Betula miomaximowicziana* ENDO
- *Betula onbaraensis* TANAI and ONOE
- *Betula protoermani* ENDO

Carpinus subcordata NATHORST
Corylus sp.
Ostrya shiragiana HUZIOKA

Fagaceae
Fagus palaeocrenata OKUTSU
Fagus protojaponica K. SUZUKI
Quercus protodentata TANAI and ONOE

Ulmaceae
Celtis nordenskioldii NATHORST
Ulmus protojaponica TANAI and ONOE

Polygonaceae
Polygonum megalophyllum new species
Rumex ezoensis new species

Magnoliaceae
Magnolia elliptica TANAI and ONOE

Hamamelidaceae
Hamamelis protojaponica new species

Rosaceae
Prunus ishidai new species
Prunus protossiori TANAI and ONOE
Prunus rubeshibensis new species
Prunus subserotina new species
Sorbus lanceolata new species

Leguminosae
Cladrastis chaneyi new species
Gleditsia miosinensis HU and CHANEY

Anacardiaceae
Rhus miosuccedanea HU and CHANEY
Rhus protoambigua K. SUZUKI

Aceraceae
Acer palaeodiabolicum ENDO
Acer palaeorufinerve TANAI and ONOE
Acer protojaponicum TANAI and ONOE
Acer pseudocarpinifolium ENDO
Acer pseudoginnala TANAI and ONOE
Acer subpictum SAPORTA
Acer subukurunduense N. SUZUKI
Acer yabei ENDO
Acer sp.

Vitaceae
Vitis naumanni (NATHORST) TANAI

Theaceae
Stewartia okutsui TANAI

Cornaceae
Cornus megaphylla HU and CHANEY

Clethraceae
Clethra maximowiczii NATHORST

Ebenaceae
Diospyros sublotus new species

Caprifoliaceae
Lonicera sp.

Assumed Growth Habit

The probable habit of the members of the Rubeshibe flora, judging from their most similar living species, is indicated in Table 11, with totals of 37 trees, 9 shrubs and small trees, 2 vines, and 2 herbs.

Small trees and shrubs are less numerous than in the Shanabuchi flora. This numerical representation will be discussed in detail in the section which follows.

Table 11. Assumed Growth Habit of the Rubeshibe Plants.

Trees	
Abies protofirma	*Prunus protossiori*
Picea kaneharai	*Prunus subserotina*
Tsuga oblonga	*Sorbus lanceolata*
Thuja nipponica	*Cladrastis chaneyi*
Populus balsamoides	*Gleditsia miosinensis*
Populus kitamiana	*Acer palaeodiabolicum*
Salix crenatoserrulata	*Acer palaeorufinerve*
Alnus protohirsuta	*Acer protojaponicum*
Betula miomaximowicziana	*Acer pseudocarpinifolium*
Betula onbaraensis	*Acer pseudoginnala*
Betula protoermani	*Acer subpictum*
Carpinus subcordata	*Acer subukrunduense*
Ostrya shiragiana	*Acer yabei*
Fagus palaeocrenata	*Acer* sp.
Fagus protojaponica	*Stewartia okutsui*
Quercus protodentata	*Cornus megaphylla*
Celtis nordenskioldii	*Clethra maximowiczii*
Ulmus protojaponica	*Diospyros sublotus*
Magnolia elliptica	
Small Trees and Shrubs	
Salix kitamiensis	*Prunus ishidai*
Salix misaotatewakii	*Prunus rubeshibensis*
Alnus protomaximowiczii	*Rhus miosuccedanea*
Corylus sp.	*Lonicera* sp.
Hamamelis protojaponica	
Vines	
Rhus protoambigua	*Vitis naumanni*
Herbs	
Polygonum megalophyllum	*Rumex ezoensis*

Table 12. Numerical Representation of Rubeshibe Species.

Species	Number of specimens	Percentage
Fagus protojaponica (leaves)	1737	45.11
Betula onbaraensis (leaves)	803	20.86
Acer subpictum (total)	448	11.64
(leaves)	(440)	
(winged seeds)	(8)	
Carpinus subcordata (total)	142	3.69
(leaves)	(131)	
(involucres)	(11)	
Betula miomaximowicziana	132	3.43
(leaves)	(130)	
(cone scales)	(2)	
Populus kitamiana (leaves)	87	2.26
Acer protojaponica (leaves)	83	2.15
Populus protomaximowiczii (leaves)	80	2.08
Cladrastis chaneyi (leaves)	75	1.95
Alnus protohirsuta (total)	53	1.38
(leaves)	(51)	
(cones)	(2)	
Ulmus protojaponica (total)	41	1.07
(leaves)	(39)	
(winged seeds)	(2)	
Acer palaeodiabolicum (total)	28	0.73
(leaves)	(26)	
(winged seeds)	(2)	
Prunns protossiori (leaves)	16	0.41
Prunus subserotina (leaves)	16	0.41
Alnus protomaximowiczii (leaves)	10	0.26
Salix misaotatewakii (leaves)	9	0.23
Celtis nordenskioldii (leaves)	9	0.23
Picea kaneharai (winged seeds)	5	0.13
Prunus rubeshibensis (leaves)	5	0.13
Sorbus lanceolata (leaves)	5	0.13
Diospyros sublotus (leaves)	5	0.13
Fagus palaeocrenata (leaves)	4	0.10
Prunus ishidai (leaves)	4	0.10
Rhus protoambigua (leaflets)	4	0.10
Acer pseudoginnala (total)	4	0.10
(leaves)	(3)	
(winged seeds)	(1)	
Acer yabei (winged seeds)	4	0.10
Vitis naumanni (leaves)	4	0.10
Abies protofirma (cone scales)	3	0.08
Acer pseudocarpinifolium (leaves)	3	0.08
Acer subukrunduense (leaves)	3	0.08
Stewartia okutsui (total)	3	0.08
(leaves)	(2)	
(capsule)	(1)	
Salix kitamiensis (leaves)	2	0.05
Betula protoermani (leaves)	2	0.05

Table 12—(*Continued*)

Species	Number of specimens	Percentage
Ostrya shiragiana (leaves)	2	0.05
Quercus protodentata (leaves)	2	0.05
Polygonum megalophyllum (leaves)	2	0.05
Clethra maximowiczii (leaves)	2	0.05
Tsuga oblonga (cone)	1	0.03
Thuja nipponica (foliaged shoot)	1	0.03
Salix crenatoserrulata (leaf)	1	0.03
Corylus sp. (leaf)	1	0.03
Rumex ezoensis (leaf)	1	0.03
Magnolia elliptica (leaf)	1	0.03
Hamamelis protojaponica (leaf)	1	0.03
Gleditsia miosinensis (leaflet)	1	0.03
Rhus miosuccedanea (leaflet)	1	0.03
Acer palaeorufinerve (leaf)	1	0.03
Acer sp. (leaf)	1	0.03
Cornus megaphylla (leaf)	1	0.03
Lonicera sp. (leaf)	1	0.03
totals	3850	100.00

Numerical Representation

Table 12 shows the numerical representation of the Rubeshibe plants as based on a count of 3850 specimens, all of which came from one locality. Our count is not sufficient large to preclude the possibility that certain species, especially the rare ones, may have been more numerous in the Rubeshibe forest than is suggested by these figures. It appears unlikely, however, that the proportionate representation of its dominants would be greatly changed by a larger count. Actually, the percentages of several dominant species did not materially change during three period of collecting in 1960 and 1961.

Fagus protojaponica is the predominant species, making up about 45 per cent of the total specimens counted; this species is also the most abundant species in the Shanabuchi flora. It is followed by two species, *Betula onbaraensis* and *Acer subpictum*; these three dominant species comprise nearly 78 per cent of the total. Only eight other species make up as much as one or two per cent of the total respectively: *Carpinus subcordata, Betula miomaximowicziana, Populus kitamiana, P. balsamoides, Acer potojaponicum, Cladrastis chaneyi, Alnus protohirsuta,* and *Ulmus protojaponica.* All eleven of the abundantly represented species were deciduous broad-leafed trees as listed in Table 11, making up nearly 92 per cent of the total. Like the Shanabuchi, the Rubeshibe flora has few conifers; there are only four species, *Abies protofirma, Picea kaneharai, Tsuga oblong,* and *Thuja nipponica,* all of which total only 0.27 per cent. As suggested in the following section, the rarity of conifers coincides with the meagre representation of upland or montane deciduous broad-leafed trees. In contrast to the abundant occurrence of *Fagus*, it is noteworthy that there is no record of *Zalkova* or of ever-green broad-leafed trees, which are present, though only sparingly in the Shanabuchi flora.

Nine species listed as shrubs and small trees show meagre representation, and comprise only 0.89 per cent of the total. The 10 least numerous tree species of angiosperms, represented by only one or two specimens, make up only 0.44 per cent.

Table 13. Present-day Distribution of the Rubeshibe Genera.

Region / Genus	East Asia		North America	
	Japan	China & Formosa	Western	Eastern
Abies	×	×	×	×
Picea	×	×	×	×
Tsuga	×	×	×	×
Thuja	×	×	×	×
Populus	×	×	×	×
Salix	×	×	×	×
Alnus	×	×	×	×
Betula	×	×	×	×
Carpinus	×	×	...	×
Corylus	×	×	×	×
Ostrya	×	×	×	×
Fagus	×	×	...	×
Quercus	×	×	×	×
Celtis	×	×	×	×
Ulmus	×	×	...	×
Polygonum	×	×	×	×
Rumex	×	×	×	×
Magnolia	×	×	...	×
Hamamelis	×	×	...	×
Prunus	×	×	×	×
Sorbus	×	×	×	×
Cladrastis	×	×	...	×
Gleditsia	×	×	...	×
Rhus	×	×	×	×
Acer	×	×	×	×
Vitis	×	×	×	×
Stewartia	×	×	...	×
Cornus	×	×	×	×
Clethra	×	×	...	×
Diospyros	×	×	...	×
Lonicera	×	×	×	×
total	31	31	21	31

Table 14. Modern Equivalents of the Rubeshibe Plants and their Distribution in eastern Asia and North America.

Fossil species	Modern equivalent	East Asia													North Amer.	
			Japan					China								
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Abies protofirma	*A. firma*			×	×	×	×									
Picea kaneharai	*P. polita*				×	×	×									
Tsuga oblonga	*T. diversifolia*			×	×	×	×									
	(*T. caloriniana*)															(×)
Thuja nipponica	*T. standishii*			×	×		×		×							
Populus kitamiana	*P. grandidentata*															×
	(*P. sieboldi*)		(×)	(×)	(×)	(×)	(×)									
Populus protomaximowiczii	*P. maximowiczii*	×	×	×	×				×					×		
Salix crenatoserrulata	*S. chaenomeloides*			×	×	×	×		×	×	×					
Salix kitamiensis	*S. vulpina*	×	×	×	×	×	×									
Salix misaotaewakii	*S. glacilistyla*		×	×	×	×	×		×	×	×					
Alnus protohirsuta	*A. hirsuta*	×	×	×	×	×	×							×		
Alnus protomaximowiczii	*A. maximowiczii*	×	×	×	×				×					×		
Betula miomaximowicziana	*B. maximowicziana*		×	×	×											
Betula onbaraensis	*B. grossa*			×	×	×	×									
Betula protoermani	*B. ermani*	×	×	×	×				×							
Carpinus subcordata	*C. cordata*		×	×	×	×	×		×	×	×			×		
Corylus sp.	*C. heterophylla* var. *thunbergii*		×	×	×	×	×									
Ostrya shiragiana	*O. japonica*		×	×	×	×	×		×	×	×					
Fagus palaeocrenata	*F. crenata*		×*	×	×	×	×									
Fagus protojaponica	*F. japonica*			×	×	×	×									
Quercus dentata	*Q. dentata*	×	×	×	×	×	×		×	×	×		×	×		
Celtis nordenskioldii	*C. occidentalis*														×	×
Ulmus protojaponica	*U. davidiana* var. *japonica*	×	×	×	×	×	×		×	×				×		
Polygonum megalophyllum	*P. sachalinense*	×	×	×	×											
Rumex ezoensis	*R. longifolius*		×	×	×	×	×		×							
Magnolia elliptica	*M. liliflora*										×					
Hamamelis protojaponica	*H. japonica*		×	×	×	×	×									
	(*H. virginiana*)															(×)
Prunus ishidai	*P. nipponica*		×	×	×											
Prunus protossiori	*P. ssiori*	×	×	×	×									×		
Prunus rubeshibensis	*P. sargentii*	×	×	×	×				×							
	(*P. nigra*)															(×)

Prunus subserotina	*P. serotina*															×
Sorbus lanceolata	*S. matsumurana*		×	×	×											
Cladrastis chaneyi	*C. lutea*															×
	(C. platycarpa)				(×)	(×)	(×)				(×)		(×)			
Gleditsia miosinensis	*G. sinensis*									×	×					
	(C. japonica)				(×)	(×)	(×)									
Rhus miosuccedanea	*R. succedanea*			×	×	×	×	×								
Rhus protoambigua	*R. ambigua*	×	×	×	×	×	×			×	×					
Acer palaeodiabolicum	*A. diabolicum*			×	×	×	×									
Acer palaeorufinerve	*A. rufinerve*			×	×	×	×									
Acer protojaponicum	*A. japonicum*		×	×	×	×	×									
Acer pseudoginnala	*A. ginnala*	×	×	×	×	×	×		×	×	×			×		
Acer pseudocarpinifolium	*A. carpinifolium*			×	×	×	×									
Acer subpictum	*A. mono*	×	×	×	×	×	×		×	×			×	×		
Acer subukurunduense	*A. ukurunduense*	×	×	×	×		×		×					×		
Acer yabei	*A. saccharinum*															
Acer sp.	*A. tchonoskii*		×	×	×											
Vitis naumanni	*V. coignetiae*		×	×	×	×	×									
Stewartia okutsui	*S. pseudo-camellia*			×	×	×	×									
Cornus megaphylla	*C. macrophylla*									×	×					
	(C. controversa)		(×)	(×)	(×)	(×)	(×)		(×)	(×)	(×)	(×)	(×)	(×)		
Clethra maximowiczii	*C. barvinervis*		×	×	×	×	×		×		×	×	×			
Diospyros sublotus	*D. lotus*								×				×			
Lonicera sp.	*L. gracilipes*		×*	×	×	×	×									
Nearest species		14	29	41	40	29	30	1	17	11	12	2	5	11	1	5
Closely similar but not nearest species		(0)	(2)	(2)	(4)	(4)	(4)	(0)	(1)	(1)	(2)	(1)	(2)	(1)	(0)	(3)
Totals		14	31	43	44	33	34	1	18	12	14	3	7	12	1	8

MODERN DISTRIBUTION

1. Saghalien and Kurile Islands.
2. Hokkaido, Japan.
3. Northern Honshu, Japan.
4. Central Honshu, Japan.
5. Southern Honshu, Japan.
6. Kyushu and Shikoku, Japan.
7. Formosa and Loochoo Islands.
8. Korea including Quelpart Island.
9. Northern China including Shantung Province.
10. Central China.
11. Southeastern China.
12. Southwestern China.
13. Manchuria.
14. Western North America.
15. Eastern North America.

* Hokkaido species with an asterik are confined to the southwestern part of the island.

Most of these rare members appears to have lived at some distance from the lake borders where leaves were accumulating in the deposits. Further discussion of species representation will be included in the section which follows.

PALEOECOLOGY

The preceding discussion of the Rubeshibe flora has suggested its resemblance to the Shanabuchi, with nearly all of the genera and more than three-fifths of the species in common. It is significant to note that these are for the most part typical slope species, and that there is no occurrence of the strictly lowland species which are found in small numbers in the Shanabuchi flora. In the discussion which follows the author will present evidence that the Rubeshibe flora represents a forest which lived on the shores of upland lakes, and on the slopes adjacent.

Distributional Considerations

All the Rubeshibe genera are typically temperate in their distribution, as shown by Table 13. *Clethra*, *Diospyros* and *Lonicera* are now found also at low latitudes, but they regularly range into middle latitudes and altitudes where they may be rather common. *Quercus* also occupies subtropical and tropical regions as an evergreen, but the Rubeshibe oak was a temperate, deciduous tree. All of the Rubeshibe genera now live in Japan, China, and the eastern United States, and most of them live in western North America as well.

Table 14 gives a list of the Rubeshibe species, with their nearest living species in eastern Asia and North America. On the basis of these modern relationships, the fossil species may be assigned to the East Asian Element and the East American Element. Forty-five species, making up 92 per cent of the total, and about 95 per cent of the specimens counted, make the East Asian Element more dominant in the Rubeshibe than in the Shanabuchi flora. The four genera of the Shanabuchi flora which are no longer living in Japan, *Ailanthus*, *Liquidambar*, *Taiwania* and *Zizyphus*, are not recorded in the Rubeshibe flora, and appear to have become extinct in Japan during the interval between Shanabuchi and Rubeshibe time. A further trend toward modernity may be seen in the increased number of relationships between Rubeshibe plants and members of their genera now living in Japan, and reduced relationships to the modern vegetation of China. Only five North American species are known to be closely similar to Rubeshibe plants.

The East Asian Element

Table 14 shows that modern equivalents of the Rubeshibe species are most abundantly concentrated in temperate regions of Japan. The 33 Rubeshibe species common to the Shanabuchi flora and its East Asian Element have already been discussed in detail. It will therefore not be necessary to consider at length the occurrence of three modern equivalents of the Rubeshibe flora in eastern Asia.

Nearly all of the living equivalents of the dominant species are typical slope members of the Honshu forests. The abundance of *F. protojaponica* emphasizes the close resemblance between the Rubeshibe flora and the lower forest of the beech zone in Honshu, where its living equivalent, *F. japonica*, is a common member. The following species have living equivalents which are growing in the slope forests of central Honshu and northern Kwanto region.

Abies protofirma (*A. firma*)
Populus balsamoides (*P. maximowiczii*)
Populus kitamiana (*P. sieboldi*)
Salix crenatoserrulata (*S. chaenomeloides*)
Salix kitamiensis (*S. vulpina*)
Salix misaotatewakii (*S. glacilistyla*)
Alnus protohirsuta (*A. hirsuta*)
Betula miomaximowicziana (*B. maximowicziana*)
Betula onbaraensis (*B. grossa*)
Carpinus subcordata (*C. cordata*)
Corylus sp. (*C. heterophylla*)
Ostrya shiragiana (*O. japonica*)
Fagus palaeocrenata (*F. crenata*)
Fagus protojaponica (*F. japonica*)
Quercus protodentata (*Q. dentata*)
Ulmus protojaponica (*U. davidiana* var. *japonica*)
Polygonum megalophyllum (*P. sachalinense*)
Rumex ezoensis (*R. longifolius*)
Hamamelis protojaponica (*H. japonica*)
Prunus rubeshibensis (*P. sargentii*)
Prnuus protossiori (*P. ssiori*)
Gleditsia miosinensis (*G. japonica*)
Rhus miosuccedanea (*R. succedanea*)
Rhus protoambigua (*R. ambigua*)
Acer palaeodiabolicum (*A. diabolicum*)
Acer palaeorufinerve (*A. rufinerve*)
Acer protojaponicum (*A. japonicum*)
Acer pseudoginnala (*A. ginnala*)
Acer pseudocarpinifolium (*A. carpinifolium*)
Acer subpictum (*A. mono*)
Vitis naumanni (*V. coignetiae*)
Clethra maximowiczii (*C. barbinervis*)
Lonicera sp. (*L. gracilipes*)

Of the fossil species listed above, some may have had wide altitudinal ranges as judged from the habitats of their living equivalents, such as *Alnus protohirsuta*, *Carpinus subcordata*, *Ulmus protojaponica*, *Acer subpictum* and *A. protojaponicum*. As they occur relatively abundantly, they may have lived near sites of deposition; in other words, they appear to have been common members on lower slopes. The relative abundance in the record of *Populus balsamoides* (2.15 per cent), *P. kitamiana* (2.26 per cent) and *Alnus protohirsuta* (1.38 per cent) suggests that they lived on valley slopes along the stream, as judged from the habitats of their living equivalents, and that their leaves had many chances of entering sites of deposition.

There are many upper slope and montane species in the Rubeshibe flora as judged by the occurrence of their living equivalents.

Picea kaneharai (*P. polita*)
Tsuga oblonga (*T. diversifolia*)
Thuja nipponica (*T. standishii*)
Populus balsamoides (*P. maximowiczii*)
Alnus protomaximowiczii (*A. maximowiczii*)
Betula protoermani (*B. ermani*)
Betula miomaximowicziana (*B. maximowicziana*)
Betula onbaraensis (*B. grossa*)
Ulmus protojaponica (*U. davidiana* var. *japonica*)
Fagus palaeocrenata (*F. crenata*)
Prunus ishidai (*P. nipponica*)
Sorbus lanceolata (*S. matsumurana*)
Acer protojaponicum (*A. japonicum*)
Acer subukurunduense (*A. ukurunduense*)
Acer subpictum (*A. mono*)
Acer palaeorufinerve (*A. rufinerve*)
Acer sp. (*A. tchonoskii*)
Clethra maximowiczii (*C. barbinervis*)

There is a good deal of overlap among the plants of the above lists. The limite representation of such overlapping species as *Acer palaeorufinerve* (0.03 per cent) and *Clethra maximowiczii* (0.05 per cent) suggests that they may have been upland trees. The relative abundance in the record of *Betula miomaximowicziana* (3.43 per cent) and *B. onbaraensis* (20.86 per cent) suggests that they lived largely at lower or middle elevation.

The Rubeshibe plants also have many living eqivalents in the slope and upland forests of central and northern China. The habitats of these modern species were fully described in the case of the Shanabuchi flora, and the comparison of the Rubeshibe flora with the modern forest of China needs not be repeated here.

North American Relationships

The Rubeshibe flora has few typical members of the North American Elements, but if some of the less closely similar species are included in the comparison, it would show some resemblance to the modern forest of the Appalachian Mountains. This resemblance can be briefly summarized, since it has been fully discussed for the Shanabuchi flora. The Rubeshibe equivalents include the following characteristic Appalachian plants: *Tsuga canadensis, Thuja occidentalis, Populus grandidentata, Alnus rugosa, Betula lutea, Fagus grandifolia, Ostrya virginiana, Celtis occidentalis,* *Prunus nigra, P. serotina, Cladrastis lutea,* and *Diospyros virginiana.* In addition, there are a few members of the Atlantic Coastal Plain forest such as *Alnus rugosa, Ostrya virginiana, Fagus grandifolia, Celtis occidentalis, Hamamelis virginiana, Acer saccharinum* and *Diospyros virginiana.* These species are, however, not confined to this region, and range down from the Appalachian slopes to the Coastal Plain. Excluding the conifers and *Celtis occidentalis* which are widely distributed in North America, no Rubeshibe species has a close modern equivalent in the western United States.

Comparison of the Rubeshibe and Shanabuchi Percentage Representation

Table 15 shows the 33 species common to the Rubeshibe and Shanabuchi floras,

Table 15. Percentage Representation of Species common to the Rubeshibe and Shanabuchi floras.

Species	Rubeshibe	Shanabuchi
Fagus protojaponica	45.11	25.4
Acer subpictum	11.64	0.4
Carpinus subcordata	3.69	4.2
Populus kitamiana	2.26	0.4
Acer protojaponicum	2.15	3.5
Cladrastis chaneyi	1.95	7.3
Alnus protohirsuta	1.38	0.7
Ulmus protojaponica	1.07	7.1
Prunus protossiori	0.41	0.4
Alnus protomaximowiczii	0.26	0.3
Celtis nordenskioldii	0.23	2.1
Prunus rubeshibensis	0.13	0.1
Sorbus lanceolata	0.13	0.1
Picea kaneharai	0.13	2.1
Diospyros sublotus	0.13	0.6
Fagus palaeocrenata	0.10	0.3
Prunus ishidai	0.10	0.4
Rhus protoambigua	0.10	0.3
Acer yabei	0.10	0.3
Vitis naumanni	0.10	0.1
Abies protofirma	0.08	0.5
Acer pseudocarpinifolium	0.08	0.2
Stewartia okutsui	0.08	0.4
Betula protoermani	0.05	6.9
Polygonum megalophyllum	0.05	0.2
Clethra maximowiczii	0.05	0.4
Tsuga oblonga	0.03	0.2
Thuja nipponica	0.03	1.6
Rumex ezoensis	0.03	0.3
Magnolia elliptica	0.03	3.4
Hamamelis protojaponica	0.03	0.1
Gleditsia miosinensis	0.03	0.3
Rhus miosuccedanea	0.03	0.1

with the percentage representation of specimens in each. Of the eight dominant species of the Rubeshibe in this list, only five have dominant representation in the Shanabuchi. Five additional Shanabuchi species are abundant, but have only limited representation (less than 0. 25 per cent) in the Rubeshibe. Only species with one per cent representation or more will be considered in the following comparisons:

(1) Four of the Rubeshibe dominants are much more numerous in the Shanabuchi with the following ratios: *Populus kitamiana* 5.7 : 1; *Alnus protohirsuta* 2 : 1; *Fagus protojaponica* 1.8 : 1; *Acer subpictum* 29.1 : 1. The modern equivalents of these species are typically slope dwellers, and the first two are especially common in valley forests along streams. These ratios emphasize the slope character of the Rubeshibe forest.

(2) Three of the Shanabuchi species are much more numerous than in the Rubeshibe, with the following ratios: *Betula protoermani* 138 : 1; *Picea kaneharai* 16 : 1; *Thuja nipponica* 56 : 1. Since these species are considered to have lived at high levels, as judged by their modern equivalents, it may be suggested that there were mountains more closely adjacent to the Shanabuchi sites of deposition to the Rubeshibe.

(3) Four of the more numerous Shanabuchi species have living equivalent which are common on moist areas along stream, with the following ratios: *Ulmus protojaponica* 7 : 1; *Celtis nordenskioldii* 9 : 1; *Magnolia elliptica* 113 : 1; *Cladrastis chaneyi* 3.7 : 1. This again suggests the slope character of the Rubeshibe forest.

On the basis of these comparison, the Shanabuchi topography appears to have been more varied than the Rubeshibe, with valley-flats and adjacent mountains. The Rubeshibe forest was made up largely of slope species.

The Rubeshibe Plant Associations

Combining the evidence derived from the distribution of its modern equivalents in East Asia and North America and the frequency records of its members, the Rubeshibe flora may be assigned to a Slope and a Montane Association, as in the case of the Shanabuchi flora.

Slope Association

Abies protofirma
Acer palaeodiabolicum
Acer palaeorufinerve
Acer protojaponicum
Acer pseudocarpinifolium
Acer pseudoginnala
Acer subpictum
Acer yabei
Alnus protohirsuta
Betula miomaximowicziana
Betula onbaraensis
Carpinus subcordata
Celtis nordenskioldii
Cladrastis chaneyi
Clethra maximowiczii
Cornus megaphylla
Corylus sp.
Diospyros sublotus
Fagus palaeocrenata
Fagus protojaponica
Gleditsia miosinensis
Hamamelis protojaponica
Lonicera sp.
Magnolia elliptica
Ostrya shiragiana
Polygonum megalophyllum

Populus balsamoides
Populus kitamiana
Prunus protossiori
Prunus rubeshibensis
Prunus subserotina
Quercns protodentata
Rhus miosuccedanea
Rhus protoambigua
Rumex ezoensis
Salix crenatoserrulata
Salix kitamiensis
Salix misaotatewakii
Stewartia okutsui
Ulmus protojaponica
Vitis naumanni

These 41 members of the Slope Association make up about 99 per cent of the total specimens recorded. The numerical representation of most of them is consistent with their occurrence on the borders of an upland lake and on immediately adjacent slopes. The members of this Association include several species, whose modern equivalents may range to low altitudes such as *Populus protomaximowiczii, Salix crenatoserralata, S. misaotatewakii, Carpinus subcordata, Ulmus protojaponica, Celtis nordenskioldii, Rhus miosuccedanaea* and *Acer subpictum.* All of these might be expected to have lived both on moist river borders and on upland lake borders.

The slope Association of the Rubeshibe flora includes 26 of the 65 species listed for the Shanabuchi slope forest. Of the 39 Shanabuchi slope members not represented, elimination of several species such as *Ailanthus yezoense, Cinnamomum* sp., *Liquidambar miosinica, Zalkova ungeri* and *Zizyphus miojujuba,* suggests that temperature during Rubeshibe time had become lower. Such a suggestion is supported by the increased numbers of birches, poplars and willows in the Rubeshibe forest.

Montane Association

Acer palaeorufinerve
Acer protojaponicum
Acer subpictum
Acer subukurunduense
Acer sp.
Alnus protomaximowiczii
Betula protoermani
Fagus palaeocrenata
Picea kaneharai
Populus balsamoides
Prunus ishidai
Sorbus lanceolata
Thuja nipponica
Tsuga oblonga

The 14 members of the Montane Association comprise 16.84 per cent of the total specimens counted, but if the more typical slope species are omitted, the montane species limited to high elevations make up only 0.84 per cent. Several species such as *Acer palaeorufinerve, A. protojaponicum, A. subpictum,* and *Populus balsamoides,* may have ascended up into the montane Association, but it seems apparent that they lived largely at middle elevations where their leaves were readily accummulated in the deposits of the Rubeshibe lakes. *Fagus palaeocrenata, Picea kaneharai* and *Thuja nipponica,* are considered to have lived both on upper slopes and mountains during Shanabuchi time, as judged from the occurrence of their modern equivalents. However they appear to have been limited to mountains in the Rubeshibe forest, since they are so poorly represented. Typical members of the Montane Association include only 9 species, *Acer subukurunduense*, *Acer* sp., *Betula protoermani*, *Fagus palaeocrenata*, *Picea kaneharai*, *Prunus ishidai*, *Sorbus lanceolata*, *Thuja nipponica*, and *Tsuga oblonga*, all of whose living equivalents are common trees of the subalpine forest of Japan.

Climate

The Rubeshibe flora shows a close similarity to the Shanabuchi in its composition and components; resemblances involve the cool-temperate trees; it contains no exotic and southern trees. In the preceding discussion we have noted that the Rubeshibe flora is closely similar to the slope forest of northern Kwanto region and central Honshu, and also to those of central and northern China. Rubeshibe climate appears to have been similar to that a middle altitudes of these region. It will not be necessary to consider at length Rubeshibe climate, since climatic conditions indicated by the slope forest of the above-noted regions have already been discussed in detail for the Shanabuchi. The predominance of beech, hornbeams, maples, and poplars in the Slope association provides a basis for concluding that the Rubeshibe climate was cool-temperate, with comparatively well distributed precipitation. Absence of southern trees from the Rubeshibe slope forest appears to indicate that the mean annual temperature must have been lower than during Shanabuchi time, and especially that temperature in winter fell below freezing, with snow.

OTHER LATE TERTIARY FLORAS OF NORTHEASTERN HOKKAIDO

There are two additional floras of small size: one is the Samakesaroma flora northeast of Rubeshibe-machi, and the other is the Ikutawara flora south of Engaru-machi (see Fig. 1). These floras are poor in number of species and individuals, but since they throw a significant light on the distribution of Late Tertiary flora in northeasten Hokkaido, they will be discussed briefly.

THE SAMAKESAROMA FLORA

Along the upper course of the Samakesaroma-gawa, about 8 kilometers northeast of Rubeshibe-machi, plant-bearing deposits with narrow distribution lie unconformably upon the Mesozoic, and are covered by a rhyolite flow which is widely distributed in central Kitami region. The plant-bearing formation is made up largely of tuffaceous siltstone, with rarely intercalated fine sandstone; the siltstone contains many plant fossils, though ill-preserved. These plant fossils were first discovered by M. ISHIDA of Geological Survey of Japan in 1959; in the summer of 1960 N. SUZUKI collected many specimens, mostly fragmentary.

There are 18 species represented in the 150 specimens collected as follows:

Salicaceae
Populus kitamiana new species

Salix misaototewakii new species

Betulaceae
Alnus protohirsuta ENDO
Alnus protomaximowiczii TANAI
Carpinus subcordata NATHORST

Fagaceae
Fagus protojaponica K. SUZUKI

Ulmaceae
Ulmus protojaponica TANAI and ONOE

Polygonaceae
Polygonum megalophyllum new species

Cercidiphyllaceae
Cercidiphyllum crenatum (UNGER) BROWN

Magnoliaceae
Magnolia elliptica TANAI and ONOE

Hamamelidaceae
Liquidambar miosinca HU and CHANEY

Leguminosae
Robinia nipponica TANAI

Aceraceae
Acer palaeorufinerve TANAI and ONOE
Acer protojaponicum TANAI and ONOE
Acer subpictum SAPORTA

Oleaceae
Fraxinus k-yamadai new species
Fraxinus honshuensis TANAI and ONOE

Ebenaceae
Diospyros sublotus new species

Of these, 16 species excluding *Robinia nipponica* and *Fraxinus honshuensis* are found also in the Shanabuchi and Rubeshibe floras. *Fagus protojaponica* with 68 specimens makes up about 45 per cent of the total specimes recorded; the next is *Acer subpictum* with 22 specimens (14.6 per cent), followed by *Populus kitamiana* with 19 specimens (12.6 per cent) and *Acer protojaponicum* with 10 specimens (6.6 per cent); the remaining species are represented by less than 4 specimens.

The Samakesaroma flora is similar to the Shanabuchi and Rubeshibe floras in composition, especially in the abundant occurrence of *Fagus protojaponica, Acer subpictum,* and *A. protojaponicum,* but it is too small to permit a satisfactory comparison. The presence of exotics such a *Liquidambar miosinica* and *Robinia nipponica* indicates more similarity to the Shanabuchi flora rather than to the Rubeshibe; this is also supported by the stratigraphic relationships of plant-bearing deposits.

THE IKUTAWARA FLORA

Near Ikutawara-machi, Monbetsu-gun, about 16 kilometers south of Engaru-machi, the plant-bearing deposits unconformably overly rhyolite, and are locally and narrowly distributed. They are composed mainly of tuffaceous siltstone and sandstone diatomaceous, and tuff, and are closely similar to the Kamatsuzawa formation near Rubeshibe-machi. The tuffaceous and diatomaceous siltstone contains numerous plant fossils, though most of them are fragmentary. The occurrence of plant fossils from these rocks has been known since 1920, but no floral list has been reported. In the summer of 1960 N. SUZUKI made collections at three localities near Ikutawara-machi, as shown in Figure 1.

There are only 11 species represented among the 46 specimens collected, as follows:

Salicaceae
- *Salix parasachalinensis* new species
- *Salix crenatoserrulata* new species

Betulaceae
- *Alnus protohirsuta* ENDO
- *Betula miomaximowicziana* ENDO
- *Carpinus stenophylla* NATHORST
- *Fagus protojaponica* K. SUZUKI
- *Quercus protodentata* TANAI and ONOE

Ulmaceae
- *Ulmus protojaponica* TANAI and ONOE

Cercidiphyllaceae
- *Cercidiphyllum crenatum* (UNGER) BROWN

Aceraceae
- *Acer protojaponicum* TANAI and ONOE
- *Acer subpictum* SAPORTA

All of these species are included in the Shanabuchi and Rubeshibe floras.

Betula miomaximowicziina, Fagus protojaponica, Cercidiphyllum crenatum, and *Acer subpictum* are comparatively abundant; the remaining species are poorly represented. It is difficult to compare the Ikutawara flora with the preceding floras because of its limited size. Abscence of exotic or southern elements suggests that it is of same age as the Rubeshibe flora; this is supported by the stratigraphic relationships and lithology of the plant-bearing rocks.

CORRELATION AND AGE

The precise age of Tertiary formations in northeastern Hokkaido has long been a subject of controversy, and various suggestions regarding correlation have been made. Uncertainties in age evaluation have been due mainly to the lack of adequate paleontologic evidence, and also to insufficient investigation of the stratigraphy in surrounding areas. With the discovery of the Rubeshibe flora, and full investigation of previously known Shanabuchi, it is hoped that sufficient evidence may be available to establish their age relationships.

STRATIGRAPHIC EVIDENCE

The Shanabuchi formation was originally considered to be of Early Pliocene age. This assignment was based on its terrestrial phase, and on the age implication of a small molluscan fauna recoverd from the unconformably underlying Konomai group (TAKAHASHI et al., 1936; TAKEUCHI, 1942). Many geologists (SASA and INOUE, 1939; UOZUMI and FUJIE, 1958, p. 30) have considered that the Shanabuchi formation is correlative with the Lower Pliocene Takikawa group of terrestrial origin, which is widely distributed in central Hokkaido, and that there is a great hiatus between the Konomai and Shanabuchi groups. The molluscan fauna from the Konomai group is not similar to that of the Kunnui formation of southwestern Hokkaido and the Takinoue formation of central Hokkaido, which are of typical Middle Miocene age (UOZUMI, 1962, p. 520-523); it is considered slightly younger, and to be upper Middle Miocene in age. It may be noted that the Shanabuchi formation is closely similar to the upper part of the Konomai group in lithology and structure; the break between these two seems not to be great, though there was a definite erosional interval. According to the current survey by SAWAMURA and HATA (1962, p. 18) the Okedo formation, which is the southern extension of the Shanabuchi group, is stratigraphically contemporaneous with the Ainonai formation; its marine molluscan fauna is correlative with the Upper Miocene Atsunai fauna, which was reported from the Chokubetsu formation of the Kushiro coal field, southeastern Hokkaido (TANAI, 1957, pp. 25-31, 1961, p. 31; UOZUMI, 1962, p. 527). Accordingly, it is appropriate to conclude on the basis of its stratigraphic relationships that the Shanabuchi formation is Late Miocene in age. The Shanabuchi formation oversteps the Mesozoic in the east of Engaru-machi, and is covered by a rhyolite flow. The Samakesaroma plant-bearing formation lies directly on the Mesozoic and is covered by rhyolite flow. Considering the stratigraphic relations and lithology, the Samakesaroma plant-bearing formation is probably correlative with the Shanabuchi.

The terrestrial sediments containing the Rubeshibe flora were originally considered to be Pleistocene in age. This assignment was not based on paleontological evidence, but only on lithology and nearly horizontal structure. The Komatsuzawa formation containing the Rubeshibe flora unconformably overlies the Okedo formation, which is correlative with the Shanabuchi formation, and appears to be younger than the Shanabuchi. Its final age evaluation must be determined on the basis of paleobotanical evidence. The Ikutawara plant-bearing formation is correlated with the Komatsuzawa, on the basis of stratigraphic relationships and lithology.

Table 16. Occurrence of Shanabuchi and Rubeshibe Plants in Other Neogene Floras of Northern Japan.
(×, identical species; ○, closely similar species)

Floras / Species			Miocene													Pliocene					
			Lower				Middle				Upper					Lower			Upper		
	Shanabuchi	Rubeshibe	Ainoura	Kaminokuni	Aniai	Seki	Yoshioka	Abura	Utto	Kamigo	Low. Nenoshiroishi	Gosho	Nishihaga	Obayashi	Takamine	Up. Nenoshiroishi	Shinjo	Koyanaizu	Fukurohara	Upper Sendai	Hanamaki
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21
Abies protofirma	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Picea kaneharai	×	×	…	×	…	…	×	×	×	…	…	…	…	…	…	…	…	…	…	×	…
Pinus sp.	×	..	…	…	…	…	○	○	○	…	…	…	…	…	…	…	…	○	…	…	○
Tsuga oblonga	×	×	…	…	…	…	…	○	…	…	…	○	…	…	…	…	…	…	…	…	…
Taiwania japonica	×	…	…	…	…	…	×	…	×	…	…	×	…	…	…	…	…	…	…	…	…
Juniperus honshuensis	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Thuja nipponica	×	×	…	…	…	…	…	×	…	…	×	×	…	…	…	…	×	…	…	…	…
Disporum ezoanum	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Smilax trinervis	×	…	…	…	…	…	×	…	×	…	…	…	×	×	×	…	×	×	×	…	○
Populus kitamiana	×	×	…	…	…	…	…	…	…	…	…	…	○	…	○	…	…	…	…	…	○
Populus kobayashii	×	…	…	…	○	○	○	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Populus balsamoides	…	×	…	…	…	…	…	…	…	○	○	○	○	×	×	○	…	…	…	…	…
Salix hokkaidoensis	×	…	…	…	…	…	…	…	…	…	…	…	×	…	○	…	…	…	…	…	…
Salix parasachalinensis	×	…	○	…	○	○	○	…	…	…	…	…	×	…	…	…	…	…	…	…	…
Salix kitamiensis	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Salix misaotatewakii	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Salix crenatoserrulata	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Juglans japonica	×	…	○	…	×	…	…	…	×	…	×	○	…	…	×	×	…	×	○	×	○
Pterocarya asymmetrosa	×	…	×	×	×	×	…	…	×	×	×	○	×	…	…	×	…	×	○	…	…
Pterocarya protostenoptera	×	…	…	…	…	…	…	…	…	…	…	…	…	×	…	…	…	…	…	…	…
Alnus miojaponica	×	…	…	×	…	…	×	×	×	×	…	…	×	…	×	…	…	×	×	×	×
Alnus protohirsuta	×	×	…	…	…	…	○	…	…	…	×	…	×	…	×	…	…	…	…	…	…
Alnus protomaximowiczii	×	×	×	…	…	○	×	×	×	…	×	×	…	…	…	…	…	…	…	…	…
Alnus subfirma	×	…	…	…	…	…	…	…	…	…	×	×	…	…	…	…	…	…	…	…	…
Betula miomaximowicziana	…	×	…	…	…	…	…	…	…	…	×	×	…	×	×	…	…	…	…	…	…
Betula onbaraensis	…	×	…	…	…	…	…	…	…	…	○	×	×	…	…	…	…	×	…	…	…
Betula protoermani	×	×	…	…	…	○	○	○	…	…	×	×	×	×	×	…	…	…	…	…	…
Carpinus stenophylla	×	…	…	×	…	…	…	…	…	…	×	×	…	×	×	×	×	…	…	…	…
Carpinus subcordata	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×	…	…	…	…	…
Carpinus subyedoensis	×	…	…	×	×	×	×	×	×	…	×	×	×	…	×	×	×	×	…	…	…
Corylus sp.	…	×	○	○	…	○	○	○	…	…	○	…	…	…	○	…	…	…	…	…	○
Ostrya shiragiana	…	×	…	×	…	…	…	…	○	…	×	○	×	…	×	×	…	×	…	…	…
Fagus palaeocrenata	×	×	…	…	…	…	…	…	…	…	×	×	×	×	×	×	×	×	…	○	…
Fagus protojaponica	×	×	○	○	○	○	…	○	○	○	×	×	×	×	×	×	…	×	…	…	○
Quercus protodentata	…	×	…	…	…	…	…	…	…	…	○	…	…	×	…	×	×	×	…	…	…
Celtis nordenskioldii	×	×	…	…	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…
Celtis miobungeana	×	…	○	○	…	…	…	…	…	×	…	…	×	×	…	…	…	…	…	…	…
Ulmus miopumila	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	○	…
Ulmus protojaponica	×	×	○	○	○	○	○	○	○	…	…	○	×	×	×	×	×	×	…	…	…
Zelkova ungeri	×	…	×	×	×	…	×	×	×	×	×	×	×	×	×	×	×	×	×	×	×
Polygonum megalophyllum	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Rumex ezoensis	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Cercidiphyllum crenatum	×	…	×	×	…	×	×	×	…	…	×	…	…	…	×	…	…	…	…	…	…
Magnolia elliptica	×	×	…	…	…	…	…	…	…	…	…	…	○	○	…	…	…	○	○	…	○
Cinnamomum sp.	×	…	…	…	…	…	…	…	○	○	…	○	○	…	…	…	○	○	…	…	…
Hamamelis protojaponica	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Liquidambar miosinica	×	…	×	…	…	…	×	…	×	×	…	×	×	…	…	…	×	…	…	×	…
Crataegus sugiyamae	×	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…

Table 16—(*Coutinned*)

Floras / Species			Miocene													Pliocene					
			Lower				Middle				Upper					Lower			Upper		
	Shanabuchi	Rubeshibe	Ainoura	Kaminokuni	Aniai	Seki	Yoshioka	Abura	Utto	Kamigo	Low. Nenoshiroishi	Gosho	Nishihaga	Obayashi	Takamine	Up. Nenoshiroishi	Shinjo	Koyanaizu	Fukurohara	Upper Sendai	Hanamaki
	1	2	3	4	5	6	7	3	9	10	11	12	13	14	15	16	17	18	19	17	18
Prunus ishidai	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Prunus protossiori	×	×	…	…	…	…	…	…	…	…	×	×	…	…	×	…	…	…	…	…	…
Prunus rubeshibensis	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Prunus subserotina	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Rubus sp.	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Sorbus lanceolata	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Sorbus protoalnifolia	×	…	…	…	…	…	…	…	…	…	×	×	…	…	…	…	…	…	…	…	…
Sorbus uzenensis	×	…	…	…	…	×	…	×	…	…	…	×	…	…	…	…	…	…	…	…	…
Spiraea protothunbergi	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Cladrastis chaneyi	×	×	…	…	…	…	…	…	○	…	…	…	…	…	…	…	…	…	…	…	…
Gleditsia miosinensis	×	×	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…	…	…
Wisteria fallax	×	…	…	…	…	…	…	…	×	…	…	×	…	…	…	…	…	○	…	○	…
Phellodendron mioamurense	×	…	…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Ailanthus yezoense	×	…	…	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…	…
Rhus miosuccedanea	×	×	…	…	…	…	…	…	×	×	…	…	…	…	…	…	…	…	…	…	…
Rhus protoambigua	×	×	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…	…	…
Acer palaeodiabolicum	…	×	…	…	×	…	×	…	…	×	×	×	×	×	×	×	…	…	×	×	…

Acer palaeorufinerve		…	×	…	×	…	…	×	…	…	…	×	×	…	…	…	×	…	…	…	…	…
Acer protojaponicum		×	×	…	×	…	×	×	×	…	…	×	…	…	…	…	…	…	…	…	…	…
Acer pseudocarpinifolium		×	×	…	…	…	…	…	…	…	…	×	…	…	…	…	×	…	…	…	…	…
Acer pseudoginnala		…	×	…	…	…	○	×	…	…	×	…	×	…	…	…	…	…	…	…	…	…
Acer subpictum		×	×	…	×	×	×	×	×	×	×	×	×	…	…	×	×	×	×	×	…	…
Acer subukurunduense		…	×	…	…	…	○	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Acer yabei		×	×	…	…	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…
Acer sp.		…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Aesculus majus		×	…	…	…	×	…	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…
Zizyphus miojujuba		×	…	…	…	…	…	×	…	×	…	…	…	×	…	…	…	…	○	…	…	…
Vitis naumanni		×	×	…	…	×	○	…	…	○	…	…	…	…	…	○	…	…	…	×	…	…
Stewartia okutsui		×	×	…	…	…	…	…	…	…	…	×	○	○	…	○	…	○	○	○	…	…
Aralia subelata		×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Kalopanax acerifolius		×	…	…	…	…	…	…	…	…	…	×	…	…	…	…	…	…	…	…	…	…
Cornus subkousa		×	…	…	…	…	…	…	…	…	…	…	…	○	×	…	…	×	…	…	×	…
Cornus megaphylla		…	×	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Clethra maximowiczii		×	×	…	…	…	…	…	…	…	…	×	○	…	×	○	…	…	…	…	…	…
Rhododendron tatewakii		×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Diospyros sublotus		×	×	…	…	…	…	○	…	○	○	…	○	…	…	…	…	…	…	…	…	…
Forsythia kitamiensis		×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Fraxinus k-yamadai		×	…	…	…	…	…	…	○	…	…	…	…	…	…	…	…	…	…	…	…	…
Lonicera sp.		…	×	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…
Shanabuchi	identical			5	11	8	8	18	13	17	9	24	16	14	11	17	11	10	10	5	4	2
	closely similar			5	3	4	6	8	6	7	3	0	5	5	1	3	2	2	6	4	4	1
Rubeshibe	identical			3	6	4	3	10	7	7	5	20	13	9	10	11	9	5	7	3	1	0
	closely similar			3	4	2	7	8	6	6	2	4	7	4	1	4	1	1	2	2	2	0
Shanabuchi-identical		70		19				24				37					16			7		
Rubeshibe-identical			50	9				12				24					12			4		

EVIDENCE OF FLORAL COMPOSITION

The composition of any flora is the end result of the interweaving of many complex factors; for instance, it is greatly influenced by latitude, altitude, age, position with respect to continental masses, site as related to regional and local topography, and the known evolutional and distributional history. The author (1963, p. 96) have already noted in the case of Middle Miocene floras of southwestern Hokkaido that floral composition varies at different altitudes and latitudes. Since the floras here under consideration are situated in the northeastern extreme of Japan, we must take their geographic position into full account in our evaluation of age.

A method commonly used to indicate age relationships is to show in tabular form the occurrence of species at other localities, and this procedure may have some merit when it is used within restricted area. The distribution of the Shanabuchi and

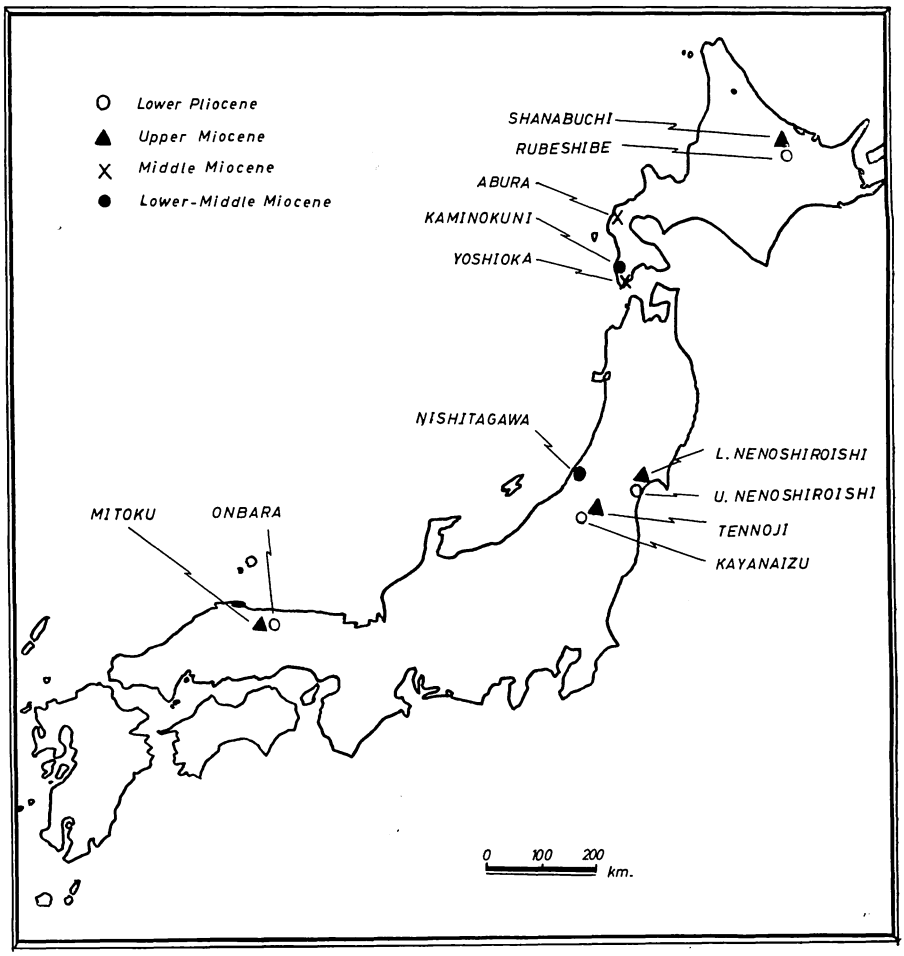


Figure 2. Localities of Principal Neogene Floras in Japan.

Rubeshibe species in principal Neogene floras of northern Japan is shown in Table 16; the location of these floras is indicated in Figure 2. The Shanabuchi flora shows the higher number of species in common with Middle to Upper Miocene floras such as the Yoshioka, the Utto, the Lower Nenoshiroishi, and the Takamine floras. The Rubeshibe flora shows the higher number of species in common with Middle to Upper Miocene floras such as the Yoshioka, the Lower Nenoshiroishi, the Gosho, and to such Lower Pliocene floras as the Koyanaizu and the Upper Nenoshiroishi. This comparison does not indicate conclusively the age of the Shanabuchi and Rubeshibe floras. Such vagueness of age evaluation is due mainly to regional differences in composition, insufficient collection of the floras already described, and partly to stratigraphically wide-ranging species.

One of the weaknesses in interpreting such numerical evidence is that fossil floras vary greatly in size. As a result there may be found in common more species of a large than of a small flora when comparisons are made to the flora whose age is to be determined. Admitting some sources of error, we find that the Shanabuchi flora shows its closest relation to those of Late Miocene age, with 37 species in common, as compared to Middle Miocene floras with 24 species in common, and Early Pliocene floras with 16 species in common. So far as the relationships shown in Table 16 are concerned, the age of the Shanabuchi may tentatively be indicated as Late Miocene.

Similar comparisons with the Rubeshibe show that it has only 12 species in common with Middle Miocene floras, and an equal number with Early Pliocene floras. Twenty-four Rubeshibe species have been recorded from floras of Late Miocene age. On this basis alone we might conclude that the age of the Rubeshibe flora is also Late Miocene, though an age is younger than the Shanabuchi is indicated on stratigraphic grounds, as above noted. In northeastern Honshu and Hokkaido the occurrence of Neogene plants is well known, but most of the floras studied in detail are of Middle to Late Miocene age, and few are Pliocene. These Pliocene floras are generally small, and have been investigated mainly on the basis of reproductive organs such as seeds, cones, fruits and pollen; in relatively few cases are there leaves to provide a basis for comparison with Rubeshibe flora. As a result, the writer does not believe that the age relationships of the Rubeshibe can be accurately determined by comparisons of species occurrence like those given in Table 16, and he is turning to other lines of evidence for indicating age.

One of the most productive means of dating fossils of any age or kind is to determine their position in a well established trend whose time-coverage is known. Care must be taken to select a trend which is progressive, or whose reversals can be readily detected. Such a trend has been recognized by the writer (1961, p. 200-233) in the changes in representation of the Japanese and the Chinese Components in the Neogene floras of Japan. These floras are composed largely of species whose modern equivalents are living in Japan proper, and in China including Formosa. Sufficient information is now at hand to indicate a gradual reduction in representation of the Chinese Component from Early Miocene to the present, and an increase in the Japanese Component. The North American Elements are not used in these comparisons, since their representation is too low to be statistically adequate. Table 17 shows the percentage representation of the Asiatic Element in 11 floras from Hokkaido and Honshu, ranging in age from Early Miocene to Early Pliocene. In the preparation of this table the writer has used only those species whose modern relationships are well established, and have omitted aquatics because of their wide distribution in time and space. When there is more than one living species showing similarity to a fossil species, the more similar is used. When fossil species have living equivalents in both Components, they are scored as members of each.

To allow for some variation which may have resulted from differences in contemporary vegetation, the author has averaged the percentage scores of the Lower Middle Miocene floras (Kaminokuni, Nishitagawa), the Middle Miocene (Abura, Yoshioka), the Upper Miocene (Tennoji, Lower Nenoshiroishi, Mitoku, Gosho), and the Early Pliocene (Koyanaizu, Onbara, Upper Nenoshiroishi) at the bottom of Table 17. The Shanabuchi flora, with 70 per cent of its members belonging to the Japanese Component,

Table 17. Percentages of Element Representation in Neogene Floras of Japan.

Floras*	Japanese	Chinese
Lower-Middle Miocene		
Kaminokuni (40)	55	65
Nishitagawa (31)	52	61
Middle Miocene		
Abura (50)	54	56
Yoshioka (79)	49	58
Upper Miocene		
Tennoji (36)	67	53
Lower Nenoshiroishi (60)	78	50
Mitoku (39)	77	54
Gosho (61)	74	51
Lower Pliocene		
Koyanaizu (43)	84	54
Onbara (36)	86	52
Upper Nenoshiroishi (37)	89	46
Averages:		
Lower-Middle Miocene	53	63
Middle Miocene	51	57
Upper Miocene	74	52
Lower Pliocene	86	51

* The number of species in each flora is shown in Parentheses.

and with 50 per cent belonging the Chinese, can readily be placed in the Neogene sequence at the Upper Miocene level. The Rubeshibe flora shows a great increase in representrtion of species assignable to the Japanese Component, with 84 per cent; its percentage of Chinese species is reduced to 44 per cent; on this basis it falls in the Early Pliocene group of floras.

As previously indicated, the Rubeshibe and Shanabuchi floras are largely composed of the members of such typically temperate families as the Salicaceae, Betulaceae, Fagaceae, Ulmaceae, Rosaceae and Aceraceae. Many of the genera and some of the species have been found in older rocks, chiefly in the Middle and Lower Miocene of Japan. But in general species in the floras here under consideration have a more modern aspect than of Middle and Early Miocene plants, and seem more closely related to the existing vegetation of Japan. As compared with Middle Miocene floras, they include greater diversity in species of Salicaceae and Rosaceae. This relation is also to be seen in the Late and Mio-Pliocene floras of western North America (AXELROD, 1956, 1957), and in the Late Miocene floras of Europe (ANDREANSZKY, 1959; BERGER, 1953). A significant difference in composition between the Shanabuchi and the Rubeshibe floras is the precence of warm-temperate and exotic genera in the Shanabuchi, as above noted. Such genera as *Ailanthus*, *Cinnamomum*, *Diospyros*, *Liquidambar*, *Taiwania* and *Zizyphus* are well-represented in Middle Miocene floras of Japan; they are present but not represented by many specimens in the Shanabuchi, and are absent in the Rubeshibe. Having in mind the well-established climate trend toward cool-temperate climate from Middle Miocene to Pliocene time, the Late Miocene age of the Shanabuchi flora, and the Early Pliocene age of the Rubeshibe flora, are confirmed. The latter is closely similar to the Shinjo-type flora (TANAI, 1961, pp. 185-190), of Early Pliocene age.

SUMMARY

In the Tertiary section of northeastern Hokkaido, where the lower part of sediments contains only small molluscan faunas, and where extrusive rocks provide little evidence of age, plant fossils must carry the principal burden of age determination. Following are the basis for assigning the Shanabuchi flora to the Upper Miocene, and the Rubeshibe to the Lower Pliocene:

1. Stratigraphic relationships indicate that the Shanabuchi flora is younger than the Middle Miocene, and that the Rubeshibe flora is younger than the Shanabuchi and older than the Pleistocene.

2. Table 16 shows that both the Shanabuchi and the Rubeshibe floras have the highest number of species in common with floras of Late Miocene age in northern Japan. While it indicates that both these floras are younger than Middle Miocene, it does not provide an adequate basis for comparing them with floras of Pliocene age, since floras of this age are little known.

3. It is possible to distinguish between the Shanabuchi flora and the Rubeshibe on the basis of their representation of members of the Central China Upland Component, as indicated in Table 17. In its reduced representation of Chinese plants, and its greater number of plants whose modern equivalents live in Japan, the Rubeshibe flora falls into the group of Early Pliocene floras listed. In the same way, the Shanabuchi flora is shown to be younger than the common Middle Miocene floras of northern Japan by its increased amount of Japanese representation and its reduced number of species whose modern equivalents live in central China.

4. Exotics also provide a basis for determining, by their sparse representation, that the Shanabuchi flora is younger than Middle Miocene, and older than the Rubeshibe flora from which these plants are wholly absent.

On this basis of their stratigraphic occurrence and composition, the Samakesaroma flora appears to be contemporaneous with the Shanabuchi, and the Ikutawara flora is considered to be of approximately the same age as the Rubeshibe.

CONCLUSION

The two major and two minor floras of the Late Tertiary of northeastern Hokkaido are divided into two groups on the basis of their geologic occurrence, composition, paleoecology and age.

Following deposition of the marine Middle Miocene, gradual uplift of the Kitami massif joining with the backbone range of central Hokkaido brought on terrestrial environment in central Kitami region during Late Miocene time, and eastward withdrawal of the sea; the Shanabuchi and Samakesaroma plant-bearing sediments were deposited in inland lakes on this expanded land area. The Shanabuchi and Samakesaroma floras represent a temperate forest which lived on the borders of these lakes and on adjacent slopes; this forest seems to have covered a range in altitude from 300 to 1000 meters. Late Miocene climate indicated by the flora appears to have been typically temperate, and to have been lower in temperature than during Middle Mioccene time. As described by UOZUMI (1962, p. 535), the Late Miocene sea of northeastern Hokkaido had a temperate current occupying the nearshore area, whereas a cold current occupied the off-shore area, judging from the Later Miocene invertebrate faunas in this region. Lowered temperature in the Late Miocene seems to have been resulted in elimination or southward migration of warm-temperate trees, which flourished on lowlands during Middle Miocene time; on the other hand, it probably accelerated the appearance of new species of typical cool-temperate trees in such families as the Salicaceae, Betulaceae, Fagaceae, and Rosaceae.

Early Pliocene sea regressed entirely southward from northeastern Hokkaido, and a cold current, indicated by the Honbetsu fauna, reached only the Kushiro area of southeastern Hokkaido. The Rubeshibe and Ikutawara floras represent a cool-temperate forest which lived on the borders of upland lakes and their adjacent slopes. Several exotic and southern trees which had barely survived into Late Miocene time, were eliminated from these Early Pliocene forests. Gradual lowering temperature since Late Miocene time is already stated by the author (TANAI, 1961, pp. 241-243), observed in the whole of Japanese archipelago, and also in western North America, both of which border the Pacific.

BIBLIOGRAPHY

ANDREANSZKY, C. 1959. Die Flora der Sarmatischen Stufe in Ungarn. *Akademia Kiado, Budapest.*

AXELROD, D. I. 1950. Studies in Late Tertiary paleobotany. *Carn. Inst. Wash. Publ. 590.*

1956. Mio-Pliocene floras from west-central Nevada. *Univ. Calif. Publ. Geol. Sci., vol. 33,* pp. 1-322.

1957. Late Tertiary floras and the Sierra Nevada uplift. *Bull. Geol. Soc. Amer., vol. 68,* pp. 19-46.

1958. The Pliocene Verdi flora of western Nevada. *Univ. Calif. Publ. Geol. Sci., vol. 34,* pp. 91-160.

BECKER, H. F. 1960. The Tertiary Mormon Creek flora from the Upper Ruby basin in southwestern Montana. *Palaeontgr. B., vol. 107,* pp. 83-126.

BERGER, W. 1953. Die altpliozäne Flora der Congerienschichten von Brunn-Vösendorf bei Wien. *Palaeontogr. B., vol. 92.*

BERRY, E. W. 1916. The Lower Eocene floras of southeastern North America. *U. S. Geol. Surv. Prof. Pap. 91.*

BROWN, R. W. 1935. Miocene leaves, fruits and seeds from Idaho, Oregon and Washington. *Jour. Paleont., vol. 9,* pp. 572-585.

CHANEY, R. W. 1944. The Dalles flora. *Carn. Inst. Wash. Publ. 553,* pp. 285-322.

1948. The bearing of the living *Metasequoia* on problems of Tertiary paleobotany. *Proc. Nat. Acad. Sci., vol. 34,* pp. 503-515.

1952. Conifer dominants in the Middle Tertiary of the John Day Basin, Oregon. *The Palaeobotanist, vol. 1,* pp. 105-114.

1959. Miocene floras of the Columbia Plateau. Part I. Composition and interpretation. *Carn. Inst. Wash. Publ. 617,* pp. 1-134.

CHANEY, R. W. and D. I. AXELROD 1959. Miocene flora of the Columbia Plateau. Part II. Systematic cosiderations. *Carn. Inst. Wash. Publ. 617,* pp. 135-224.

CHU, K. and W. S. COOPER 1950. An ecological reconnaissance in the native home of *Metasequoia glyptostroboides. Ecol., vol. 31,* no. 2, pp. 260-278.

DORF, E. 1936. A Late Tertiary flora from southwestern Idaho. *Carn. Inst. Wash. Publ. 476, II.,* pp. 73-124.

ENDO, S. 1940. A Pleistocene flora from Siobara, Japan. *Sci. Rep. Tohoku Univ., ser. 2, vol. 21,* pp. 47-80.

1950. On the fossil *Acer* from Japan, Korea and south Manchuria. I. *Short Papers IGPS, no. 1,* pp. 51-57.

1955. Icones of fossil plants from Japanese Islands. (in Japanese). *Sangyo-Tosho, Tokyo.*

FLORIN, R. 1920. Zur Kenntnis der jungtertiären Pflanzenwelt Japans. *Kgl. Vet. Akad. Handl., vol. 61,* pp. 1-71.

GOEPPERT, H. R. 1855. Fossil Flora von Schossnitz.

HARA, H. 1959. An outline of the phytogeography of Japan. *Distribution Maps of Flowering Plants in Japan. Part 2.*

HARA, H. and M. MIZUSHIMA 1954. Vegetation of the Ozegahara moor and its surrounding district, central Japan, and list of vascular plants of the Ozegahara moor and its

surrounding districts. *Sci. Research Ozegahara Moor*, pp. 401-479.
HEER, O. 1868-1883. Flora fossils Arctica. *Zurich. 7 vols.*
HOLLICK, A. 1936. The Tertiary flora of Alaska. *U.S. Geol. Surv. Prof. Paper 182.*
HONDA, S. 1928. The forest zones of Japan. (in Japanese). *Tokyo.*
HORIKAWA, Y. 1930. The vegetation of Mt. Hakkoda. *Sci. Rep. Tohoku Imp. Uniu., Ser. 4, vol. 5*, pp. 555-571.
HORIKAWA, Y. and H. ANDO 1954. Studies of the forest communities in the Ozegahara moor. *Sci. Research Ozegahara Moor*, pp. 269-287.
HORIKAWA, Y. and Y. SASAKI 1954. On the forest communties developed around the Ozegahara moor. *Sci. Research Ozegahara Moor*, pp. 288-304.
1959. Phytosociological studies on the vegetation of Geihoku-district, Hiroshima Prefecture. (in Japanese, with English summary). *Sci. Research Sandankyo Gorge and Yawata Highland*, pp. 85-107.
HOUGH, R.B. 1950. Handbook of the Trees of the Northern States and Canada. *MacMillan Co., New York.*
HU, H.H. and R.W. CHANEY 1938. A Miocene flora from Shantung Province, China. *Palaeont. Sinica new. ser. A., no. 1*, pp. 1-82.
HUZIOKA, K. 1954. Notes on some Tertiary plants from Tyosen (Korea). *Trans. Proc. Palaeont. Soc. Japan N.S., no. 13*, pp. 117-123.
1963. The Utto flora of northern Honshu. *Tertiary Floras of Japan, I. 3.* pp. 153-216.
HUZIOKA, K. and K. SUZUKI 1954. The flora of the Shiotsubo formation of the Aizu lignitefield, Hukushima Prefecture, Japan. *Trans. Proc. Palaeont. Soc. Jap. N.S., no. 14*, pp. 133-142.
HUZIOKA, K. and S. NISHIDA 1960. The Seki flora of the Island of Sado, Japan. (in Japanese). *Publ. Sado Mus., no. 3.*
IKEBE, N. 1956. Cenozoic geohistory of Japan. *Proc. 8th Pacific Congr., vol. 2*, pp. 446-456.
ISHIKAWA, T. et al. 1962. Geological report on the Onneyu Spa. (in Japanese). *Survey Rep. Hot-springs in Hokkaido, no. 19*, pp. 57-67.
KITAMURA, N. 1959. Tertiary orogenesis in Northeast Honshu, Japan. (in Japanese, with English summary). *Contr. Inst. Geol. Palaeont. Tohoku Univ., no. 49.*
KNOWLTON, F.H. 1898. The fossil plants of the Payette formation. *U.S. Geol. Surv. 18th Ann. Rept., pt. 3*, pp. 194-196.
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.
KONNO, E. 1931. Cenozoic flora in the central part of Shinano, Japan. (in Japanese). *Geology of Central Shinano (edit. by* HONMA).
KOVATS, J. 1856. Die fossil flora vón Erdöbenye. *Art. Geol. Ges. Ungarn, vol. 1.*
KRÄUSEL, R. 1917. Die Pflanzen des Schlesischen Tertiärs. *Jahrb. König. Preus. Geol. Land., vol. 38*, pp. 1-338.
KRYSHTOFOVICH, A. et al. 1956. The Oliocene flora from Ashutus region of Kazahkstan. (in Russian). *Palaeobotanica, fasc. 1.*
LAMOTTE, R.S. 1935. An Upper Oligocene florule from Vancouver Island. *Carn. Inst. Wash. Publ. 455*, pp. 49-56.
MACGINITIE, D.H. 1933. The Trout Creek flora of southeastern Oregon. *Carn. Inst. Wash. Publ. 416*, pp. 21-68.
1953. Fossil plants of the Florissant Beds, Colorado. *Carn. Inst. Wash. Publ. 599.*
MAEDA, T. and Y. SHIMAZAKI 1951. Studies on the vegetation of Chichibu mountain forest (1) The plant communities of the subalpine and alpine zones. (in Japanese, with English summary). *Bull. Tokyo Univ. Forests, no. 39*, pp. 171-184.
MAEDA, T. and J. YOSHIKA 1952. Studies on the vegetation of Chichibu Mountain forest. (2) The plant communities of the temperate mountain zones. (in Japanese, with English summary). *Bull. Tokyo Univ. Forests, no. 42*, pp. 129-150.
MATSUO, H. 1963. The Noto-Nakajima flora of Noto peninsula. *Tertiary Floras of Japan, I. 4,*

pp. 219-243.
MIKI, S. 1937. Plant fossils from the Stegodon beds and Elephas beds near Akashi. *Jap. Jour. Bot., vol. 8,* pp. 303-341.
1941. On the change of flora in eastern Asia since the Tertiary Period (1). The clay or lignite beds flora in Japan with special reference to the *Pinus trifolia* beds in Central Hondo. *Jap. Jour. Bot. vol. 11,* pp. 237-303.
1956. Seeds remains of Vitaceae in Japan. *Jour. Inst. Polytech. Osaka City Univ., ser. D, vol. 7,* pp. 247-271.
1957. Pinaceae of Japan, with special referece to its remains. *Jour. Inst. Polytech. Osaka City Univ., ser. D, vol. 8,* pp. 221-272.
MORITA, H. 1931. On new species of the genera *Cinnamomum* and *Smilax* from the Miocene deposits of Okuni-machi, Uzen province, Japan. *Jap. Jour. Geol. Geogr., vol. 9,* pp. 1-8.
MURAI, S. 1962. Geology and paleobotany of the Shizukuishi basin, Iwate Prefecture, Japan. Part I, II-1. *Rep. Tech. Iwate Univ,. vol. 15, no. 1,* pp. 131-193; *no. 2,* pp. 1-34.
NAKAI, T. 1928. Report on the vegetation of Kamikochi of the province of Shinano. (in Japanese). *Survey Rep. Nat. Monum.,* pp. 1-46.
NAKANO, H. 1942. Composition of the forest communities of the subalpine forest zone in central Honshu. (in Japanese). *Shokubutsu-Seitai-Gakuho, vol. 2, no. 1,* pp. 1-17.
1942. Composition of the forest communities of the deciduous broad-leaved forest zone of Honshu. (in Japanese). *Shokubutsu-Seitai-Gakuho., vol. 2, no. 2,* pp. 57-72.
NATHORST, A.C. 1883. Contribution à la flore fossile du Japon. *Kgl. Svesk. Vet. Akad. Handl., vol. 20,* pp. 3-92.
1888. Zur fossilen Flora Japans. *Pal. Abhandl. vol. 4,* pp. 197-250.
OHWI, J. 1956. Flora of Japan. (in Japanese). *Shibundo, Tokyo.*
OISHI, S. and K. HUZIOKA 1942. On Ailanthus from the Miocene of Hokkaido. (in Japanese). *Jour. Geol. Soc. Jap., vol, 49* pp. 180-182.
1943. Tertiary *Acers* from Hokkaido and Karahuto. *Jour. Fac. Sci. Hokkaido Univ. ser. 4, vol. 7,* pp. 81-101.
1954. Tertiary Ulmaceae from Hokkaido and Karahuto. *Jap. Jour. Geol. Geogr., vol. 24,* pp. 123-144.
OKUTSU, H. 1940. Fossil plants from the Nenoshiroishi plant beds. *Saito Ho-on-kai Mus. Res. Bull., no. 19,* pp. 153-169.
1955. On the stratigraphy and palaeontology of the Cenozoic. *ser. 2, vol. 26,* pp. 1-114.
OTAGAKI, T. 1951. Geology and ore deposits of the Numanoue mine in Kitami district. (in Japanese). *Bull. Geol. Comm. Hokkaido, no, 18,* pp. 5-17.
SARGENT, C.C. 1922. Manual of the trees of North America. *Houghton Mifflin Co.*
SASA, Y. and T. INOUE 1939. Tertiary stratigraphy near Abashiri-machi, Kitami province. (1). (in Japanese). *Jour. Assoc. Petrol. Tech., vol. 7,* pp. 418-429.
SAWAMURA, K. and M. HATA 1962. Preliminary note on the geological map of Rubeshibe. (in Japanese). *Abstract of lectures, Hokkaido Branch, Geol. Surv. Jap., no. 14,* pp. 17-18.
SUDWORTH, G.B. 1908. Forest trees of the Pacific Slope. *U.S. Depart. Agr., Forest Serv.*
SUZUKI, K. 1959a. On the flora of the Upper Miocene Tennoji formation in Fukushima basin, Japan, and its palaeoecological aspect. (in Japanese, with English abstract and systematic description). *Monogr. Assoc. Geol. Collab. Jap., no. 9.*
1959b. On the stratigraphical succession of the Miocene and Pliocene flora in the northeastern Honshu (in Japanese). *Cenozoic Research, no. 30,* pp. 1-24.
1961. The important and characteristic Pliocene and Miocene species of plants from the southern part of the Tohoku district, Japan. *Sci. Rep. Fac. Art Sci. Fukushima Univ., no. 10,* pp. 1-95.
SUZUKI, N. 1963. Late Tertiary maples from northeastern Hokkaido, Japan. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol, 11,* pp. 683-694.
SUZUKI, T. 1954. Forest and bog vegetation within Ozegahara basin. *Sci. Research Ozegahara Moor.* pp. 205-268.

TAKAHASHI, Ke. 1943. Studies of the vegetation on the volcano Ontake in Kiso. (in Japanese). *Ecol. Rev. vol. 9,* pp. 75-90.

TAKAHASHI, Ki. 1954. Zur fossilen Flora aus der Oya-formation von Kiushu, Japan. *Mem. Fac. Sci. Kyushu Univ., ser. D, vol. 5, no. 1,* pp. 47-67.

TAKAHASHI, M. 1948. On the plant communities on mountains of Japan. (in Japanese). *Kyodo Shizenkagaku no Kenkyu, 1.* pp. 155-184.

TAKAHASHI, T. et al. 1936. Mineral Resources in Hokkaido. no. 6. (in Japanese). *Bull. Indust. Stat. Hokkaido, no. 60,* pp. 1-58.

TAKEUCHI, K. 1942. Explanatory text of the geological map of Konomai. (in Japanese). *Bull. Geol. Indust. Stat. Hokkaido. no. 6.*

TANAI, T. 1952. Des fossiles végétaux dans le bassin houiller de Nishitagawa, Préfecture de Yamagata, Japon. (1). *Jap. Jour. Geol. Geogr., vol. 22,* pp. 119-135.

1955. Illustrated Catalogue of Tertiary plants in Japanese coal fields. I. Early and Middle Miocene Floras. (in Japanese, with English abstract). *Geol. Surv. Jap. Rep., no. 163.*

1957. Explanatory text of the geological map of Japan, Onbetsu, (in Japanese, with English summary). *Hokkaido Develop. Agency.*

1959. On the formation of the coal-bearing deposits in northeastern Honshu, Japan. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10,* pp. 209-233.

1960. On the fossil beech leaves from the Ningyo-toge area, in the Chugoku district, Japan. *Trans. Proc. Palaeont. Soc. Jap. N.S., no. 37,* pp. 200-207.

1961a. Neogene floral change in Japan. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10,* pp. 119-398.

1961b. Explanatory text of the geological map of Japan, Atsunai. (in Japanese with English summary). *Hokkaido Develop. Agency.*

1963. Miocene floras of southwestern Hokkaido, Japan. 1. Composition and interpretation. *Tertiary Floras of Japan. I. 2.* pp. 1-95.

TANAI, T. and T. ONOE 1959. A Miocene flora from the northern part of the Joban coal field, Japan. *Bull. Geol. Surv. Jap., vol. 10, no. 4,* pp. 261-286.

1961. A Mio-Pliocene flora from the Ningyo-toge area on the border between Tottori and Okayama Prefectures, Japan. *Geol. Surv. Jap. Rep., no. 187.*

TANAI, T. and N. SUZUKI 1960. Miocene maples from southwestern Hokkaido, Japan. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 10,* pp. 551-570.

1961. The Shanabuchi and Rubeshibe floras from northeastern Hokkaido. (preliminary report). (in Japanese). *Abstract of lectures, Hokkaido Branch. Geol. Surv. Jap., no. 13,* pp. 59-62.

1963. Miocene floras of southwestern Hokkaido, Japan. Part 2. Systematic considerations. *Tertiary Floras of Japan. I. 2.* pp. 96-194.

1963. On the genus *Ailanthus* from the Tertiary of Japan. *Trans. Proc. Palaeont. Soc. Jap. N.S. no. 52,* pp. 135-144.

TATEWAKI, M. 1940. Distribution of the forest trees in northern Japan. *Lectures of Soc. Invest. North. Forest.* (in Japanese). *1.* pp. 1-18.

1954. The sketch note of vegetation. (in Japanese) *Nagoya Forest Office.*

1958. Geobotanical Study on the *Fagus crenata* forest in the district of its northern limit. *Tatewaki's Iconography of the vegetation of the natural forest in Japan (IV)* (in Japanese, with English summary).

TATEWAKI, M. et al. 1961a. Vegetation of the deciduous broad-leafed forest along the Ochotsk sea, Prov. Kitami, Hokkaido. *Tatewaki's Iconography of the vegetation of the natural forest in Japan (VI).* (in Japanese, with English summary). *Kitami Forest Office.*

1961b. The forest vegetation along the valley in the forest zone of *Fagus crenata* of Northern Japan. *Tatewaki's Iconography of the vegetation of the natural forest in Japan (VII).* (in Japanese, with English summary). *Bot. Inst. Fac. Agr. Hokkaido Univ.*

UOZUMI, S. 1962. Neogene molluscan fauna in Hokkaido. Part 1. Sequence and distribution of

Neogene molluscan faunas. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 11,* pp. 507-544.

UOZUMI, S. and T. FUJIE 1958. Tentative correlation chart of the Neogene formation in Hokkaido. (in Japanese). *Cenozoic Research, no. 26,* pp. 24-33.

URASHIMA, Y. 1957. Mineralization of central Kitami mining district in Hokkaido Japan. *Jour. Fac. Sci. Hokkaido Univ., ser. 4, vol. 9,* pp. 597-606.

URASHIMA, Y. et al. 1953. Epochs of the igneous activities and mineralization of the central part of Kitami in Hokkaido. (in Japanese). *Bull. Geol. Comm. Hokkaido, no. 21,* pp. 1-14.

WADACHI, K. 1958. Climate of Japan. (in Japanese). *Fuzanbo, Tokyo.*

YOSHIOKA, K. 1937-8. Montane Forests on Mt. Hakkoda 1. On the forests of *Fagus-Sasae* climax zone. (in Japanese). *Ecol. Review. vol. 3,* pp. 187-205; pp. 322-338; *vol. 4,* pp. 27-38.

1938. Montane forests on Mt. Hakkoda 2. On the forest of *Abies mariesi* climax zone. (in Japanese). *Ecol. Review., vol. 4,* pp. 150-158; pp. 352-364.

YUNG, C. 1957. Illustrated manual of Chinese trees and shrubs. (in Chinese) (Rev. Edit.) *Sci. Tech. Publ., Shanghai.*

Abashiri 網走
Engaru-machi 遠軽町
Fumi River 富美川
Ikutawara 生田原
Kami-shanabuchi 上社名渕
Kitami 北見
Monbetsu-gun 紋別郡
Muka River 無加川
Ootmi 大富
Rubeshibe-machi 留辺蘂町
Samakesaroma サマケ佐呂間
Shanabuchi-machi 社名渕町

INDEX OF FOSSIL NAMES

Aesculus majus ······················· 40
Abies protofirma ·························
···· 2; pl. 15, fig. 8; pl. 16, fig. 3.
Acer palaeorufinerve ··················· 38
Acer palaeodiabolicum ···· 37; pl. 10, fig. 3.
protojaponicum ··················· 38
pseudocarpinifolium ·················
···· 38; pl. 10, fig. 8; pl. 11, fig. 1.
pseudoginnala ······· 38; pl. 10, fig. 9.
subpictum ··········· 39; pl. 2, fig. 1a.
subukurunduense ················· 39
yabei ··39; pl. 10, figs, 2, 10; pl. 13, fig. 4.
Acer sp.······························· 40
Ailanthus yezoense ·· 36; pl. 10, figs. 6, 7, 11.
Alnus miojaponica ······ 14; pl. 20, fig. 3.
protohirsuta ·······················
14; pl. 14, figs. 5, 9; pl. 19, figs. 5.
protomaximowiczii ··14; pl. 5, fig. 4; pl.
6, fig. 3; pl. 15, fig. 4; pl. 20, fig. 6.
subfirma ··15; pl. 5, fig. 3a; pl. 10, fig. 5.
Aralia subelata ·········· 42; pl. 2, fig. 9.
Betula miomaximowicziana ···············
···· 16; pl. 16, fig. 1; pl. 17, fig. 1.
onbaraensis ·························
···· 16; pl. 7, fig. 1; pl. 16, fig. 2.
protoermani ········· 17; pl. 16, fig. 6.
Carpinus stenophylla ·····················
···· 18; pl. 8, fig. 4; pl. 19, fig. 3.
subcordata ···························
·· 18; pl. 13, figs. 5, 9; pl. 14, fig. 6.
subyedoensis ·········· 19; pl. 13, fig. 8.
Celtis miobungeana ········ 22; pl. 3, fig. 6.
nordenskioldii ········ 22; pl. 14, fig. 3.
Cercidiphyllum crenatum ·················
···· 26; pl. 12, fig. 4; pl. 19, fig. 2.
Cinnamomum sp. ········ 26; pl. 18, fig. 2.
Cladrastis chaneyi ······················
···· 33; pl. 10, fig. 1; pl. 21, fig. 1.
Clethra maximowiczii ···· 44; pl. 6, fig. 1.
Cornus megaphylla ······ 43; pl. 12, fig. 5.
subkousa ························· 43
Corylus sp. ·············· 19; pl. 15, fig. 7.
Crataegus sugiyamae ······ 28; pl. 3, fig. 4.
Diospyros sublotus ············· 45; pl. 12,
fig. 7; pl. 13, fig. 1; pl. 18, fig. 5.
Disporum ezoanum ······· 5; pl. 20, fig. 1.
Fagus palaeocrenata ·· 20; pl, 16, figs. 4, 5.
protojaponica ··············· 21; pl. 6,
fig. 2; pl. 16, fig. 8; pl. 20, fig. 5.
Forsythia kitamiensis ···· 46; pl. 11, fig. 4.
Fraxinus honshuensis ·· 47; pl. 12, figs. 1, 2.
k-yamadai ··········· 47; pl. 13, fig. 6.
Gleditsia miosinensis ······ 34; pl. 2, fig. 4.
Hamamelis protojaponica ·················
···· 27; pl. 5, fig. 3b; pl. 17, fig. 4.
Juglans japonica ········· 12; pl. 18, fig. 4.
Juniperus honshuensis ······ 5; pl. 5, fig. 5.
Kalopanax acerifolius ···· 43; pl. 20, fig. 2.
Liquidambar miosinica ·· 28; pl. 21, fig. 9.
Lonicera sp.·········· 47; pl. 12, figs. 3, 6.
Magnolia elliptica ······ 26; pl. 11, fig. 2.
Ostrya shiragiana ······· 20; pl. 19, fig. 1.
Phellodendron mioamurense ·············
·· 35; pl. 8, figs. 1, 3; pl. 19, fig. 4.
Picea kaneharai ········ 3; pl. 7, figs. 2, 3.
Pinus sp. ················· 3; pl. 9, fig. 3.
Polygonum megalophyllum ·· 24; pl. 9, fig. 6.
Populus kitamiana ······ 7; pl. 2, figs. 3, 8.
kobayashii.......... 8; pl. 3, figs. 2, 3.
balsamoides ·······················
······ 6; pl. 3, fig. 1; pl. 8, fig. 2.
Prunus ishidai ··························
···· 29; pl. 3, fig. 5; pl. 13, fig. 7.
protossiori ··························
···· 29; pl. 12, fig. 8; pl. 18. fig. 3.
rubeshibensis ························
······ 30; pl. 5, fig. 1; pl. 17, fig. 2.
subserotina ··········· 30; pl. 7, fig. 6.
Pterocarya asymmetrosa ·················
·· 12; pl. 11, fig. 5; pl. 21, figs. 7, 8.
protostenoptera ·· 13; pl. 21, figs. 4, 5.
Quercus protodentata ·· 21; pl. 6, figs. 4, 5.
Rhododendron tatewakii ················
······ 45; pl. 5, fig. 7; pl. 19, fig. 6.
Rhus miosuccedanea ······ 36; pl. 20, fig. 4.
protoambigua ··············· 37; pl. 5,
fig. 2; pl. 8, fig. 5; pl. 17. fig. 3.
Robinia nipponica ········ 34; pl. 5, fig. 6.
Rubus sp.··············· 31; pl. 12, fig. 9.
Rumex ezoensis ······· 25; pl. 9, figs. 2, 5.
Salix crenatoserrulata ···· 8; pl. 15, fig. 2.
hokkaidoensis ·····················
···· 9; pl. 15, fig. 6; pl. 16, fig. 7.
kitamiensis ··························
······ 10; pl. 4, fig. 5; pl. 18, fig. 7.
misaotatewakii ······················

······ 10; pl. 2, fig. 6; pl. 4, fig. 2.
parasachalinensis············ 11; pl. 2, fig. 5; pl. 4, figs. 1, 4a; pl. 15, fig. 1.
Smilax trinervis ·········· 6; pl. 7, fig. 5.
Sorbus lanceolata········ 32; pl. 13, fig. 3.
protoalnifolia········ 32; pl. 21, fig. 3.
uzenensis······························ 33; pl. 10, fig. 4; pl. 18, fig. 1.
Spiraea protothunbergi···· 33; pl. 2, fig. 7.
Stewartia okutsui ························ 42; pl. 14, figs. 7, 8; pl. 20, fig. 7.
Taiwania japonica ········ 4; pl. 7, fig. 4.
Thuja nipponica············ 5; pl. 8, fig. 6.
Tsuga oblonga ········ 4; pl. 15. figs. 3, 5.
Ulmus miopumila ························ 23; pl. 14, fig. 1; pl. 18, fig. 6.
protojaponica························ 23; pl. 2, figs. 1b, 2; pl. 4, fig. 4b, pl. 9, fig. 1; pl. 13, fig. 2; pl. 14, fig. 4.
Vitis naumanni·········· 41; pl. 11, fig. 3.
Wisteria fallax············ 35; pl. 9, fig. 4.
Zelkova ungeri .... 24; pl. 14, fig. 2.
Zizyphus miojujuba···· 40; pl. 21, figs. 2, 6

Plate 1

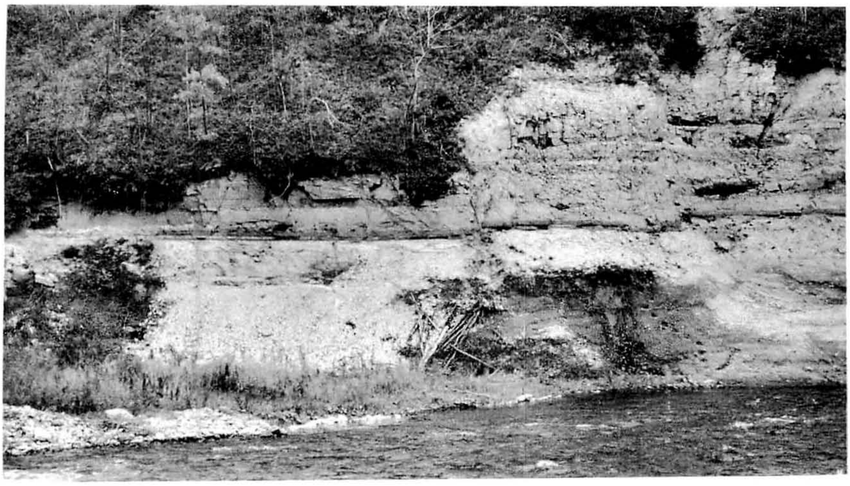
Explanation of Plate 1

Fig. 1. Plant-bearing rocks at Kamishanabuchi locality, Engaru-machi, Monbetsu-gun.
Fig. 2. Plant-bearing diatomaceous siltstone at Ootomi-village, Rubeshibe-machi, Tokoro-gun.
Fig. 3. Broad-leafed forest, about 10 kilometers west of the Kamishanabuchi.

Photo by T. TANAI

1

2



3

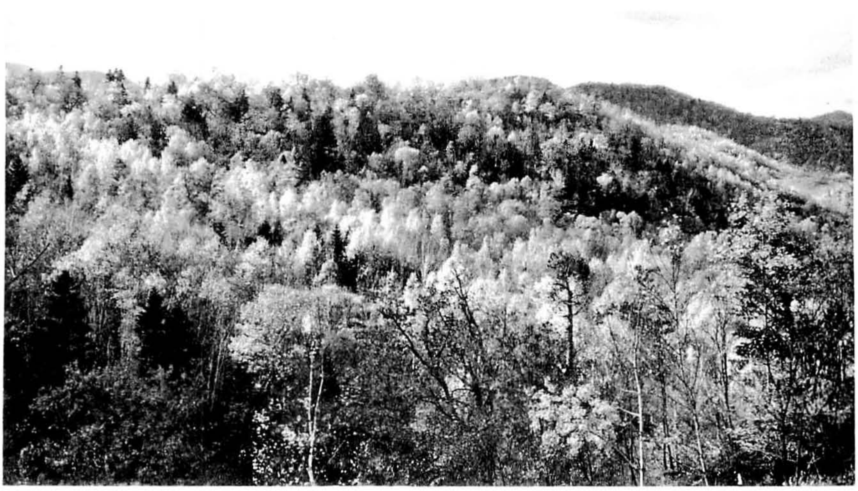


Plate 2

Explanation of Plate 2

(All figures in natural size, unless otherwise stated)

Fig. 1a. *Acer subpictum* SAPORTA. Hypotype U. H. M. P. Reg. No. 25803c. Rubeshibe.

Figs. 1b, 2. *Ulmus protojaponica* TANAI and ONOE. Hypotypes U. H. M. P. Reg. Nos· 25803a, b. Rubeshibe.

Fig. 3. *Populus kitamiana* TANAI and N. SUZUKI. Holotype U. H. M. P. Reg. No. 25743. Rubeshibe.

Fig. 4. *Gleditsia miosinensis* HU and CHANEY. Hypotype U. H. M. P. Reg. No. 25712. Shanabuchi.

Fig. 5. *Salix parasachalinensis* TANAI and N. SUZUKI. Paratype U. H. M. P. Reg. No. 25624. Shanabuchi.

Fig. 6. *Salix misaotatewakii* TANAI and N. SUZUKI. Paratype U. H. M. P. Reg. No. 25757. Rubeshibe.

Fig. 7. *Spiraea protothunbergi* TANAI and N. SUZUKI. Holotype U. H. M. P. Reg. No. 25704. Shanabuchi. (×2)

Fig. 8. *Populus kitamiana* TANAI and N. SUZUKI. Paratype U. H. M. P. Reg. No. 25749. Rubeshibe.

Fig. 9. *Aralia subelata* TANAI and N. SUZUKI. Holotype U. H. M. P. Reg. No. 25725. Shanabuchi.

Photo by. N. SUZUKI

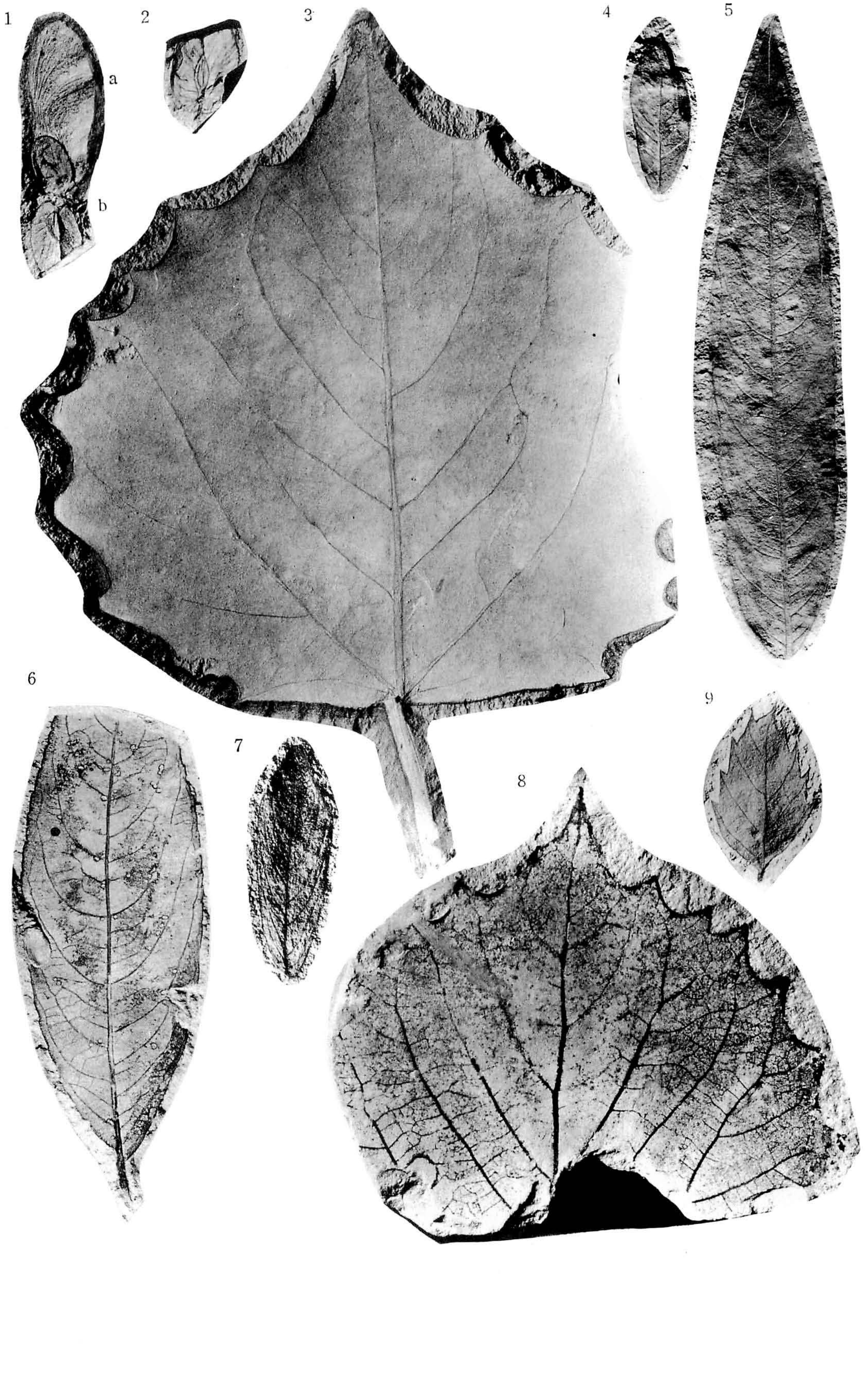

1
a
b
2
3
4
5
6
7
8
9

Plate 3

Explanation of Plate 3

(All figures in natural size)

Fig. 1. *Populus balsamoides* GOEPPERT. Hypotype U. H. M. P. Reg. No. 25745. Rubeshibe.

Figs. 2, 3. *Populus kobayashii* K. SUZUKI. Hypotypes, U. H. M. P. Reg. Nos. 25616, 25617. Shanabuchi.

Fig. 4. *Crataegus sugiyamae* HUZIOKA and NISHIDA. Hypotype, U. H. M. P. Reg. No. 25690. Shanabuchi.

Fig. 5. *Prunus ishidai* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25691. Shanabuchi.

Fig. 6. *Celtis miobungeana* HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25663. Shanabuchi.

Photo by N. SUZUKI

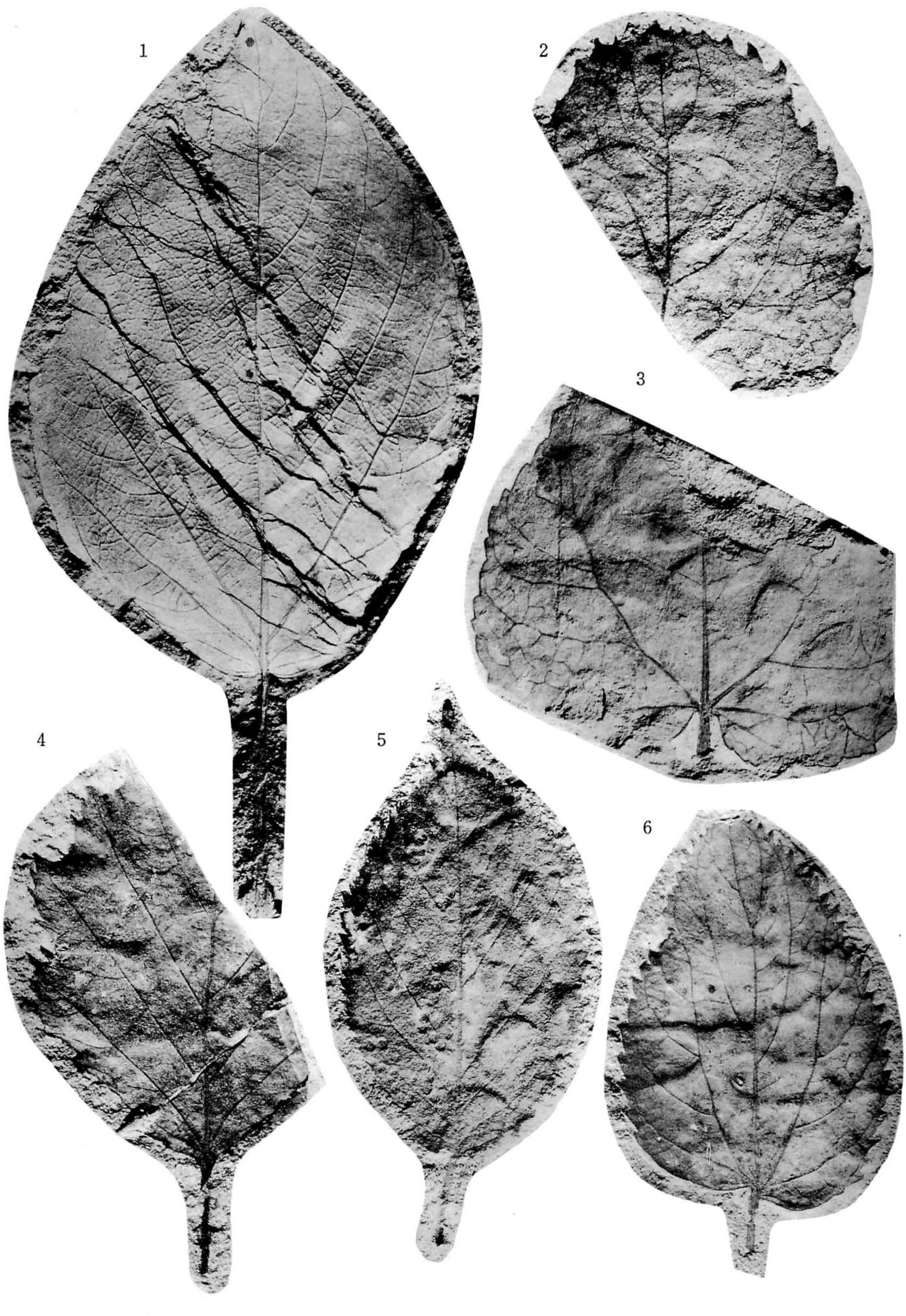

1
2
3
4
5
6

Plate 4

Explanation of Plate 4

(All figures in natural size)

Fig. 1. *Salix parasachalinensis* TANAI and N. SUZUKI. Paratype, U.H.M.P. Reg. No. 25622. Shanabuchi.

Fig. 2. *Salix misaotatewakii* TANAI and N. SUZUKI. Holotype, U.H.M.P. Reg. No. 25756. Rubeshibe.

Fig. 3. *Betula protoermani* ENDO. Hypotype, U.H.M.P. Reg. No. 25647. Shanabuchi.

Fig. 4a. *Salix parasachalinensis* TANAI and N. SUZUKI. Holotype, U.H.M.P. Reg. No. 25621a. Shanabuchi.

Fig. 4b. *Ulmus protojaponica* TANAI and ONOE. Hypotype, U.H.M.P· Reg. No. 25621b. Shanabuchi.

Fig. 5. *Salix kitamiensis* TANAI and N. SUZUKI. Holotype, U.H.M.P. Reg. No. 25753. Rubeshibe.

Photo by N. SUZUKI

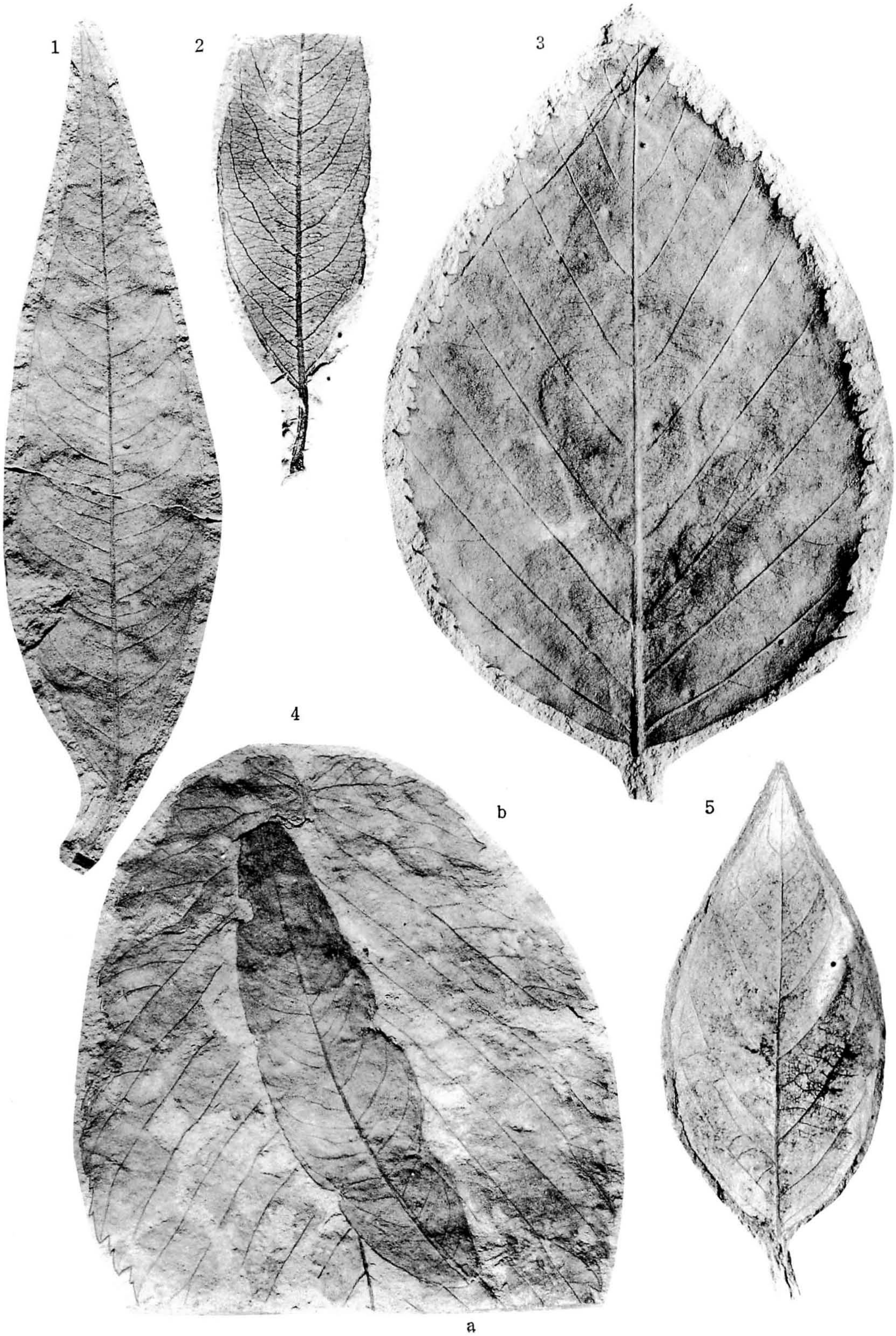

1
2
3
4
b
5
a

Plate 5

Explanation of Plate 5

(All figures in natural size, unless otherwise stated)

Fig. 1. *Prunus rubeshibensis* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25812. Rubeshibe.

Fig. 2. *Rhus protoambigua* SUZUKI. Hypotype, U. H. M. P. Reg. No. 25820. Rubeshibe.

Fig. 3a. *Alnus subfirma* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25644a. Shanabuchi.

Fig. 3b. *Hamamelis protojaponica* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25644b. Shanabuchi.

Fig. 4. *Alnus protomaximowiczii* TANAI. Hypotype, U. H. M. P. Reg. No. 25638. Shanabuchi.

Fig. 5. *Juniperus honshuensis* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25609. Shanabuchi. (×2)

Fig. 6 *Robinia nipponica* TANAI. Hypotype, U. H. M. P. Reg. No. 25841. Samakesaroma.

Fig. 7. *Rhododendron tatewakii* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25731.

Photo by N. SUZUKI

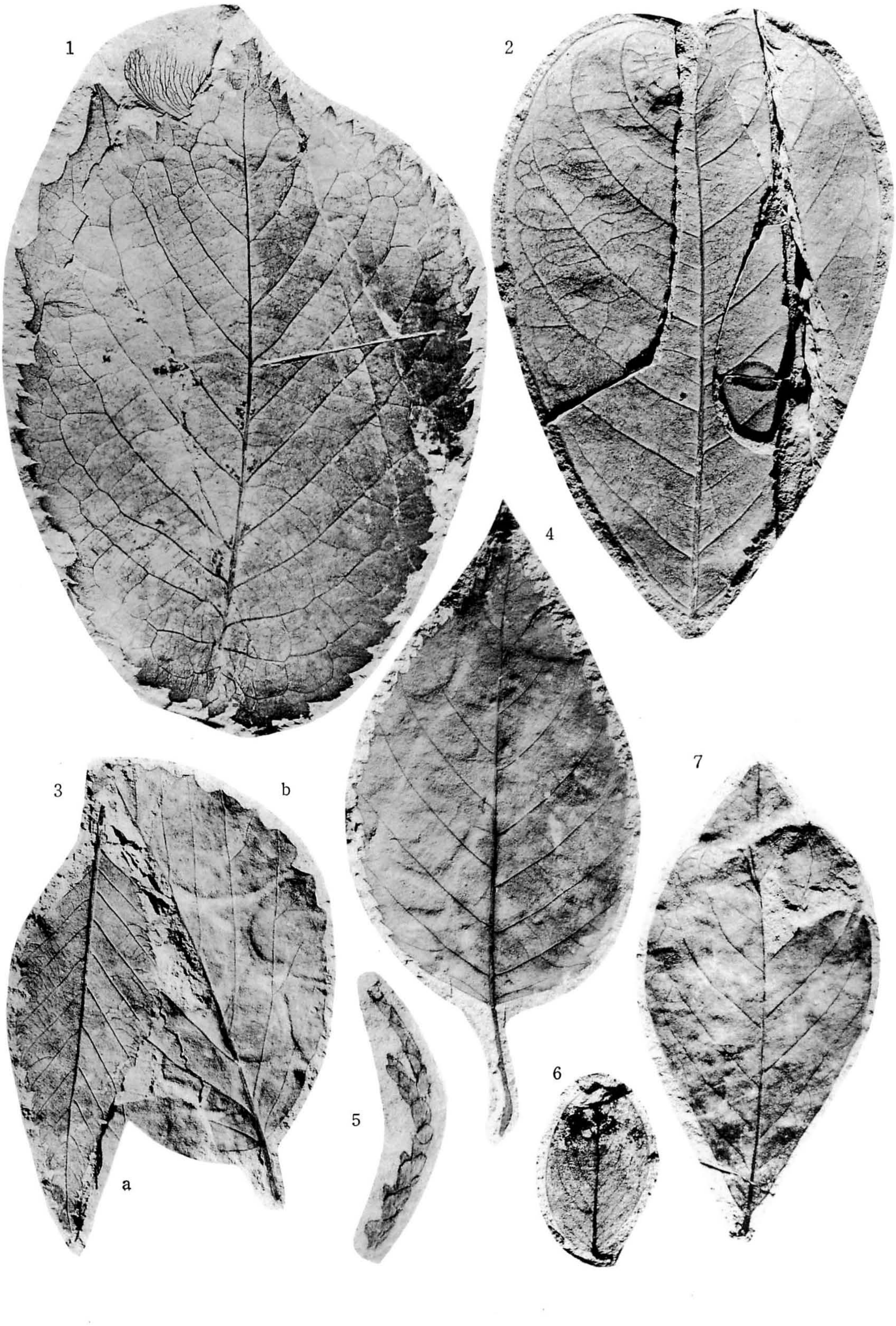

1
2
3
b
a
4
5
6
7

Plate 6

Explanation of Plate 6

(All figures in natural size)

Fig. 1. *Clethra maximowiczii* NATHORST. Hypotype, U. H. M. P. Reg. No. 25729. Shanabuchi.
Fig. 2. *Fagus protojaponica* K. SUZUKI. Hypotype, U. H. M. P. Reg. No. 25794. Rubeshibe.
Fig. 3. *Alnus protomaximowiczii* TANAI. Hypotype, U. H. M. P. Reg. No. 25768. Rubeshibe.
Figs. 4, 5. *Quercus protodentata* TANAI and ONOE. Hypotype, U. H. M. P. Reg. Nos. 25848b, 25849. Ikutawara.

Photo by N. SUZUKI

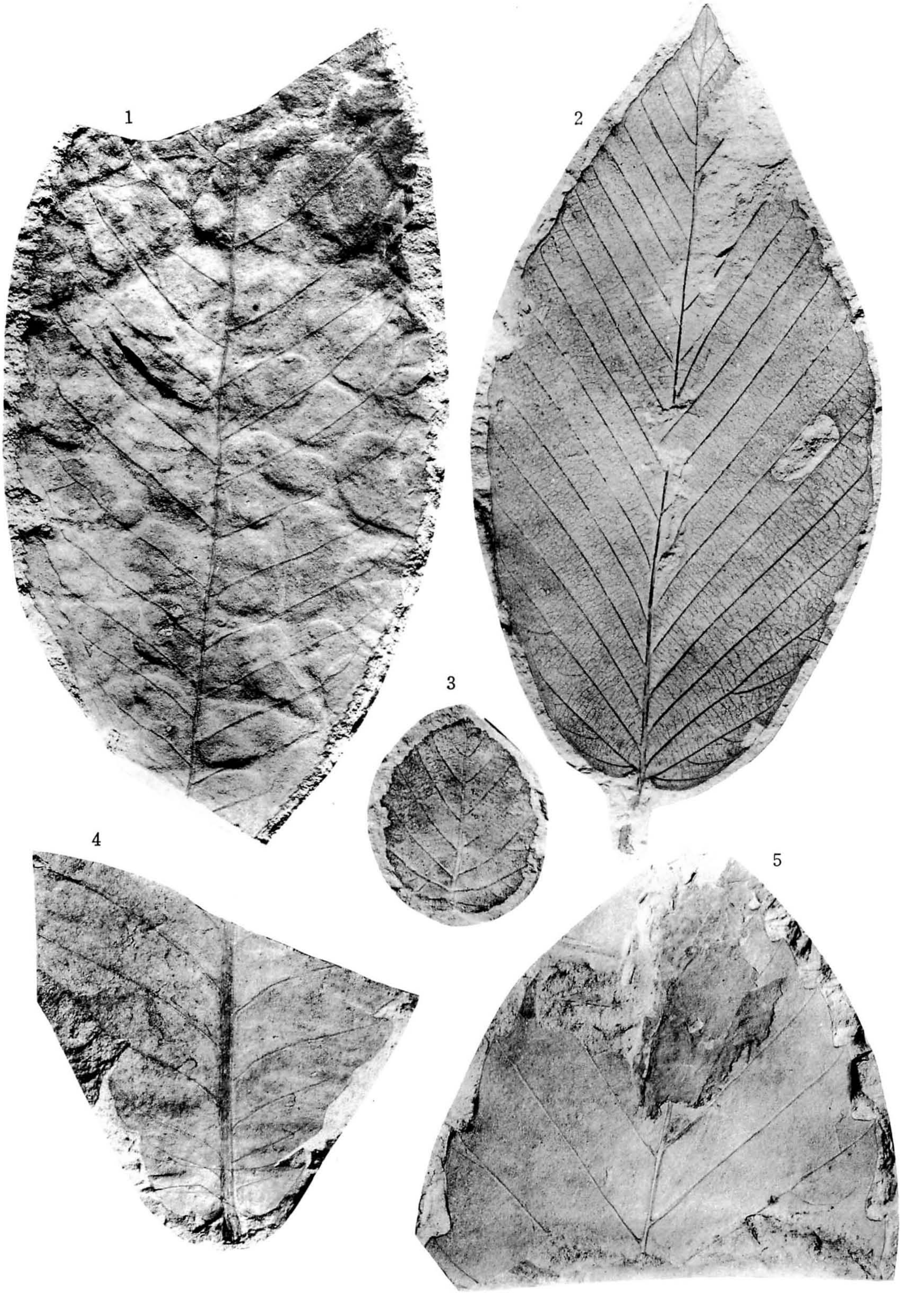

1
2
3
4
5

Plate 7

Explanation of Plate 7

(All figures in natural size, unless otherwise stated)

Fig. 1. *Betula onbaraensis* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25778. Rubeshibe.

Figs. 2, 3. *Picea kaneharai* TANAI and ONOE. Hypotypes, U. H. M. P. Reg. Nos. 25602, 25603. Shanabuchi. (×2)

Fig. 4. *Taiwania japonica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25608a. Shanabuchi. (×2)

Fig. 5. *Smilax trinervis* MORITA. Hypotype, U. H. M. P. Reg. No. 25614. Shanabuchi.

Fig. 6. *Prunus subserotina* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25814. Rubeshibe.

Photo by N. SUZUKI

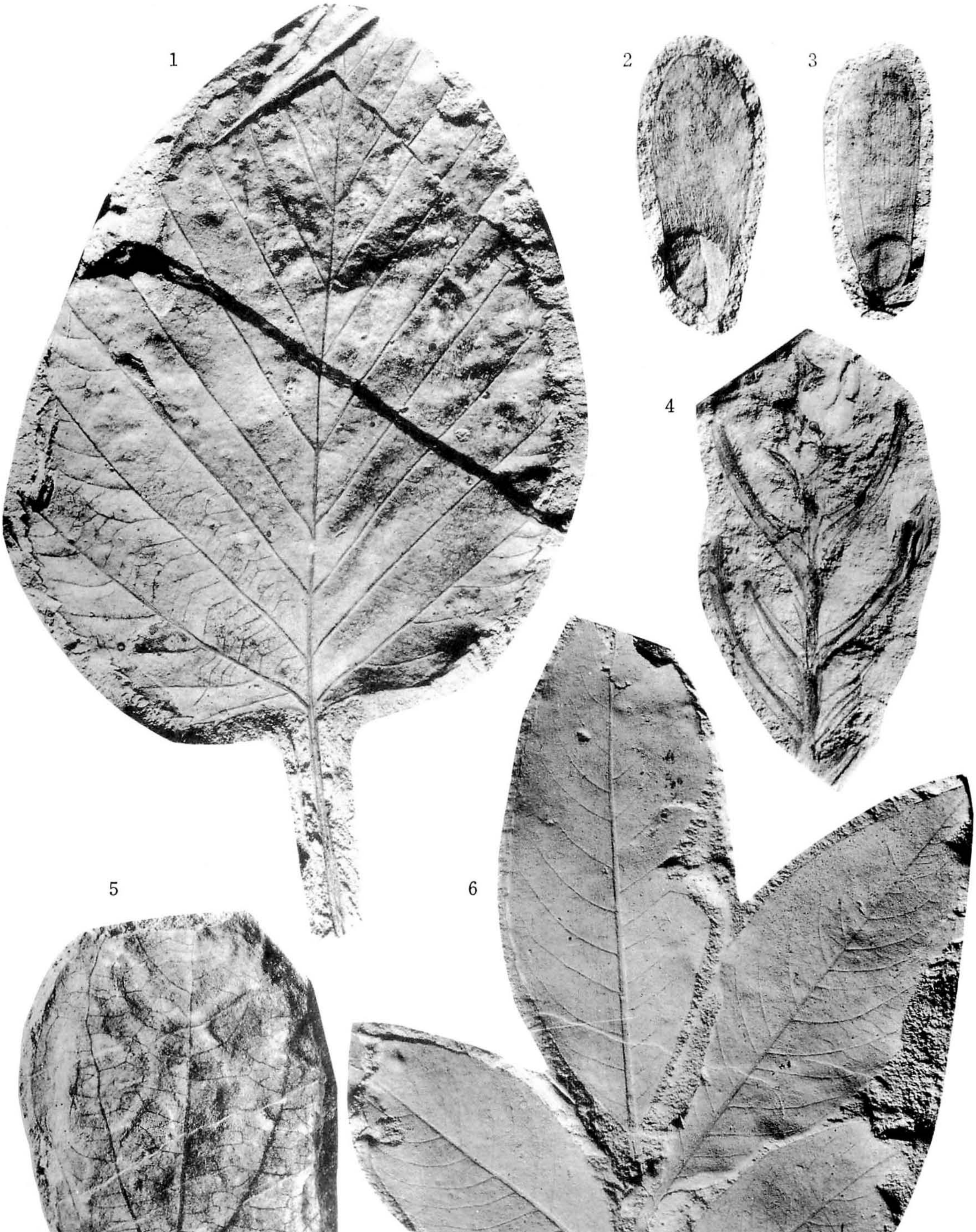

1
2
3
4
5
6

Plate 8

Explanation of Plate 8

(All figures in natural size, unless otherwise stated)

Figs. 1, 3. *Phellodendron mioamurense* TANAI and N. SUZUKI. Hypotypes, U. H. M. P. Reg. Nos. 25679b, 25680b. Shanabuchi.

Fig. 2. *Populus balsamoides* GOEPPERT. Hypotype, U. H. M. P. Reg. No. 25747. Rubeshibe.

Fig. 4. *Carpinus stenophylla* NATHORST. Hypotype, U. H. M. P. Reg. No. 25651. Shanabuchi.

Fig. 5. *Rhus protoambigua* SUZUKI. Hypotype, U. H. M. P. Reg. No. 25719. Shanabuchi.

Fig. 6. *Thuja nipponica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25610. Shanabuchi. (×2)

Photo by N. SUZUKI

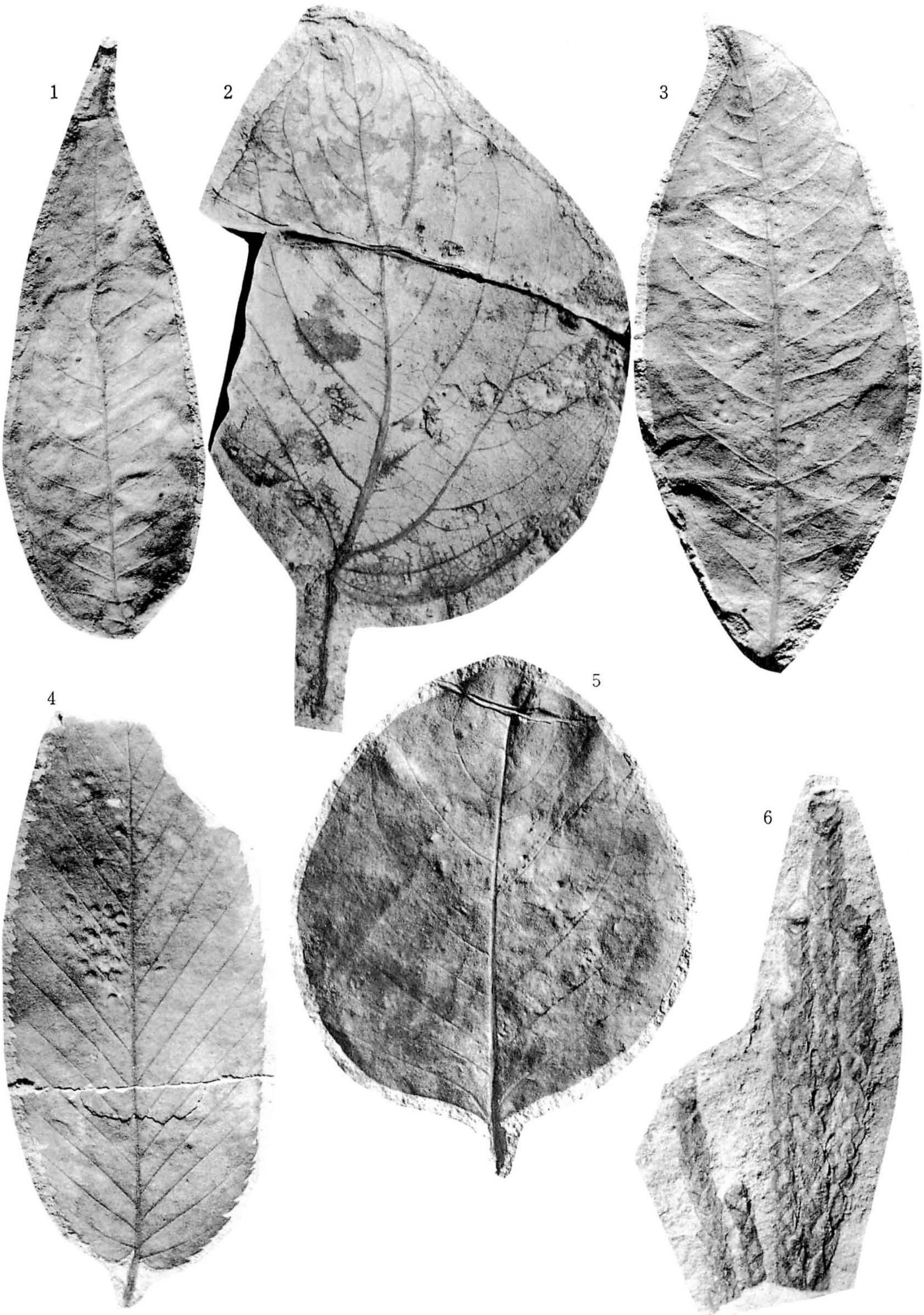

1
2
3
4
5
6

Plate 9

Explanation of Plate 9

(All figures in natural size, unless otherwise stated)

Fig. 1. *Ulmus protojaponica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25673. Shanabuchi.

Fig. 2. *Rumex ezoensis* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25677. Shanabuchi. (× 1/2)

Fig. 3. *Pinus* sp. U. H. M. P. Reg. No. 25607. Shanabuchi.

Fig. 4. *Wisteria fallax* (NATHORST) TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25713. Shanabuchi.

Fig. 5. *Rumex ezoensis* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25805. Rubeshibe. (× 4/5)

Fig. 6. *Polygonum megalophyllum* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25676. Shanabuchi. (× 1/2)

Photo by N. SUZUKI

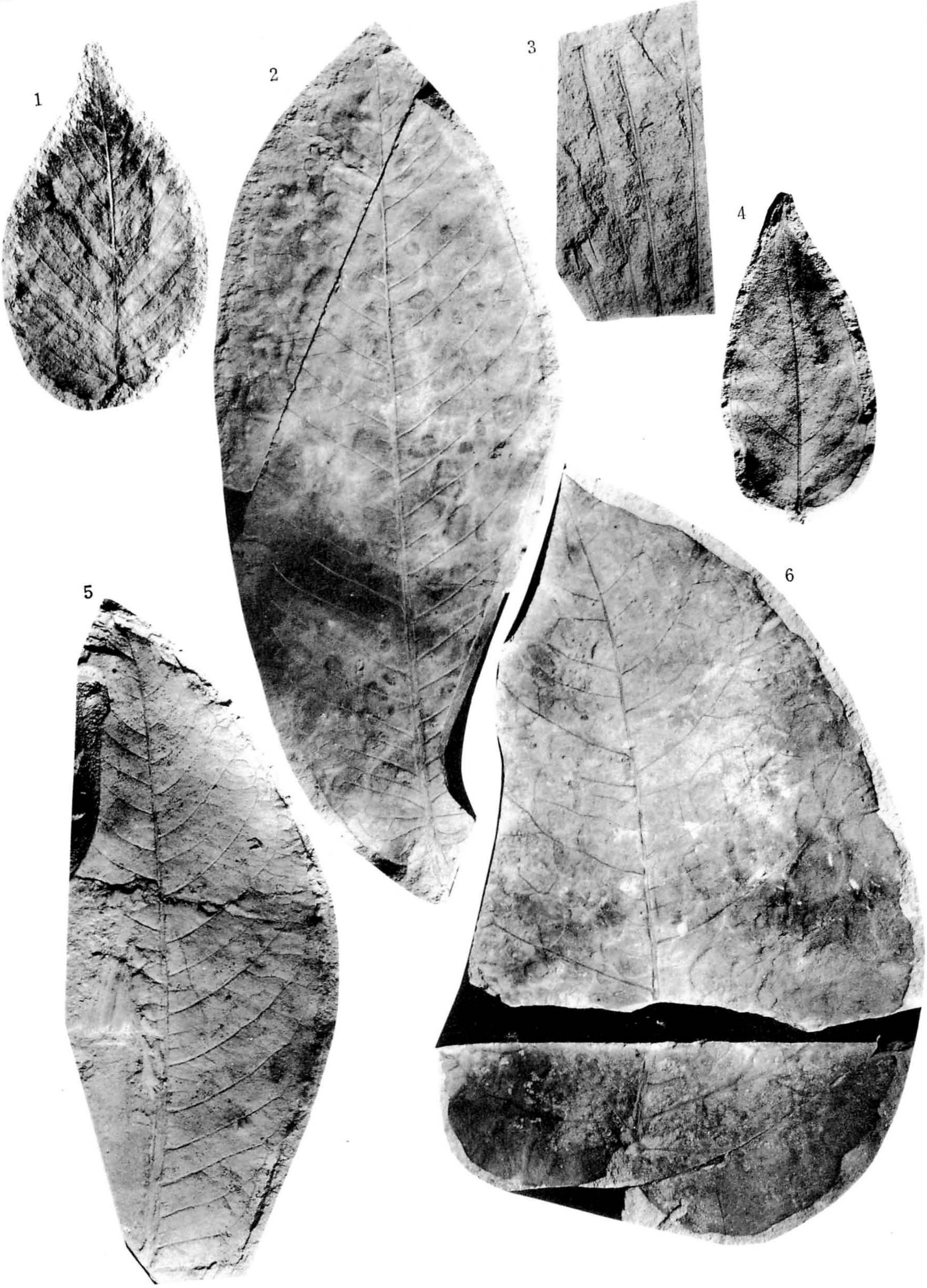


Plate 10

Explanation of Plate 10

(All figures in natural size)

Fig. 1. *Cladrastis chaneyi* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25723. Shanabuchi.

Fig. 2. *Acer yabei* ENDO. Hypotype, U. H. M. P. Reg. No. 25906. Rubeshibe.

Fig. 3. *Acer palaeodiabolicum* ENDO. Hypotype, U. H. M. P. Reg. No. 25897. Rubeshibe.

Fig. 4. *Sorbus uzenensis* HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25706. Shanabuchi.

Fig. 5. *Alnus subfirma* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25642. Shanabuchi.

Fig. 6. *Ailanthus yezoense* OISHI and HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25750. Shanabuchi.

Fig. 7. *Ailanthus yezoense* OISHI and HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25752. Shanabuchi.

Fig. 8. *Acer pseudocarpinifolium* ENDO. Hypotype, U. H. M. P. Reg. No. 25766. Shanabuchi.

Fig. 9. *Acer pseudoginnala* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25908. Rubeshibe.

Fig. 10. *Acer yabei* ENDO. Hypotype, U. H. M. P. Reg. No. 25916. Rubeshibe.

Fig. 11. *Ailanthus yezoense* OISHI and HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25757. Shanabuchi.

dhoto by N. SUZUKI

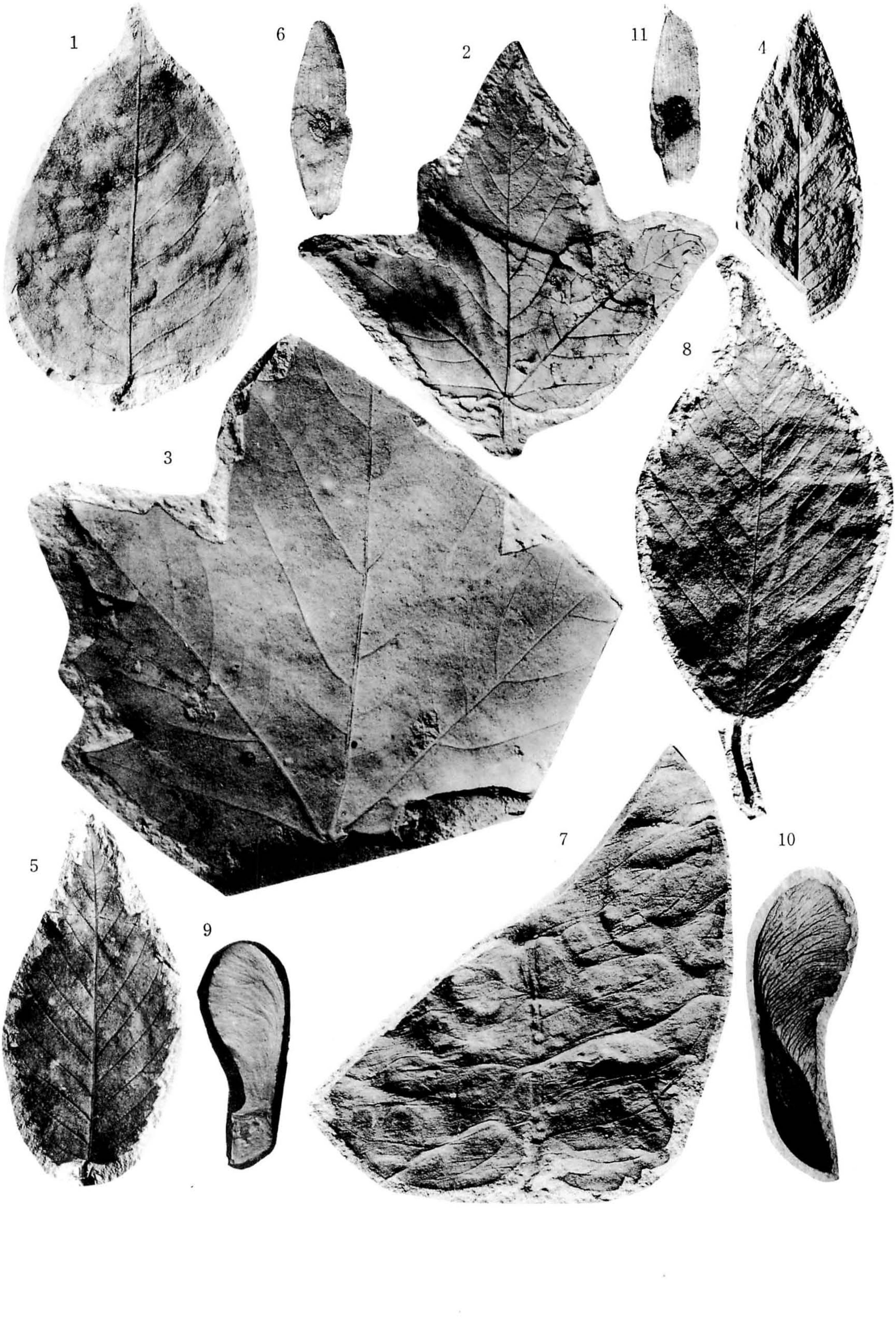

1
6
2
11
4
8
3
7
10
5
9

Plate 11

Explanation of Plate 11

(All figures in natural size)

Fig. 1. *Acer pseudocarpinifolium* ENDO. Hypotype, U. H. M. P. Reg. No. 25910. Rubeshibe.

Fig. 2. *Magnolia elliptica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25684. Shanabuchi.

Fig. 3. *Vitis naumanni* (NATHORST) TANAI. Hypotype, U. H. M. P. Reg. No. 25824. Rubeshibe.

Fig. 4. *Forsythia kitamiensis* (OISHI and HUZIOKA) TANAI and N. SUZUKI. Hypotype, U.H.M.P. Reg. No. 25737. Shanabuchi.

Fig. 5. *Pterocarya asymmetrosa* KONNO. Hypotype, U. H. M. P. Reg. No. 25631. Shanabuchi.

Photo by N. SUZUKI


1
2
4
3
5

Plate 12

Explanation of Plate 12

(All figures in natural size)

Figs. 1, 2. *Fraxinus honshuensis* TANAI and ONOE. Hypotypes, U. H. M. P. Reg. Nos. 25843a, b. Samakesaroma.

Figs. 3, 6. *Lonicera* sp. U. H. M. P. Reg. Nos. 26834a, b. Rubeshibe.

Fig. 4. *Cercidiphyllum crenatum* (UNGER) BROWN. Hypotype, U. H. M. P. Reg. No. 25680. Shanabuchi.

Fig. 5. *Cornus megaphylla* HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25828. Rubeshibe.

Fig. 7. *Diospyros sublotus* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25736. Shanabuchi.

Fig. 8. *Prunus protossiori* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25693. Shanabuchi.

Fig. 9. *Rubus* sp. U. H. M. P. Reg. No. 25701. Shanabuchi.

Photo by N. SUZUKI

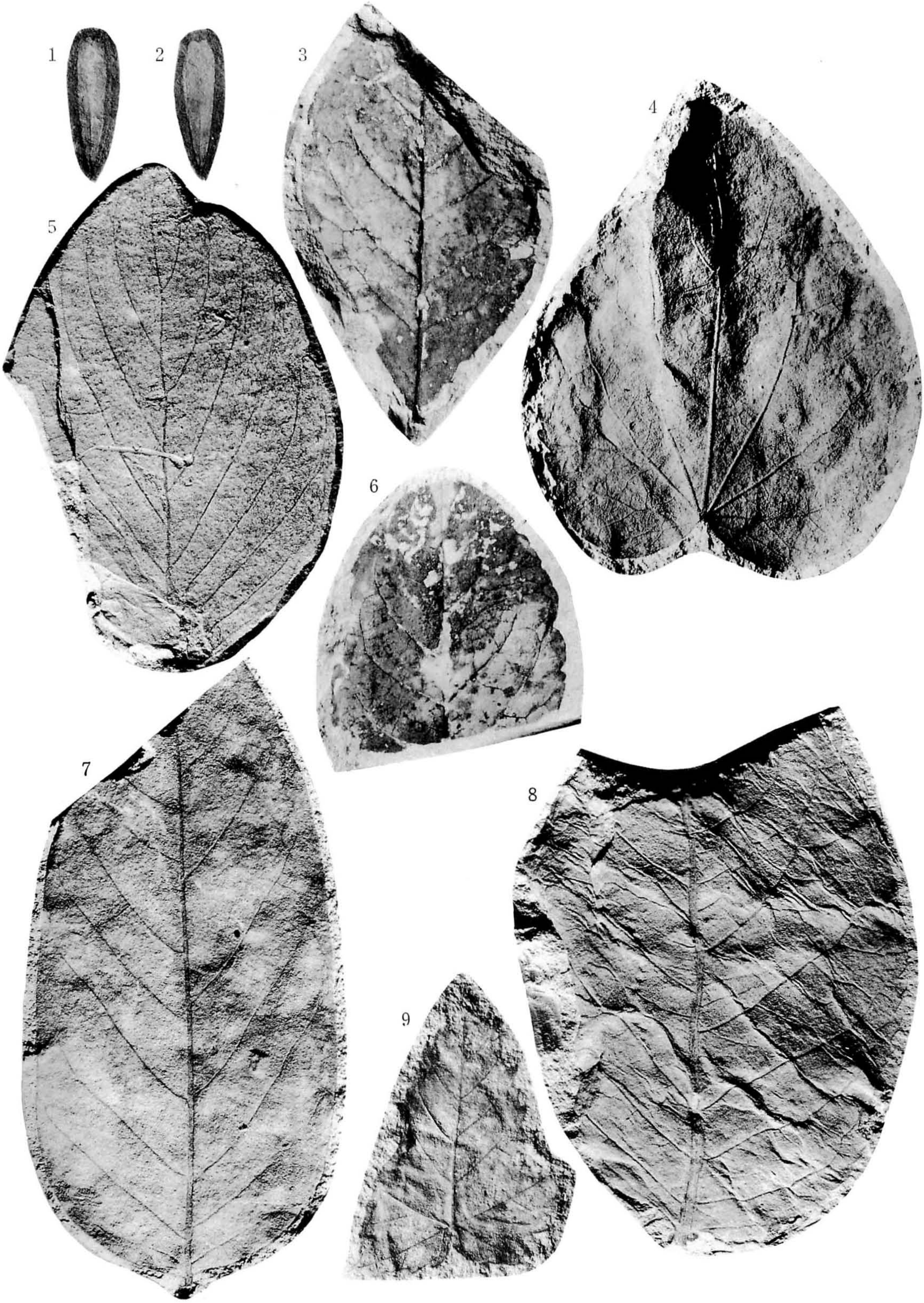

1
2
3
4
5
6
7
8
9

Plate 13

Explanation of Plate 13

(All figures in natural size)

Fig. 1. *Diospyros sublotus* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25735. Shanabuchi.

Fig. 2. *Ulmus protojaponica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25672. Shanabuchi.

Fig. 3. *Sorbus lanceolata* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25702. Shanabuchi.

Fig. 4. *Acer yabei* ENDO. Hypotype, U. H. M. P. Reg. No. 25767. Shanabuchi.

Fig. 5. *Carpinus subcordata* NATHORST. Hypotype, U. H. M. P. Reg. No. 25790. Rubeshibe.

Fig. 6. *Fraxinus k-yamadai* TANAI and N. SUZUKI Holotype, U. H. M. P. Reg. No. 25738. Shanabuchi.

Fig. 7. *Prunus ishidai* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25692. Shanabuchi.

Fig. 8. *Carpinus subyedoensis* KONNO. Hypotype, U. H. M. P. Reg. No. 25650. Shanabuchi.

Fig. 9. *Carpinus subcordata* NATHORST. Hypotype, U. H. M. P. Reg. No. 25789. Rubeshibe.

Photo by N. SUZUKI

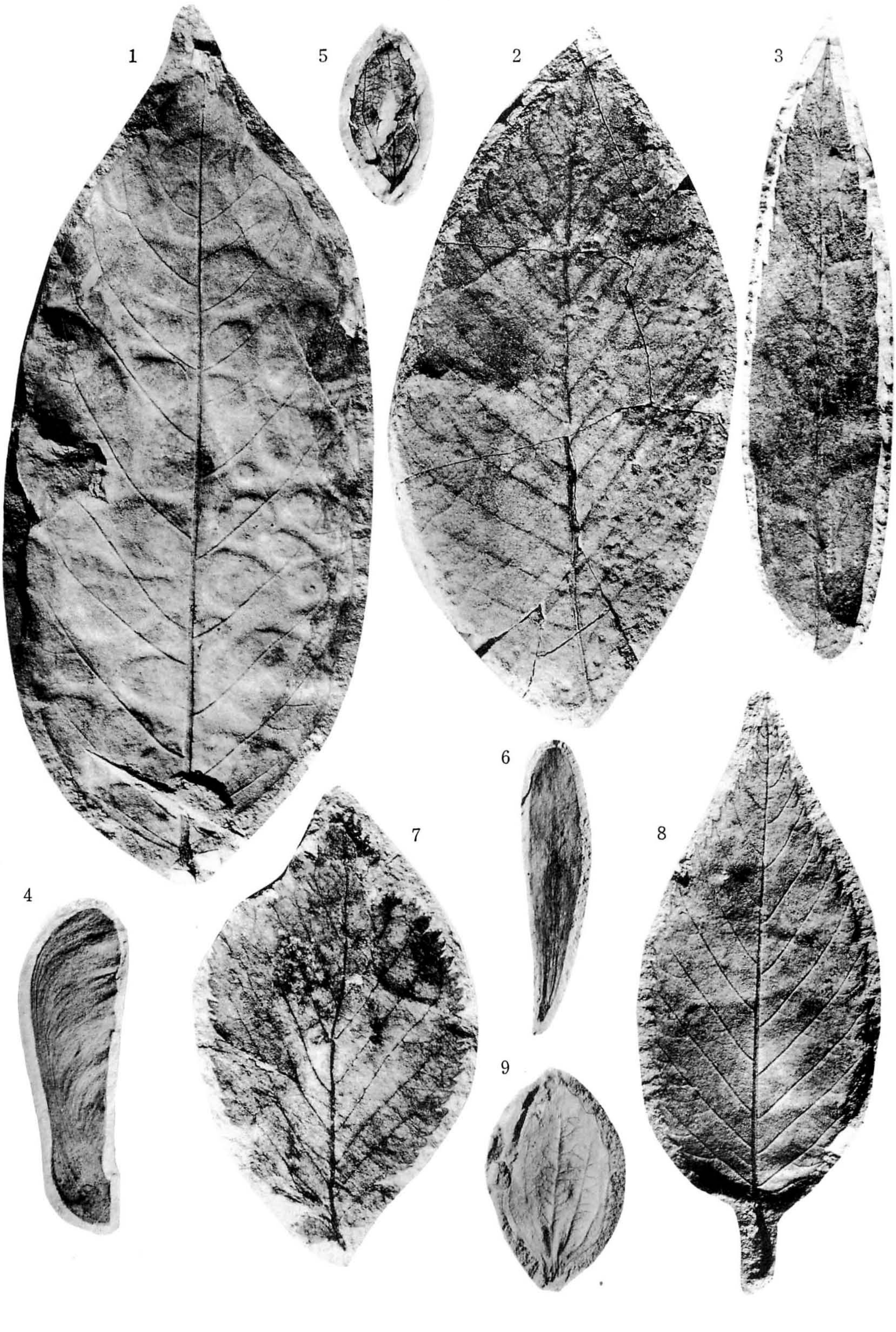

1
5
2
3
6
7
8
4
9

Plate 14

Explanation of Plate 14

(All figures in natural size)

Fig. 1. *Ulmus miopumila* HU et CHANEY. Hypotypes, U. H. M. P. Reg. No. 25627a. Shanabuchi.
Fig. 2. *Zelkova ungeri* KOVATS. Hypotype, U. H. M. P. Reg. No. 25671. Shanabuchi.
Fig. 3. *Celtis nordenskioldii* NATHORST. Hypotype, U. H. M. P. Reg. No. 25666. Shanabuchi.
Fig. 4. *Ulmus protojaponica* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25670a. Shanabuchi.
Figs. 5, 9. *Alnus protohirsuta* ENDO. Hypotypes, U. H. M. P. Reg. Nos. 25835. 25836. Rubeshibe.
Fig. 6. *Carpinus subcordata* NATHORST. Hypotype, U. H. M. P. Reg. No. 25782a. Rubeshibe.
Fig. 7. *Stewartia okutsui* TANAI. Hypotype, U. H. M. P. Reg. No. 25827. Rubeshibe.
Fig. 8. *Stewartia okutsui* TANAI. Hypotype, U. H. M. P. Reg. No. 25825. Rubeshibe.

Photo by N. SUZUKI

Plate 15

Explanation of Plate 15

(All figures in natural size, unless otherwise stated)

Fig. 1. *Salix parasachalinensis* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25623. Shanabuchi.

Fig. 2. *Salix crenatoserrulata* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25755. Rubeshibe.

Figs. 3, 5. *Tsuga oblonga* MIKI. Hypotypes, U. H. M. P. Reg. Nos. 25600, 25601. Shanabuchi. (× 2)

Fig. 4. *Alnus protomaximowiczii* TANAI. Hypotype, U. H. M. P. Reg. No. 25736. Rubeshibe.

Fig. 6. *Salix hokkaidoensis* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25618. Shanabuchi.

Fig. 7. *Corylus* sp. U. H. M. P. Reg. No. 25786. Rubeshibe.

Fig. 8. *Abies protofirma* TANAI. Hypotype, U. H. M. P. Reg. No. 25740. Rubeshibe.

Photo by N. SUZUKI


1
2
3
4
5
6
7
8

Plate 16

Explanation of Plate 16

(All figures in natural size)

Fig. 1. *Betula miomaximowicziana* ENDO. Hypotype, U. H. M. P. Reg. No. 25772. Rubeshibe.

Fig. 2. *Betula onbaraensis* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25777. Rubeshibe.

Fig. 3. *Abies protofirma* TANAI. Hypotype, U. H. M. P. Reg. No. 25741. Rubeshibe.

Figs. 4, 5. *Fagus palaeocrenata* OKUTSU. Hypotypes, U. H. M. P. Reg. Nos. 25791, 25792. Rubeshibe.

Fig. 6. *Betula protoermani* ENDO. Hypotype, U. H. M. P. Reg. No. 25648a. Shanabuchi.

Fig. 7. *Salix hokkaidoensis* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25619. Shanabuchi.

Fig. 8. *Fagus protojaponica* K. SUZUKI. Hypotype, U. H. M. P. Reg. No. 25662. Shanabuchi.

Photo by N. SUZUKI

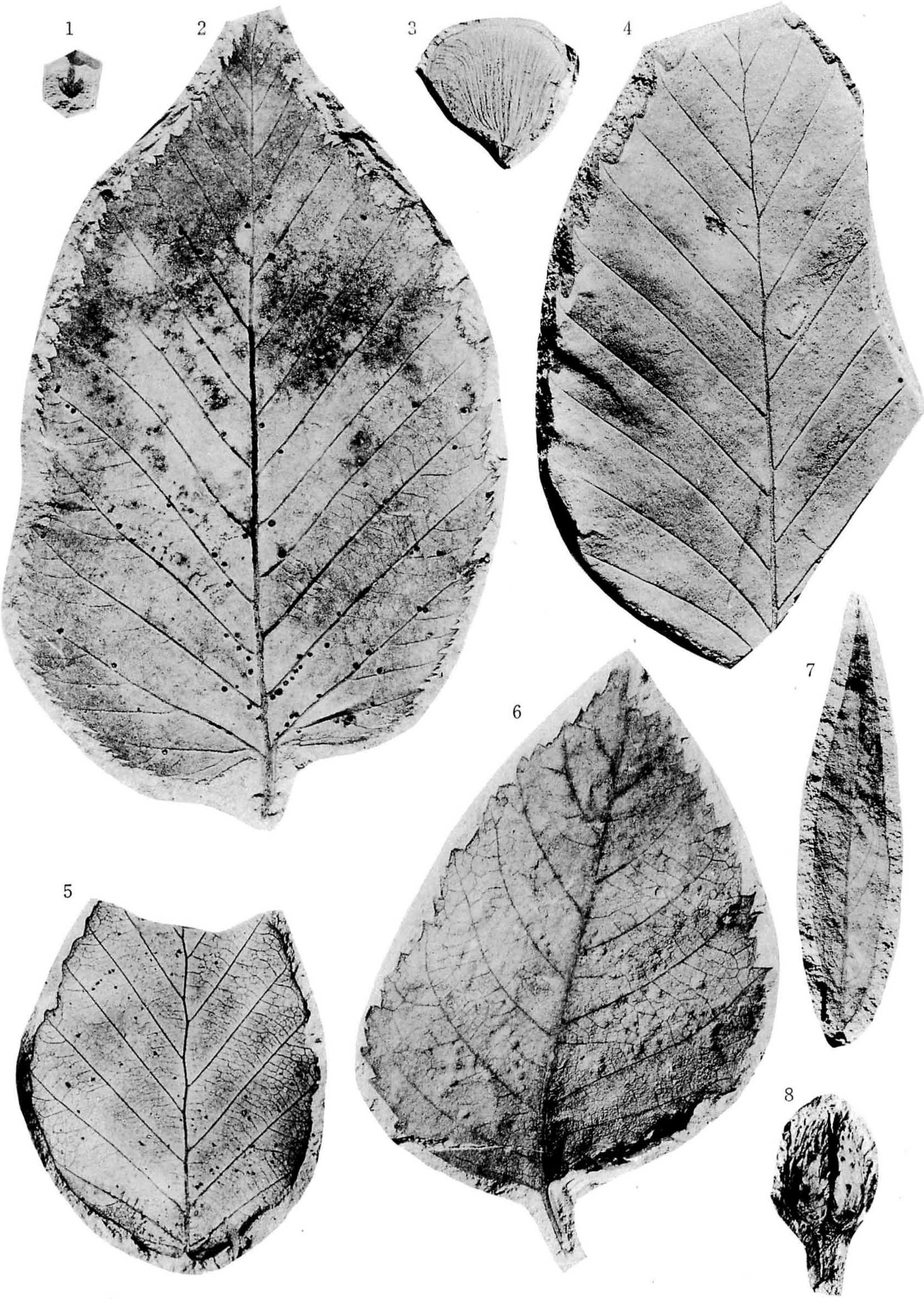

1
2
3
4
5
6
7
8

Plate 17

Explanation of Plate 17

(All figures in natural size)

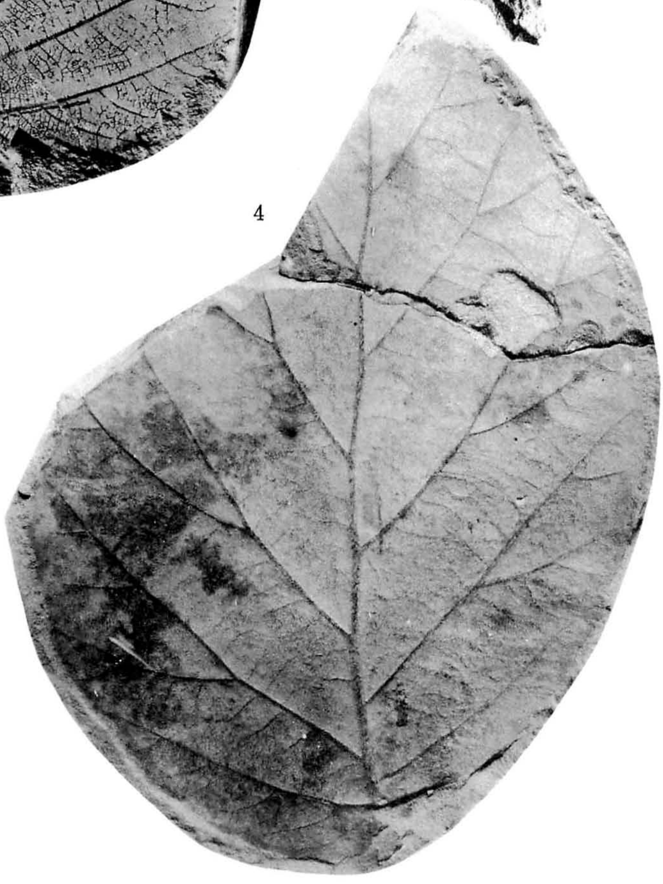
Fig. 1. *Betula miomaximowicziana* ENDO. Hypotype, U. H. M. P. Reg. No. 25774. Rubeshibe.
Fig. 2. *Prunus rubeshibensis* TANAI and N. SUZUKI. Paratype U. H. M. P. Reg. No. 25813. Rubeshibe.
Fig. 3. *Rhus protoambigua* K. SUZUKI. Hypotype, U. H. M. P. Reg. No. 25721. Shanabuchi.
Fig. 4. *Hamamelis protojaponica* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25807. Rubeshibe.

Photo by N. SUZUKI

1

2

4



3

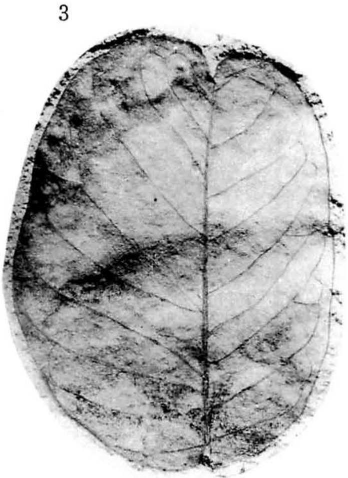


Plate 18

Explanation of Plate 18

(All figures in natural size)

Fig. 1. *Sorbus uzenensis* HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25705. Shanabuchi.
Fig. 2. *Cinnamomum* sp. U. H. M. P. Reg. No. 25688. Shanabuchi.
Fig. 3. *Prunus protossiori* TANAI and ONOE. Hypotype, U. H. M. P. Reg. No. 25694. Rubeshibe.
Fig. 4. *Juglans japonica* TANAI. Hypotype, U. H. M. P. Reg. No. 25625. Shanabuchi.
Fig. 5. *Diospyros sublotus* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25831. Rubeshibe.
Fig. 6. *Ulmus miopumila* HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25669. Shanabuchi.
Fig. 7. *Salix kitamiensis* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25754. Rubeshibe.

Photo by N. SUZUKI

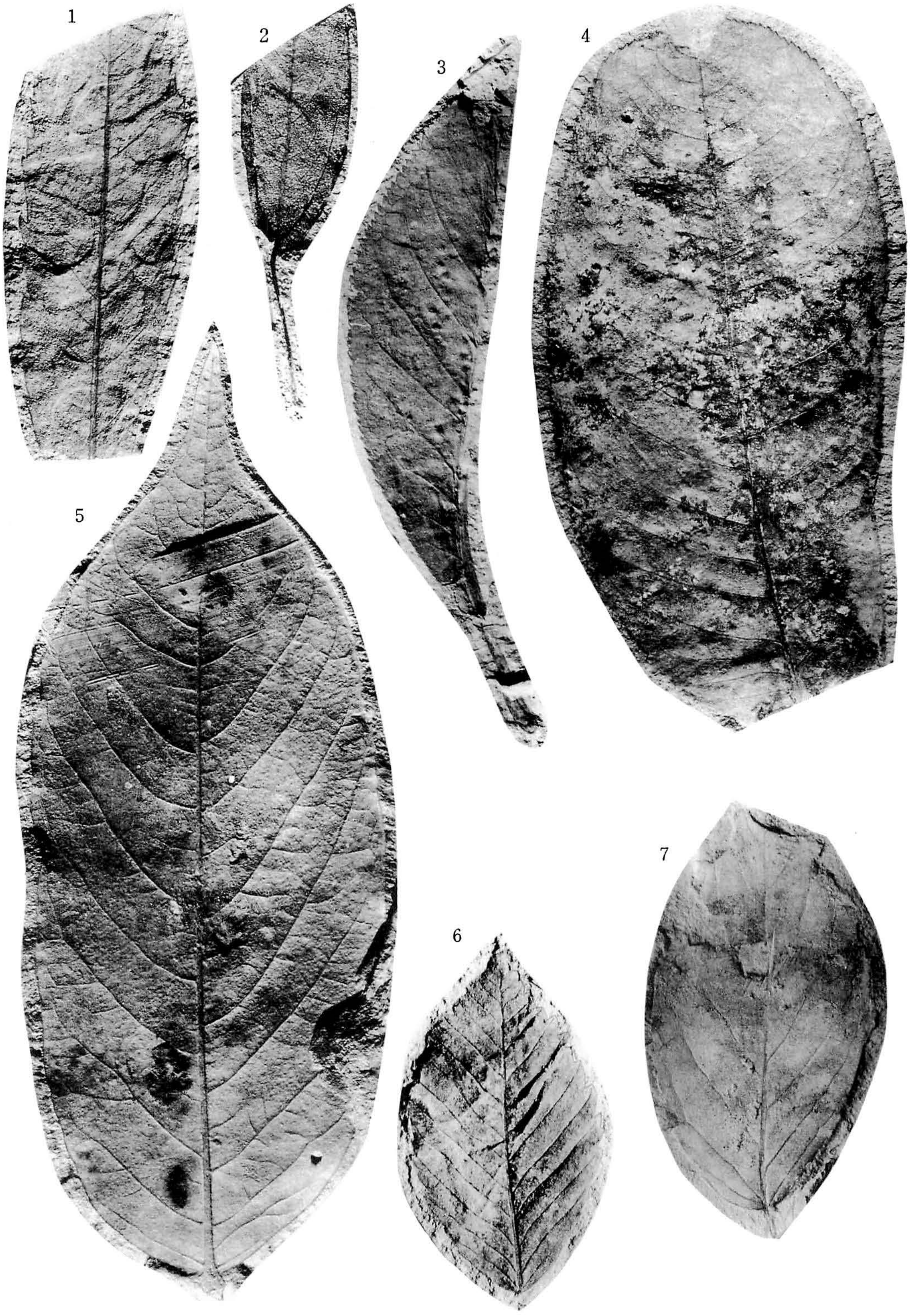

1
2
3
4
5
6
7

Plate 19

Explanation of Plate 19

(All figures in natural size)

Fig. 1. *Ostrya shiragiana* HUZIOKA. Hypotype, U. H. M. P. Reg. No. 25783a. Rubeshibe.
Fig. 2. *Cercidiphyllum crenatum* (UNGER) BROWN. Hypotype, U. H. M. P. Reg. No. 25681. Shanabuchi.
Fig. 3. *Carpinus stenophylla* NATHORST. Hypotype, U. H. M. P. Reg. No. 25650. Shanabuchi.
Fig. 4. *Phellodendron mioamurense* TANAI and N. SUZUKI. Hypotype, U. H. M. P. Reg. No. 25716. Shanabuchi.
Fig. 5. *Alnus protohirsuta* ENDO. Hypotype, U. H. M. P. Reg. No. 25637. Shanabuchi.
Fig. 6. *Rhododendron tatewakii* TANAI and N. SUZUKI. Paratype, U. H. M. P. Reg. No. 25732. Shanabuchi.

Photo by N. SUZUKI

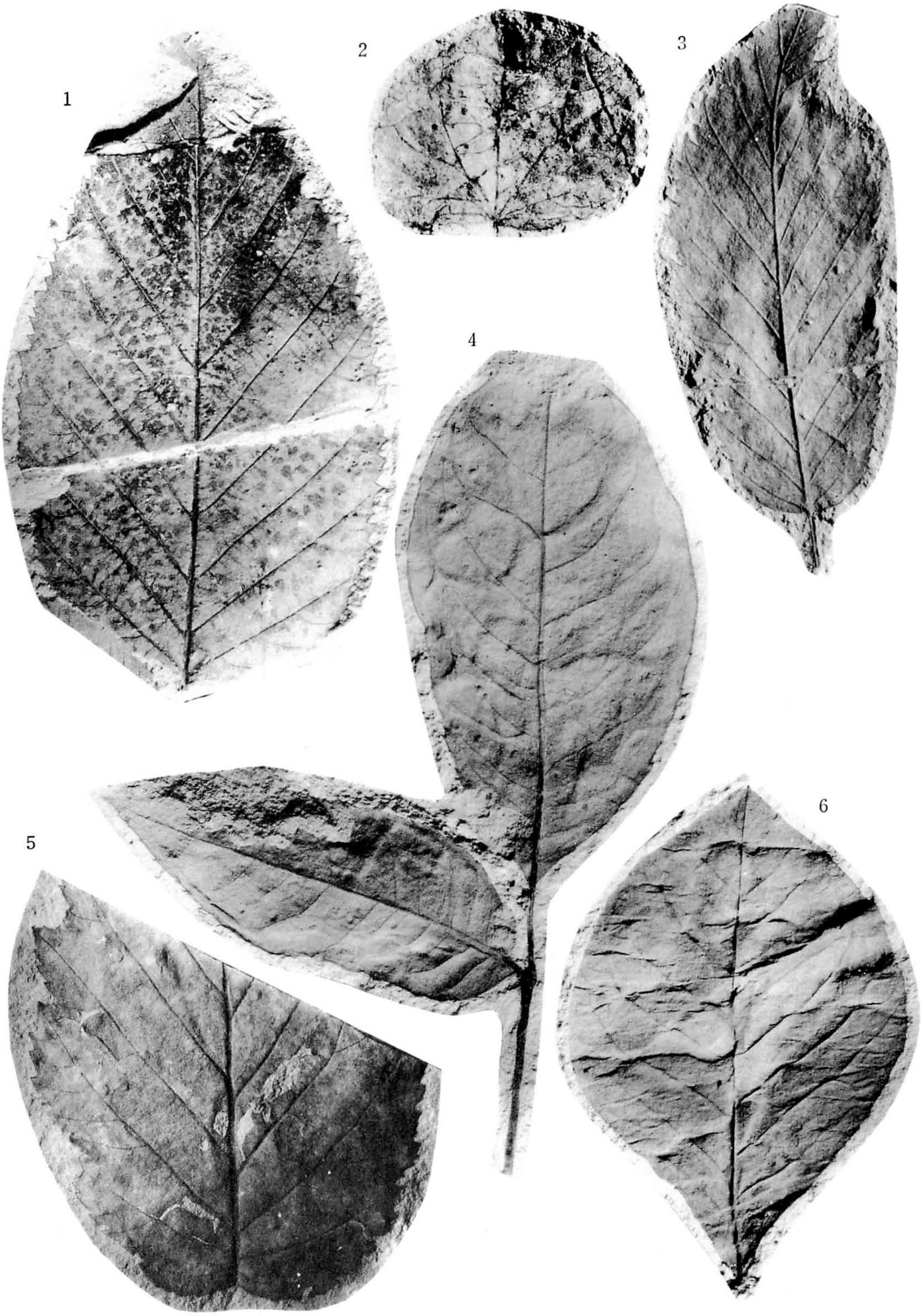

1
2
3
4
5
6

Plate 20

Explanation of Plate 20

(All figures in natural size)

Fig. 1. *Disporum ezoanum* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25613. Shanabuchi.

Fig. 2. *Kalopanax acerifolius* (NATHORST) HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25727. Shanabuchi.

Fig. 3. *Alnus miojaponica* TANAI. Hypotype, U. H. M. P. Reg. No. 25636. Shanabuchi.

Fig. 4. *Rhus miosuccedanea* HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25717. Shanabuchi.

Fig. 5. *Fagus protojaponica* K. SUZUKI. Hypotype, U. H. M. P. Reg. No. 25661. Shanabuchi.

Fig. 6. *Alnus protomaximowiczii* TANAI. Hypotype, U. H. M. P. Reg. No. 25638. Shanabuchi.

Fig. 7. *Stewartia okutsui* TANAI. Hypotype, U. H. M. P. Reg. No. 25826. Rubeshibe.

Photo by N. SUZUKI

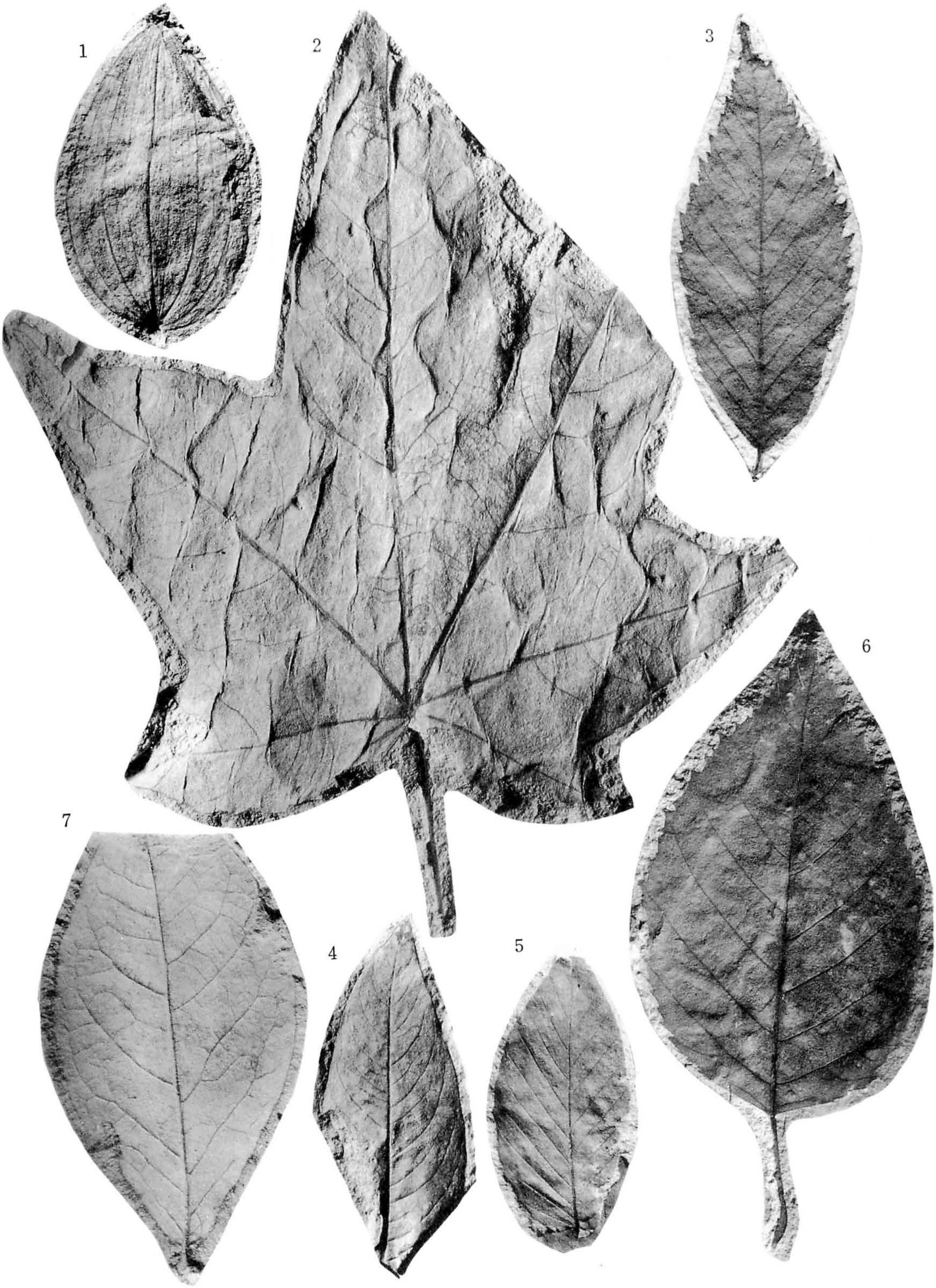

1
2
3
6
7
4
5

Plate 21

Explanation of Plate 21

(All figures in natural size, unless otherwise stated)

Fig. 1. *Cladrastis chaneyi* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25708. Shanabuchi.

Figs. 2, 6. *Zizyphus miojujuba* HU and CHANEY. Hypotypes, U. H. M. P. Reg. Nos. 25724a, b. Shanabuchi.

Fig. 3. *Sorbus protoalnifolia* TANAI and N. SUZUKI. Holotype, U. H. M. P. Reg. No. 25703. Shanabuchi.

Fig. 4. *Pterocarya protostenoptera* TANAI. Hypotype, U. H. M. P. Reg. No. 25634. Shanabuchi

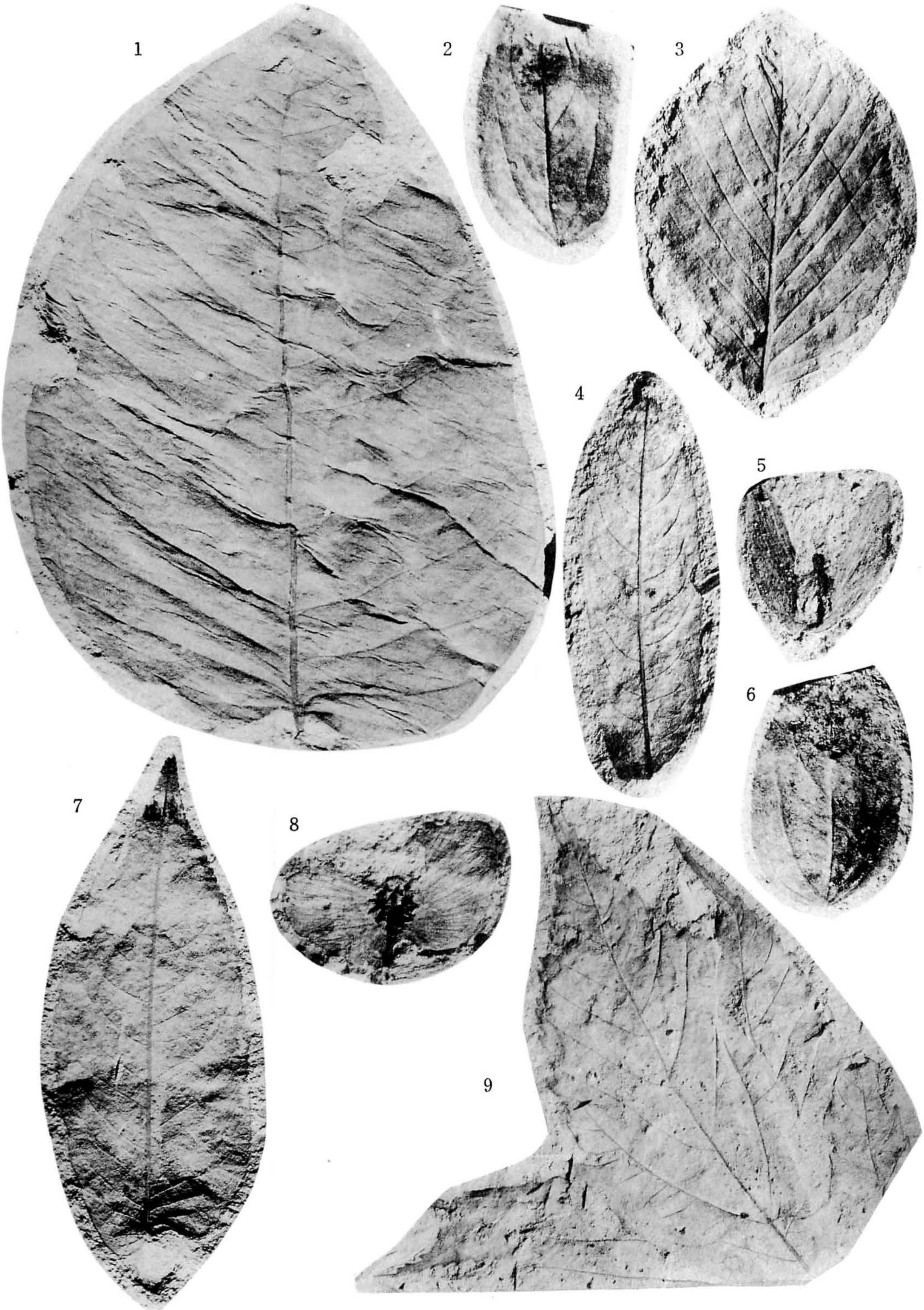
Fig. 5. *Pterocarya protostenoptera* TANAI. Hypotype, U. H. M. P. Reg. No. 25633. Shanabuchi. (×2)

Fig. 7. *Pterocarya asymmetrosa* KONNO. Hypotype, U. H. M. P. Reg. No. 25629. Shanabuchi.

Fig. 8. *Pterocarya asymmetrosa* KONNO. Hypotype, U. H. M. P. Reg. No. 25628b. Shanabuchi.

Fig. 9. *Liquidambar miosinica* HU and CHANEY. Hypotype, U. H. M. P. Reg. No. 25689. Shanabuchi.

Photo by N. SUZUKI


1
2
3
4
5
6
7
8
9

Transactions and Proceedings of the Palaeontological Society of Japan

New Series No. 54 (Issued June 30, 1964)

467. Notes on the Foraminiferal Genus *Pseudocibicidoides* ....Naoaki Aoki
468. Microplankton from the Asagai Formation in the Jōban Coal-field ....Kiyoshi Takahashi
469. Some Middle Permian Aviculopectinidae from the Kitakami Massif, Northeast Japan ....Masafumi Murata
470. On the Occurrence of *Goniatites* (s. s.) from the Hida Massif, Central Japan...... ....Hisayoshi Igo

New Series No. 55 (Issued September 20, 1964)

471. Notes on Palmaean Leaf from the Ôarai Flora (Upper Cretaceous), Ôarai machi, Ibaraki Prefecture, Japan..................Toshiji Ôyama and Hidekuni Matsuo
472. Some Molluscan Fossils from the Tertiary Muro Group in the Kii Peninsula, Japan ....Hiro'o Natori
473. A Cretaceous Trigonid from the Miocene Misaki Formation in the Miura Peninsula, Kanagawa Prefecture..Yasumochi Matoba
474. Discovery of a Fossil *Perotrochus* in the Miike Coal-field, Kyushu, Japan .... Hidetaka Kuroda and Hideo Urata
475. A Find of Spongiomorphoids from the Cretaceous System of Rebun Island and the Esashi Group of the Esashi Mountains, Hokkaido .... Wataru Hashimoto and Sutekazu Nagao
465. Naticid Gastropods from the Miyazaki Group. (Palaeontological Study of the Miyazaki Group—X) ....Tsugio Shuto

Short note 12. Discovery of Condonts and Horothurian Sclerites in Japan............. .... Klaus J. Müller

New Series 56 (Issued December 15, 1964)

477. Bryozoa of Akiyoshi. Part 2. Lower Carboniferous Bryozoa from the Uzura Quarry ....Sumio Sakagami
478. Some Solitary Corals from off Aomori Prefecture, Japan ....Kei Mori
479. A Rudistid from the Cretaceous Deposits of Ryoseki, Kochi Prefecture, Japan.... .... Yasuji Saito
480. *Yabeiceras* (Cretaceous Ammonites) from Futaba, Northeast Japan ....Tatsuro Matsumoto, Ikuwo Obata, Shiro Maeda and Teruo Sato
481. On some Lower and Middle Triassic Ammonoids from Japan ....Yuji Bando

Late Tertiary Floras from Northeastern Hokkaido, Japan

1965年2月15日 印刷
1965年2月20日 発行

定価 2,100円

東京大学理学部地質学教室内
日本古生物学会

編集者 松本達郎
発行者 市川健雄
印刷者 学術図書印刷株式会社
富田元
東京都港区芝片門前2ノ13
発売所 東京大学出版会
東京都文京区本富士町1東京大学構内
振替 東京59964 電 (811) 8814

Available from the University of Tokyo Press, University of Tokyo, Hongo, Tokyo.