



Title	Revisions of Tertiary Acer from East Asia
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Citation	北海道大学理学部紀要, 20(4), 291-390
Issue Date	1983-11
Doc URL	http://hdl.handle.net/2115/36723
Type	bulletin (article)
File Information	20_4_p291-390.pdf



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REVISIONS OF TERTIARY ACER FROM EAST ASIA

by

Toshimasa Tanai

(with 3 tables, 6 text-figures and 20 plates)

Abstract

Although a number of *Acer* species were recorded in the Tertiary of East Asia, their nomenclature and systematics have been considerably confused. Examination of previously-described and some undescribed specimens indicates that 35 species including five new species are designated with certain modern relationships in East Asia. Beside them six doubtful species of *Acer* are lacking in the definite systematic indications, and there are many specimens which are too incomplete to assign their modern relationships. Thirty-five well-defined species are included in 17 sections, of which three sections have no living species in East Asia. Considering the stratigraphic range of each species together with past and present distribution, the phylogenetic history of *Acer* in East Asia is briefly discussed. Three older lineages, the section *Spicata*, *Rubra* and *Campestris*, are confirmed. Other sections, excepting for *Distyla*, are rather young; most of them probably evolved from these three stocks, and some migrated from North America by long-distance dispersal.

Introduction

Tertiary forests in the middle latitudes of the Northern Hemisphere suddenly show the temperate aspect since Latest Eocene or Early Oligocene time, compared with the warmer aspect of Paleocene and Eocene forests (Tanai, 1967; Wolfe & Hopkins, 1967; Wolfe, 1978). The most conspicuous temperate families are represented by the Salicaceae, Betulaceae, Fagaceae and Aceraceae since the Oligocene through the Pliocene. The evolutionary trends and phytogeography of these families may provide a basis to account for the history of the temperate tree forests, which have been segregated into several regions of the Northern Hemisphere through the Tertiary.

Fossil remains of the Aceraceae are most abundant with a number of species in East Asia, as in the case of the present, compared with Europe and western North America, although these three regions show a close similarity in Tertiary temperate forests. Despite of the extensive palynological investigation of the Tertiary sediments, fossil pollen of *Acer* has been very scarcely known, because its pollen seems too weak to be preserved in the sediments. Thus, fossil records of *Acer* in East Asia are based largely on abundant foliages and winged seed, while very rarely on flowers and woods.

During these several years I have been engaged in the investigation of the genus *Acer* in the northern Pacific region (Tanai, 1977, 1978, 1981), occasionally with the cooperation of Dr. Jack A. Wolfe of the U.S. Geological Survey. This report is centered in the examination of previously described and some unlabeled specimens of *Acer* from the Tertiary of East Asia. Furthermore I will discuss briefly the stratigraphic distribution of this genus. The full discussion of evolutionary history in the northern Pacific region would appear later, when the revisions of Tertiary *Acer* from western North America would be completed.

Acknowledgments

I wish to express my thank for the loan of the type specimens to the following people: Prof. Emeritus K. Huzioka and Prof. T. Takayasu of Akita University at Akita, Dr. K. Ogasawara of Tohoku University at Sendai, Prof. K. Suzuki of Fukushima University at Fukushima, Mr. T. Onoe of the Geological Survey of Japan at Tsukuba, Mr. K. Uemura of National Science Museum at Tokyo, and Dr. H. Ina of Nagoya University at Nagoya. I thank to Prof. B. Lundblad of the Swedish Museum of Natural History at Stockholm to kindly allow to investigate some specimens of Spitzbergen for comparison with East Asian fossils. Acknowledgements are also to the curators of the following botanic gardens for offering kind facilities of collecting some extant materials: the Hillier Arboretum near Romsey, U.K., the Royal Kew Botanic Gardens, U.K., and Botanischer Garten Berlin-Dahlem, West Germany. I also thank to Mr. H. Nakasuji, one of my former students, who offered his collection for my study. Miss T. Watanabe has assisted me to make the cleared leaf slides and to type this manuscript. This investigation was carried out principally by the Grant-in-Aid for Scientific Research from the Ministry of Education, Science and Culture during these several years (to T. Tanai: no. 354287 for 1978-1979, no. 534035 for 1980-1981 and no. 574043 for 1982).

Fossil *Acer* from East Asia

Tertiary records of *Acer* were first described in Japan by Nathorst (1883), in Sakhalin by Heer (1871), in Kamchatka by Kryshstofovich (1934), in Ussuri by Heer (1878a), in Sikhote-Alin by Kryshstofovich (1921), in Korea by Huzioka (1943), and in China by Hu and Chaney (1938); thereafter a number of specific names have been established or proposed by many authors. However, some authors have erected new species on characteristics of little systematic value, while other authors, who did not compare cautiously with the original specimen, have assigned materials of widely different morphology to the same species. Thus, the taxonomy of Tertiary maples in East Asia has been greatly confused. It is due partly to the facts that the foliages among different species of maples are sometimes similar in the gross features, that leaves of even a single species are sometimes variable in shape and marginal characters, and that samaras have only a few distinct features to distinguish the specific character. Accordingly, the previously described maple fossils which were based merely on gross features or picture-matching characters, are now in need of re-examination on their generic assignments and the relationships with the extant species.

Leaf Remains

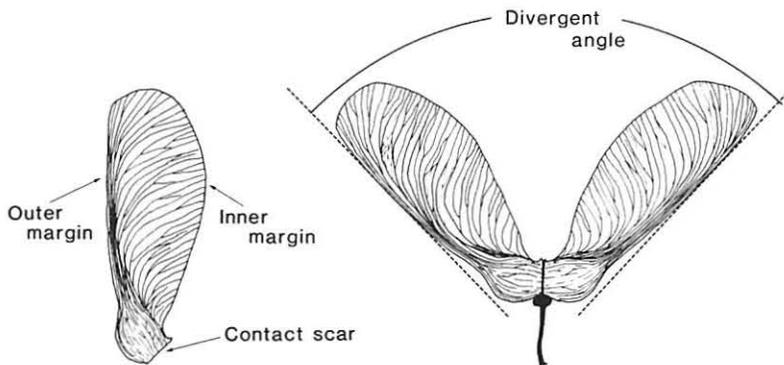
Most of *Acer* leaves are represented by impressions, and in some case by thin compressions which are difficult to detect cellular details because of ill-preservation. However, even in the impression with no anatomical detail, well-preserved venation, especially fine-veinlet patterns, can provide effective indications of the likely relation-

ships of fossil leaves.

For the comparison with the fossil leaves, I have investigated the venation characters of 123 species of *Acer* living in the world, based on the cleared leaf collections of the Paleobotanical Laboratories of Hokkaido University at Sapporo and U.S. Geological Survey at Menlo Park*. Through this investigation of the cleared leaves I could confirm that the polygonal areolation and fine veinlet pattern show a certain character peculiar to each species, and also that these characters are nearly consistent among the species of each section (Tanai, 1978a, b). Considering these venation details together with the foliar shape, lobation and marginal characters, all the leaf specimens of *Acer* previously described by various authors are reexamined on their modern relationships.

Samara Remains (Text-fig. 1)

Fossil fruits of *Acer* have been in most case found as single detached winged seed, and rarely as two divergent winged seeds attaching to pedicel. Most of these specimens are merely impressions as in the case of leaves, while the others are sometimes compressions with carbonized matter. Although the wing venation is generally preserved in fossils, its dichotomizing pattern seems too simple to be of value for specific identification.



Text-fig. 1. Explanation of Terms used in the Description of *Acer* samaras.

Investigating the exomorphic features of all the extant species, the following characters of samara are useful for classification of the sections: (1) size of samara, (2) shape and thickness of seed, (3) venation feature on the seed surface, (4) length of contact scar of seed, (5) divergent angles of two wings, (6) orientation of elongate seed to the wing, and (7) presence of hairs covering seed. The combination of these characters can provide an useful indication of the discrimination of each section.

Of the above 7 characters the hairs on the seed are generally of less value in fossils, because they are not always observable excepting for the well-preserved specimens.

*The paleobotanical laboratory of the Geological Survey recently moved from Menlo Park to Denver.

Other characters are usually well defined in fossil samara, and they well correspond with those of the extant related species. The divergent angles of two wings are determined by making double the angles, which are measured between the contact scar and the outer margin of wing, because a detached samara occur solely in most case of fossils.

Species of *Acer* in the Tertiary of East Asia

Examination of previously described and some undescribed specimens of *Acer* from the East Asian Tertiary reveals that 35 species including five new species are designated with certain modern relationships and are classified into 17 sections as shown in Table 1. Most of these species are represented by both foliage and samara, and some are only either foliage or samara. Though these 35 species are described or discussed in the systematics, the keys for the identification are presented shown in

Table 1. Tertiary *Acer* from East Asia

Section Macrantha Pax <i>Acer koreanicum</i> Endo <i>A. palaeorufinerve</i> Tanai et Onoe <i>A. uemurae</i> Tanai et Ozaki	Section Platanioidea Pax <i>Acer chiharae</i> Huzioka et Nishida <i>A. huziokae</i> Tanai <i>A. palaeoplatanoides</i> Endo <i>A. rotundatum</i> Huzioka <i>A. shanwangense</i> Tanai
Section Distyla Ogata <i>Acer protodistylum</i> Endo	Section Campestris Pax <i>Acer kushiroanum</i> Tanai <i>Acer protomiyabei</i> Endo
Section Spicata Pax <i>Acer arcticum</i> Heer <i>A. oishii</i> Tanai <i>A. subukurunduense</i> N. Suzuki	Section Saccharina Pax <i>Acer pseudoginnala</i> Tanai et Onoe <i>A. yamae</i> Tanai et Ozaki
Section Palmata Pax <i>Acer nordenskioldi</i> Nathorst <i>A. protojaponicum</i> Tanai et Onoe <i>A. protomatsumurae</i> Tanai	Section Oblonga (Hu et Cheng) Delendick <i>Acer prototrifidum</i> Tanai
Section Arguta Rehder <i>Acer tottoriense</i> Tanai et Ozaki	Section Trifoliata Pax <i>Acer subnikoense</i> Tanai et Ozaki <i>A. trifoliatum</i> Geng
Section Negundo (Boehm.) Maxim. <i>Acer protonegundo</i> Tanai	Section Lithocarpa Pax <i>Acer miofranchetii</i> Hu et Chaney <i>A. palaeodiabolicum</i> Endo
Section Cissifolia Koidzumi <i>Acer endoanum</i> Huzioka	Section Macrophylla (Pojark.) Momotani <i>Acer fatsiaefolium</i> Huzioka <i>A. grahamense</i> Knowlton et Cockerell <i>A. honshuense</i> Tanai et Ozaki
Section Trilobata Pojarkova <i>Acer subginnala</i> Guo	Section Indivisa Pax <i>Acer subcarpinifolium</i> Tanai
Section Rubra Pax <i>Acer ezoanum</i> Oishi et Huzioka <i>A. ishikariense</i> Tanai <i>A. tricuspdatum</i> Bronn	

Table 2 and 3, because of the past confusion in the nomenclature and systematics of Tertiary maples from East Asia.

Excluding Macrophylla, Negundo and Saccharina which are now endemic to North America, all other 14 sections are still native with luxuriant growth in East Asia. Of these 14 sections, Spicata and Rubra are East Asian-North American, Platanoidea and Campestris are East Asian-European, and Trilobata is East Asian-West Asian in their modern distribution; Palmata and Macrantha are mainly East Asian with specific diversity, but contain one living species respectively in North America; other 7 sections are confined to East Asia in their extant species.

Beside the 35 well-defined species, six doubtful species are lacking in the systematically exact indications because of the ill-preservation. In addition, there are many specimens which are too incomplete to assign their modern relationships, although they seem doubtlessly referable to the genus *Acer*. All these species and specimens of little systematic value are excluded from my consideration of phylogenetic and distributional history.

Table 2. A key for the Identification of *Acer* Leaves from the Tertiary of East Asia

- I. Leaf foliated.
 - 1. Ultimate veinlets branching usually more than twice within the areoles. Lateral leaflets mostly simple, irregularly coarse-serrate at the margin, sometimes with large, irregular dents.
 - A. Areoles irregular in shape, generally large in size *A. endoanum*
 - B. Areoles four- or five-sided, small to medium in size *A. protonegundo*
 - 2. Ultimate veinlets mostly single or lacking in the areoles. Each leaflet elliptical or ovate in shape.
 - A. Margin undulately dentate with obtuse teeth excepting the lower or basal part
..... *A. subnikoense*
 - B. Margin serrate with inconspicuous, acute teeth excepting the lower part
..... *A. trifoliatum*
- II. Leaf simple.
 - Secondary vein pinnate, more than 12 pairs; margin double serrate with acute teeth
..... *A. subcarpinifolium*
- III. Leaf palmately lobed.
 - 1. Each lobe separated by medium or deep, narrow sinus.
 - A. Ultimate veinlets branching usually more than twice within the areoles.
 - a. Central lobe larger than the laterals; margin incisedly serrate with acute teeth, in which the secondary veins end.
 - (1) Large principal teeth accompanied by one or two subsidiary teeth
..... *A. tottoriense*
 - (2) Large principal teeth double serrate with smaller, concave-convex teeth ...
..... *A. uemurae*
 - b. Central lobe nearly similar in size and shape to the laterals of the uppermost pairs, which are larger than other laterals.
 - (1) Margin coarsely double-serrate; lobes mostly 9 to 11
..... *A. protojaonnicum*
 - (2) Margin finely serrate or finely double-serrate; lobes mostly 5 to 7, with prolonged caudate tips *A. nordenskiöldi*
 - (3) Margin coarsely double-serrate; lobes 7, with caudate tips
..... *A. protomatsumurae*

- B. Ultimate veinlets mostly single or lacking in the areoles.
- a. Margin serrate with irregularly sized teeth, although the teeth are mostly small ...
..... *A. kushiroanum*
 - c. Margin variably dentate, accompanied by several small or minute subsidiary teeth *A. ezoanum*
2. Each lobe separated by widely opened sinus.
- A. Ultimate veinlets branching usually more than twice within large areoles.
- a. Margin finely double-serrate with bluntly pointed teeth; lobes deltoid in shape ...
..... *A. palaeorufunerve*
 - b. Margin coarsely serrate; teeth sometimes accompanied by a small subsidiary teeth.
 - (1) Marginal teeth acute to slightly acuminate; mostly five-lobed
..... *A. subukurunduense*
 - (2) Marginal teeth obtuse; usually trilobed *A. oishii*
 - c. Margin coarsely dentate or wavy with rounded, retuse-tipped teeth; lobation sometimes inconspicuous or non-lobed..... *A. arcticum*
- B. Ultimate veinlets branching more than twice within small areoles, but their branches very thin.
- a. Dentate teeth and lobe apex longly acuminate with caudate tip.... *A. honshuense*
 - b. Dentate teeth rather small and acute at the apex *A. fatsiaefolium*
- C. Ultimate veinlets mostly single or lacking in the areoles.
- a. Margin entire or remotely serrate with minute, obtuse teeth.
 - (1) Margin entire or slightly undulate; 5 to 7 lobed; areolation medium in size
..... *A. rotundatum*
 - (2) Margin entire; 3 lobed; areolation medium in size *A. huziokae*
 - (3) Margin remotely serrate; 5 to 7 lobed; areolation medium in size
..... *A. chiharae*
 - (4) Margin entire to remotely serrate; fimbrial vein conspicuous along the margin; areolation small in size *A. prototrifidum*
 - b. Margin irregularly double-serrate, sometimes with large dents.. *A. tricuspdatum*
 - c. Margin irregularly dentate.
 - (1) Dentation conspicuous with large, straight-concave dents.. *A. protomiyabei*
 - (2) Dentation inconspicuous with obtuse tips; sometimes undulate at the margin *A. yamanae*
 - (2) Dentation conspicuous with obtuse tipped teeth; tertiary veins among the intersecondary spaces well developed, percurrent..... *A. palaeodiabolicum*

Table 3. A key for the Identification for *Acer* Samaras from the Tertiary of East Asia.

- I. Seed part bulged outwardly from the margin of wing.
1. Seed very thick, considerably bulged outwardly.
 - A. Samara usually large; seed globose to ellipsoidal; divergent angles of two wings 100° to 140° *A. grahamense*
 - B. Samara medium-sized; seed orbicular; divergent angles of two wings 180° to 220°
..... *A. protomiyabei*
 - C. Samara large in size; seed orbicular; divergent angles of wings about 160°
..... *A. kushiroanum*
 2. Seed part thick, slightly bulged outwardly; seed globose.
 - A. Samara medium in size; seed large; divergent angles of two wings 60° to 90°
..... *A. yamanae*
 - B. Samara small to medium in size; seed small, globose.
 - a. wing oblanceolate, constricted at the lower part; divergent angles of two wings about 140° *A. koreanicum*
 - b. wing oblong, and its inner margin reaching the contact scar; divergent angles of two wings 120° to 180° *A. nordenskioeldi*

- II. Seed part not bulged from the outer margin of wing, and being kept within the wing width.
1. Divergent angles of two wings less than 100°.
 - A. Contact scar short, compared with seed size.
 - a. Seed thick; 2 or 3 longitudinal ridges existing on seed surface.
 - (1) Seed oblong to narrow oblong; divergent angles of two wings 40° to 60° ...
..... *A. protonegundo*
 - (2) Seed wide-elliptic; divergent angles of two wings 20° to 40° ... *A. endoanum*
 - b. Seed thick, covered by anastomosing veins.
 - (1) seed ellipsoidal to obovoid; inner margin of wing ending in the uppermost part of seed *A. ishikariense*
 - (2) Seed ellipsoidal; inner margin of wing reaching near the contact scar
..... *A. tricuspdatum*
 - c. Seed thick, spindle-shaped; samara usually large; divergent angles of two wings less than 20° *A. ezoanum*
 - d. Seed thin, narrow ovate; divergent angles of two wings 60° to 80°
..... *A. subcarpinifolium*
 - B. Contact scar long, compared with seed size; seed thick.
 - a. Wing more than 4 times long as seed.
 - (1) Wing narrow oblanceolate, and its inner margin nearly straight; divergent angles of two wings 50° to 60°.
 - i) Samara large, seed semicircular *A. fatsiaefolium*
 - ii) Samara medium in size, seed ovoid *A. honshuense*
 - (2) Wing narrow obovate, and its inner margin markedly convex; seed ovoid; divergent angles of two wings about 50° *A. protodistylum*
 - b. Seed surface irregularly wrinkled; divergent angles of two wings less than 35°; samara medium in size.
 - (1) Seed subglobose; longitudinal axis of seed nearly perpendicular to the outer margin *A. miofranchetii*
 - (2) Seed ovoid to subglobose; longitudinal axis of seed oblique to the outer margin of wing *A. palaeodiabolicum*
 - c. Seed subglobose to wide-ovate; divergent angles of two wings 20° to 45°; samara medium in size *A. pseudoginnala*
 - d. Seed ellipsoidal or oblong; divergent angles of two wings 20° to 40°; samara medium in size *A. subginnala*
 - e. Seed ovate; divergent angles of two wings 60° to 90°; samara small
..... *A. prototrifidium*
 - C. Contact scar long, compared with seed size; seed thin, flattened; divergent angles of two wings 60° to 90°; samara medium to large in size *A. rotundatum*
 2. Divergent angles of two wings more than 100°.
 - A. Samara small; wing mostly slender, narrow oblanceolate.
 - a. Seed oblong, thick; divergent angles of two wings more than 130°
..... *A. palaeorufinerve*
 - b. Seed globose, thick; inner margin of wing reaching the contact scar; divergent angles of two wings 110° to 180° *A. protojaponicum*
 - B. Samara medium in size; wing oblanceolate to oblong.
 - a. Seed thin, flattened, obovate; divergent angles of two wings 110° to 180°
..... *A. palaeoplatanoides*
 - b. Seed thin, ovate; divergent angles of two wings 90° to 120° *A. uemurae*

Stratigraphic and Areal Distribution

Compared with the Tertiary continental deposits of Asian mainland, those of Japan and Sakhalin are mostly associated with the marine deposits, and well dated in connection with marine faunas whose biostratigraphy has been recently advanced.

Although the stratigraphic correlation of Tertiary plant-bearing deposits have not yet been accomplished in whole areas of East Asia, the recent development of the paleobotanical studies has made possible to correlate Tertiary floras of Japan with those of Asian mainland. Especially, the Oligocene to Miocene floras of Sikhote-Alin (Ablaev, 1978; Akhmetjev, 1973), Ussuri (Baikovskaya, 1974) and Kamchatka (Chelebaeva, 1968, 1978) show close similarity to those of Japanese islands with a number of similar components excepting for minor difference of composition. Accordingly the stratigraphic ranges of Tertiary plants are now soundly discussed.

No Cretaceous fossils of East Asia are definitely referable to *Acer* up to the present. The Paleocene continental deposits with plant fossils have been sometimes reported by Russian workers (Shilo, 1979) in Sakhalin, Kamchatka and Asian mainland, but their age-assignments have not yet been proved. Thus, nearly all the records of *Acer* have been known from the Early Eocene and onwards in East Asia. Thirty-five well-defined species of *Acer* are summarized in their stratigraphic ranges as shown in Text-figures 2 and 3. Except for five species confined to the Paleogene, most of the species appeared since Late Oligocene or Early Miocene time. Considering the fossil occurrence, maples of East Asia were few in number of specimens during the Paleogene, while they became rapidly dominant during the Miocene. Such occurrence is consistent with that of other temperate genera during the Tertiary of East Asia.

Of five older maples *A. arcticum*, *A. oishii*, *A. ishikariense* and *A. kushiroanum* are of long range, from the Eocene through the Oligocene. The oldest species, *A. arcticum*, may go back to the Paleocene, if the plant-bearing deposits of Bureja (Heer, 1978; Konstantow, 1914) are correct in the age assignment. *A. protodistylum* is uncertain in its exact range, because it was known only from one locality. Somewhat longer ranging are five Neogen species: *A. palaeorufinerve*, *A. nordenskioldi*, *A. protojaponicum*, *A. ezoanum* and *A. rotundatum* which are from Earliest Miocene to Pliocene times. All other Neogene species show shorter or limited ranges.

The investigation of the fine veinlet pattern of the extant leaves revealed that all the sections of *Acer* are classified into two major groups (Tanai, 1978): the first group is generally characterized by complicated veinlets which are ramified usually more than twice but rarely once branching; while the second group is by the veinlets which are mostly single to once branching or almost lacking. Although various systems of classification of *Acer* have been proposed by many authors, I follow Ogata's system (1967) which is nearly consistent with the venation characters of leaves. The fossil species, as far as determined, are well consistent in the fine venation with their related extant species which were judged from the other morphological characters. The above two groups by veinlet pattern are also distinguishable in the fossil foliage, and the phylogenetic relationships seem to be preserved partly in the foliage venation. Of 17 sections confirmed by fossils, 9 sections belong to the first group (Text-fig. 2), and 8 sections to the second group (Text-fig. 3).

Four older sections in East Asia are *Spicata* of the first group, and *Rubra*, *Distyla* and *Campestris* of the second group. Excluding *Distyla* of a limited occurrence, all the species of three older sections overlap in their stratigraphic ranges during the Eocene,

and they are quite different in the morphological characters of the foliage and fruit. It is presumed that the phyletic lines of these 3 sections had diverged from the ancestor by or during Paleocene time. Judging from the fossil occurrence, other 13 Tertiary sections probably derived from these 3 stocks or were brought in East Asia from other continents by migration.

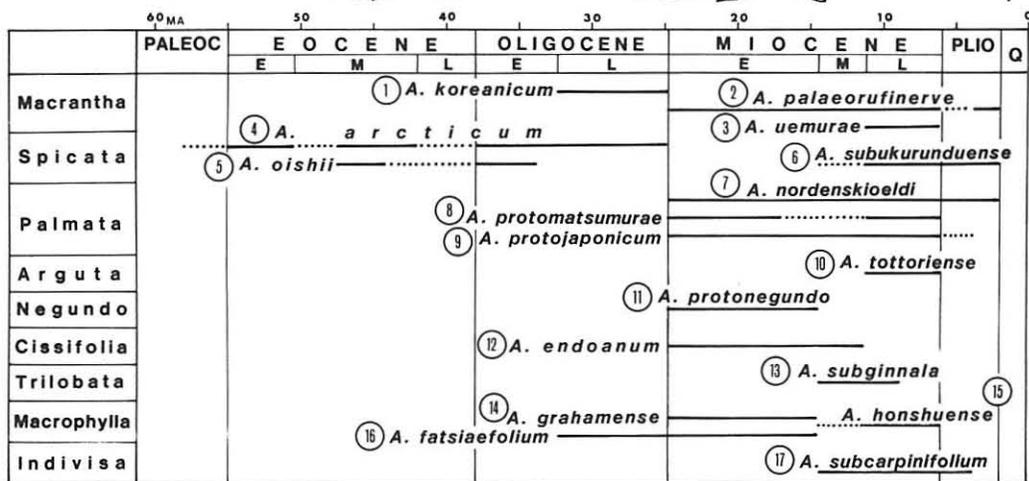
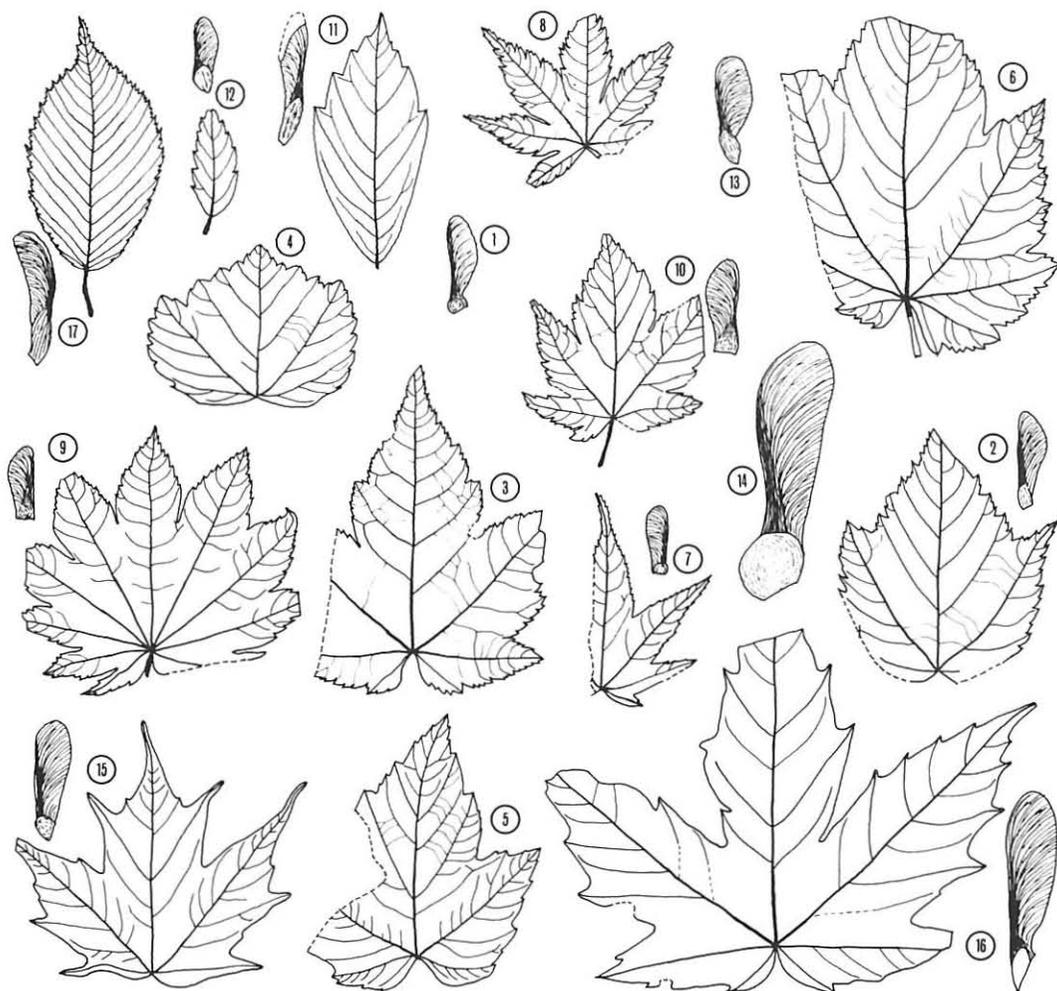
The First Group (Text-fig. 2)

The section *Spicata* contains three distinguishable species; the oldest species, *A. arcticum* which was originally described from the "Paleocene" of Spitzbergen, was widely distributed in the Eocene and Lower Oligocene of North Japan and Asian mainland. *A. oishii* seems to have diverged from *A. arcticum* in Hokkaido; it shows closer resemblance to the extant species of *Spicata* and is more limited in distribution. Though this section is older in its appearance, it is now unsolved why its Neogene species (*A. subukurunduense*) is rather limited to the younger Neogene of North Japan and Kamchatka without any Early Miocene occurrence.

The section *Macrantha*, although its antiquity was suggested by Ogata (1976), has not any older Paleogene occurrence. It appeared first since Late Oligocene time in Japan, Korea and Kamchatka, and contains two species during the Miocene, though not common in specimens excepting for *A. palaeorufinerve*. Considering the fossil occurrence together with considerable diversity of the modern species in East Asia, *Macrantha* evolved recently to diversify rapidly from a primitive stock of the *Spicata*.

The section *Palmata* also lacks its Paleogene record, but two species, *A. nordenskioldi* and *A. protojaponicum*, appeared with common occurrence since Early Miocene time in Japan, Korea, China and Sikhote-Alin. The fine venation characters of leaves suggest that *Palmata* probably derived from the *Spicata* stock. No fossil record of *Palmata* has been known in North America, though one species is living in the western region. On the other hand, *Palmata* is most diversified with more than 30 species in East Asia amongst the extant *Acer*. Compared with three Neogene species in East Asia, such diversification of *Palmata* shows a recent history.

Noticeable is the fact that North American *Negundo* and *Macrophylla* are doubtlessly confirmed by fossil foliage and fruit in East Asia. *Macrophylla* is represented by three species from Japan, Sakhalin, Korea and Sikhote-Alin: the oldest *A. fatsiaefolium* ranging from the Upper Oligocene to the Middle Miocene, is more akin to the extant *A. macrophyllum* of western North America than the other two. An Alaskan Tertiary species, *A. grahamense*, is recorded from the Miocene of North Japan and Kamchatka, and its derivative, *A. honshuense*, is found in the Upper Miocene of western Japan. Fossils of the section *Negundo* are sparsely known in Japan and North Korea, limited to the Lower and Middle Miocene. On the other hand, fossils of *Macrophylla* and *Negundo* are the maples which are most common and extensively distributed in western North America from the Eocene through the Pliocene. The comparison of such fossil occurrence between East Asia and western North America indicates that the



Text-fig. 2. Stratigraphical Distribution of the First Group of *Acer* in East Asia.

Figures of leaf and samara $\times 1/2$

Negundo and Macrophylla probably entered East Asia from western North America via the Beringia by the end of Oligocene time.

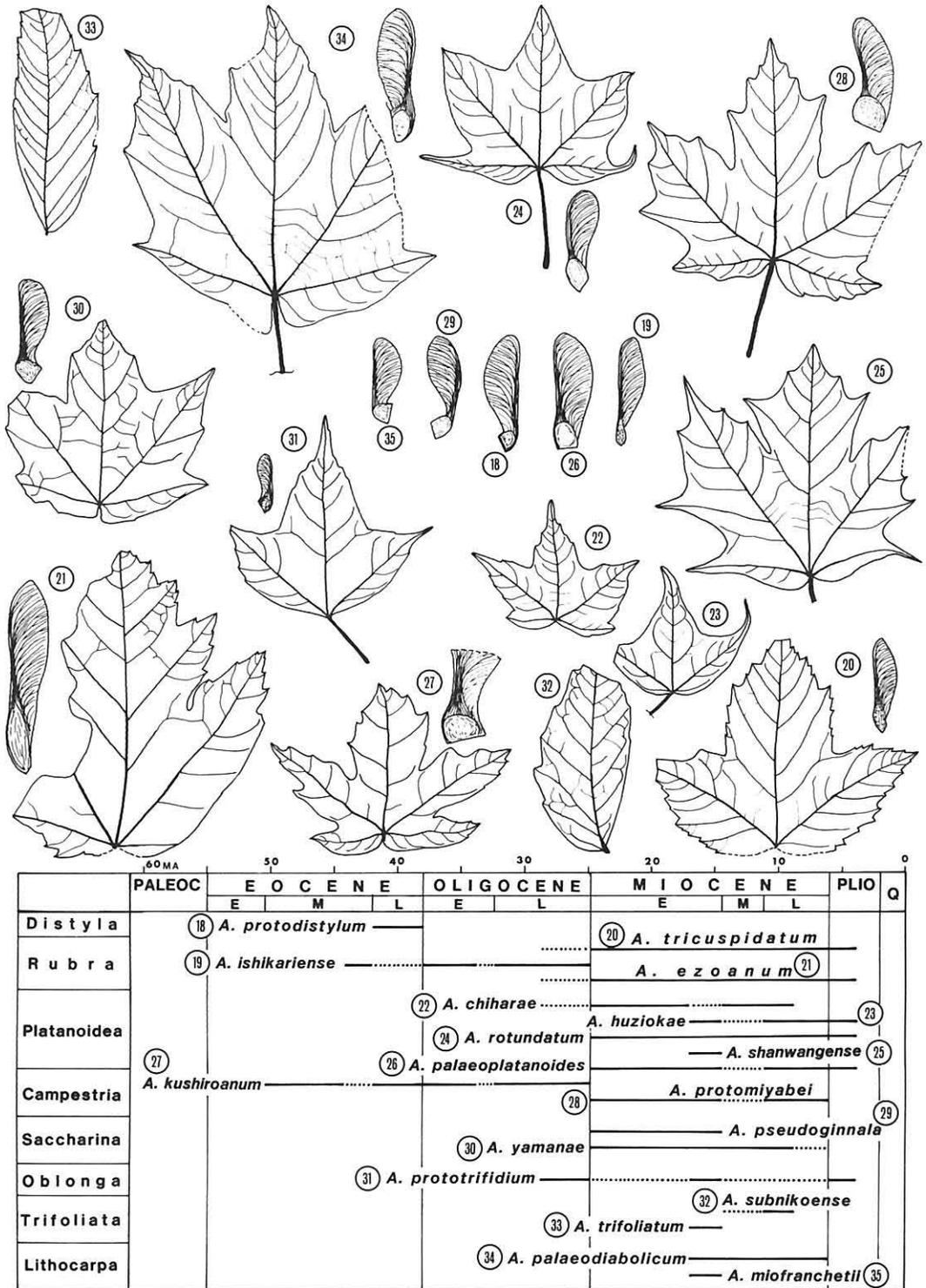
The remaining sections of the first group, Arguta, Cissifolia, Trilobata and Indivisa, are limited in their fossil occurrence or stratigraphic range. Cissifolia is akin to Negundo in the foliar and fruit characters; these two were sometimes included in a section or subgenus (Rehder, 1940; Momotani, 1962), while they are mostly considered an individual section respectively. Cissifolia is distinguishable from Negundo in the size of areoles, fine veinlets and seed shape. Despite of few occurrence, *A. endoanum* of Cissifolia is recorded through the Miocene of Japan and Korea; it probably evolved from Negundo by Earliest Miocene time.

Indivisa has an unique foliar shape which resembles some leaves of the Betulaceae, and it also shows a peculiar feature of the fine veinlets and elongate areoles differing from those of other maple leaves. *A. subcarpinifolium* of Indivisa is largely confined to the Middle and Upper Miocene of northern Hokkaido, and it is associated with *A. subukurunduense* whose record is also limited of northern Japan. Indivisa is suggested to have evolved from the Spicata stock. Arguta and Trilobata are scarcely known in their fossil records up to the present, represented by one species respectively; though their phylogenetic history is now uncertain, these two seem to have recently adapted to the cooler climate or mountain environments, considering fossil occurrence together with their recent distribution.

The Second Group (Text-fig. 3)

The oldest phyletic line in the second group is the section Campestria represented by two species, *A. kushiroanum* and *A. protomiyabei*: the latter shows a more modern aspect similar to the extant *A. miyabei* than the former. Although *A. kushiroanum* has a long range, its occurrence has been sparsely known only from Hokkaido. However, its descendant, *A. protomiyabei*, is widely distributed over the whole area of East Asia during Early Miocene time, and further extends into Alaska and southward (Wolfe and Tanai, 1980) in late-Early Miocene time. A rapid expansion of the descendant species may suggest that *A. kushiroanum* is expected to be found in the Paleogene of other regions of East Asia. As the fossil remains of Campestria are limited to the Miocene in western North America and to the Pliocene in Europe, the section Campestria is probably East Asian in origin.

Another old section Rubra contains three species, of which the oldest *A. ishikariense* is represented only by fruit from the Middle Eocene to the Oligocene; its samara is closely similar to the extant *A. rubrum* and *A. saccharinum*, especially to the latter although further smaller than the latter. *A. ishikariense* was replaced by *A. tricuspdatum* (ser. Rubra) and *A. ezoanum* (ser. Eriocarpa) since the Early Miocene; the former species has a wide distribution in the whole region of East Asian continental margin, further extending into the interior area such as the Aldan river, while the latter is rather dominant in North Japan to Kamchatka and Sikhote-Alin. Considering such



Text-fig. 3. Stratigraphical Distribution of the Second Group of *Acer* in East Asia.
 Figures of leaf and samara $\times 1/2$

occurrence together with North American fossil occurrence of ser. *Eriocarpa*, *A. ezoanum* appears to have not derived directly from *A. ishikariense* but to have come from North America to East Asia via long-distance dispersal.

A. ishikariense appeared somewhat late behind *A. kushiroanum* of *Campestris* during the Eocene in Hokkaido. The section *Rubra* appeared first in the Middle Eocene in western North America (Tanai, 1978; Wolfe, 1981) and in the Upper Oligocene in Europe (Walther, 1972), and thereafter the species of this section were widely distributed in the both continents with conspicuously abundant specimens as well as in East Asia. The comparison of fossil occurrence may show *Rubra* originated in North America and then entered East Asia. The section *Rubra* was grouped together with *Spicata*, *Macrantha*, *Palmata* and other five sections of the first group in phylogenetic relationships by Ogata (1967). However, considering the fossil occurrence together with the fine venation character, *Rubra* represents another old phyletic line of the maple history.

The section *Platanoidea* is one of the most common maples through the Neogene of East Asia. Fossils of *Platanoidea* are very variable in foliar shape and the divergent angles of wings, as in the extant *A. mono*. Distinguishable are five species, of which *A. rotundatum* represented by both leaf and fruit was widely distributed in all the regions of East Asia, ranging from the Lower Miocene to the Pliocene. *A. palaeoplatanoides* represented by only fruit, is closely akin to *A. rotundatum*, and shows nearly similar stratigraphic range and areal distribution. Other three species of *Platanoidea* have rather limited in fossil occurrence or stratigraphic range. *A. chiharae* with weakly-toothed leaves ranged from the Upper Oligocene to the Miocene, although uncommon in specimens. It is somewhat questionable to be an independent species, but it is known from Kamchatka, Japan and China. Because the extant *A. mono* has sometimes a similarly toothed leaves, especially in the juvenile shoots, *A. chiharae* may be one of the prototypes of *Platanoidea*.

Fossils of *Platanoidea* are known from the Neogene of Europe with abundant occurrence, while few in western North America. On the one hand, the extant species of *Platanoidea* are widely distributed now from East Asia through West Asia to Europe. I once considered that *Platanoidea* evolved from the stock of *Campestris* (Tanai, 1978b: fig. 6); however, no Paleogene record of *Campestris* is known in Europe (Walther, 1972). Such fossil occurrence and modern distribution may suggest that *Platanoidea* evolved from the stock of *Rubra* in both East Asia and Europe separately during Late Oligocene time. However, *Platanoidea* and *Campestris* are closely related, having many common characters as pointed out by many taxonomists; the phyletic line from which *Platanoidea* originated, should be further investigated.

It is noteworthy for phytogeographic history of *Acer* that two species of North American *Saccharina* are confirmed in the Miocene of East Asia, and that they are widely known from Japan, Korea, China and Sikhote-Alin although uncommon. *A. pseudoginnala* appearing first in the Lower Miocene, is closely similar to the extant *A. saccharum*, while its probable derivative, *A. yamanae*, resembles the extant *A. nigrum*. Fossils of *Saccharina* are commonly known in the Miocene and Pliocene of Oregon and

California. The fact that fossil record of *Saccharina* is lacking in the Neogene of Kamchatka, Sakhalin and Alaska, may suggest that *Saccharina* independently originated from the stock of *Rubra* in East Asia and western North America. Because the *Rubra* already had its wide occupation in the both regions during the Eocene and Oligocene.

Other three sections, *Oblonga*, *Trifoliata* and *Lithocarpa*, are rather limited in their stratigraphic ranges or fossil occurrences. These sections are probably East Asiatic in origin, because they have no fossil records in Europe and North America. *A. proto-trifidum* of *Oblonga* is known from Japan, China and Korea at late-Early Miocene time when the climate was warmer. If a fruit from Dembi of Primorye (Akhmetjev & Schmidt, 1976: pl. 10, fig. 10) is certainly referable to this species, *Oblonga* may be traceable back to the Upper Oligocene in East Asia.

The section *Trifoliata* contains two Neogene species; however, these two species are known from only one locality respectively, and *Trifoliata* is uncertain in its history. The section *Lithocarpa* has also two Neogene species: *A. palaeodiabolicum* is recorded widely from the Middle and Upper Miocene of Japan, and sparsely from the Miocene of Korea; while *A. miofranchetii* is known from the Miocene of China. Such fossil occurrence shows that the diversification of *Lithocarpa* may be in recent history. *Lithocarpa* was considered to be related with *Macrophylla* of the first group by Pojarkova (1933) and Ogata (1967); in actual, these two sections are common in many characters such as the imbricated bud-scales, leaf shape and stiff-hairy seed. The fine venation character, however, shows that *Lithocarpa* is rather remote from the phyletic line of *Macrophylla*.

Conclusion

Thirty-five species of *Acer* which are redesignated from the Tertiary of East Asia, are classified into 17 sections on the basis of the modern relationships of foliar and fruit characters. All these sections excluding *Macrophylla*, *Negundo* and *Saccharina* which are now endemic to North America, are still native with luxuriant growth in East Asia. It is noteworthy for the history of *Acer* that no fossils from the East Asian Tertiary are referable to three sections of *Acer*, *Goniocarpa* and *Monspessulana* whose living species are now confined to Europe and West Asia.

Fossil occurrence shows the East Asian maples have four old lineages during the Lower Tertiary: the section *Spicata*, *Distyla*, *Rubra* and *Campestris*. Judging from the combination of stratigraphic range and geographic distribution, *Spicata* and *Campestris* seem to be East Asian in origin, while *Rubra* is presumed to have entered from North America by the Middle Eocene. Although *Distyla* appeared in Late Eocene time, its history is now uncertain, due to the limited fossil occurrence. The other 13 sections are rather younger in their history; most of them are suggested to have diverged from the above old phyletic lines. *Macrantha* and *Palmata* derived from the *Spicata* stock, and *Platanoidea* and *Oblonga* from *Campestris* or *Rubra* stocks in Latest Oligocene or Earliest Miocene time. On the one hand, the comparison of fossil occurrences between East Asia and western North America indicates that *Negundo* and *Macro-*

phylla probably entered East Asia from North America via the Beringia by the end of the Oligocene, and that *Saccharina* evolved from *Rubra* which was already distributed in East Asia during the Paleogene.

Paleogene floristic composition shows that Eocene maples were mixed with tropical or subtropical trees in the forests. Since the Late Oligocene or Early Miocene 15 species of *Acer* rapidly diversified with predominant occurrence. The terminal Eocene Event and subsequent cooling could have resulted in the diversification which lead many sections. Again, the late-Early Miocene warming and subsequent cooling toward the Pleistocene also resulted in appearance of further new sections or new species since the Middle Miocene. The complexity of the history of a genus such as *Acer* is the result of a number of factors, including Cenozoic climate history and changing tolerance of individual lineages.

Systematic Descriptions

Terms of leaf architecture used in the description are mostly based on those of Hickey (1979), while those of the external morphology of samara are shown in Text-fig. 1. For the occurrences of each species, I have cited, where possible, museum catalogue numbers pertaining to individual specimens. The following abbreviations have been used:

- AKMG: Institute of Mining Geology, Akita University, Akita.
- DBGI-AN: Dalinebostochiy Geologicheskii Institute, Akademia Nauk, Vladivostok.
- GIN-AN: Geologicheskii Institute, Akademia Nauk, Moscow.
- GSJ: Museum of the Geological Survey of Japan, Tsukuba.
- GYNU-CMP: Geological Institute, Yokohama National University, Yokohama.
- HUMP: Museum of Palaeontology, Hokkaido University, Sapporo.
- IAGI: Institute of Applied Geology, Iwata University, Morioka.
- IGF: Institute of Geology, Fukushima University, Fukushima.
- IGPS: Institute of Geology and Palaeontology, Tohoku University, Sendai.
- IV-AN: Institute Vulkanologii, Akademia Nauk, Petropavlovsk, Kamchatka.
- JC88: Palaeobotanical Collection from Cenozoic Strata of Japan in the Department of Geology and Mineralogy, Kyoto University, Kyoto.
- NIGP-PB: Palaeobotany Collection, Nanking Institute of Geology and Palaeontology, Nanking.
- NSM-PP: Plant Fossil Collection, National Science Museum, Tokyo.
- PI-AN: Palaeontological Museum, Akademia Nauk, Moscow.
- SLG DAW: Museum für Naturkunde der Humboldt-Universität Berlin, East Berlin.
- SMNH: Palaeobotany Collection, Swedish Museum of Natural History, Stockholm.
- TPM: Paleontology Collection, Tottori Prefectural Museum, Tottori.
- RSG: Research Institute of Science Education of Gunma Prefecture, Maebashi.

Section *Macrantha* Pax
Acer koreanicum Endo

(pl. 17, fig. 2)

Acer koreanicum Endo. 1950. Short Papers IGPS. (1): 15. pl. 3. f. 13.

Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 64. pl. 8. f. 19., 19a.

Type: Holotype, IGPS-60996; “*Engelhardia*” Beds (Late Oligocene); Kogeonweon, Yongpukdong, North Korea.

Discussion: This species was based on a single samara from North Korea (Endo, 1950), although its modern relationship was once unknown. This specimen is characterized by the following features: the thick, globular seed is somewhat bulged outwardly; the contact scar is distinct and long in comparison with a rather small samara; angle between the contact scar and outer margin of wing is about 70°. Huzioka (1972) suggested that *A. koreanicum* may be similar to the extant *A. capillipes* Maxim. of southern Japan, but this specimen is different from samara of the modern species in thick seed. The above-noted characters show that *A. koreanicum* is rather related to the extant *A. insulare* Makino of southern Japan. However, this modern relationship needs to be further investigated by collecting more specimens of leaves and samaras.

Occurrence and collections: Kogeonweon (IGPS-60996), North Korea.

Acer palaeorufinerve Tanai et Onoe

(pl. 3, fig. 11; pl. 4, fig. 3; pl. 5, fig. 10)

Acer palaeorufinerve Tanai et Onoe. 1961. Geol. Surv. Jap. Rept. (187): 49. pl. 16. f. 2, 3.

Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 688. pl. 3. f. 5.

Tanai & N. Suzuki. 1963. Tertiary floras Japans. p. 140.

Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 65.

Huzioka & Uemura. 1973. Bull. Natl. Sci. Mus. 16 (4): 719. pl. 13. f. 5-7.

Akhmetijev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 92. pl. 10. f. 13; text-f. 1-11.

Tanai & Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 578. pl. 5. f. 10; text-f. 6-B.

Chelebaeva. 1978. Miocene floras east-Kamchatka. p. 83. pl. 20. f. 1; text-f. 31-1.

Acer rufinerve auct. non Sieb. et Zucc. Miki. 1937. Jap. J. Bot. 8: 322. f. 8-0.

Okutsu. 1940. Saito Ho-on Kai Mus. Res. Bull. (19): 164. pl. 7. f. 1, 2.

Endo. 1951. Short Papers IGPS. (3): 53. pl. 8. f. 4, 5.

Acer franchetii auct. non Pax. Okutsu. 1940. Saito-Ho-on Kai Mus. Res. Bull. (19): 162. pl. 7. f. 4.

Acer trilobatum (Sternb.) Al. Br. var. *tricuspidatum* auct. non Heer. Endo. 1951. Short Papers IGPS (3): 56. pl. 8. f. 1.

Acer nomurai auct. non Okutsu. Murai. 1957. Tech. Rept., Iwate Univ. (10): 43. pl. 1. f. 3.

Murai. 1963. ditto. 16 (1): 109. pl. 12. f. 8.

Acer protorufinerve Endo. 1963. Trans. Proc. Palaeont. Soc. Japan N.S. (5): 67. pl. 10. f. 3.

Acer pseudocarpinifolium auct. non Endo. Onoe. 1974. Geol. Surv. Jap. Rept. (253): 51. pl. 11. f. 10, 11.

Type: Holotype, GSJ no. 4182. Mitoku Formation (Late Miocene). Mitoku, Misasamachi, Tottori Prefecture.

Discussion: This species is based on both leaves and samaras, which are commonly known from the Neogene of East Asia. The fossil leaves are mostly three and rarely five in palmate lobation with broadly opened sinus, and are double serrate with bluntly pointed teeth. The ultimate veinlets are mostly once to twice branching, and rarely

single within the quadrangular or pentagonal areoles. The winged seeds of *A. palaeorufinerve* are small to medium in size, thick in oblong seed part, and more than 130° in the divergent angles of two wings. These characters of both fossil leaves and samaras are closely similar to those of the extant species of the section *Macrantha* such as *A. rufinerve* Sieb. et Zucc. of Japan and *A. pennsylvanicum* Linn. of eastern North America. Leaves of the extant *A. pectinatum* Wall. of Himalaya and *A. capillipes* Maxim. of southern Japan are also similar in general appearance to *A. palaeorufinerve*, but are distinguishable in smaller areolation and long petiole.

All the specimens listed in the above synonymy are included in *A. palaeorufinerve*. It is noteworthy that the fossil leaves are generally somewhat conspicuous in subsidiary teeth of the marginal principal teeth than in leaves of the extant analogues. A single leaves of *A. nomurai* from the Late Miocene near Sendai (Okutsu, 1940) is probably identical to *A. palaeorufinerve*, although the lateral lobes are somewhat more conspicuous than in other fossil leaves of *A. palaeorufinerve*. If this reference is valid, the epithet of “*nomurai*” has a priority for the fossil leaves resembling the extant *A. rufinerve*. However, the original specimen of *A. nomurai* was unfortunately lost in the Saito Ho-on Kai Museum of Sendai, and we cannot reinvestigate its detailed character. Thus, I prefer to retain *A. palaeorufinerve* in order to avoid a future confusion.

Occurrence and Collections: Kaminokuni (HUMP no. 25034), Yoshioka, Rubeshibe (HUMP no. 25901), Shanabuchi and Penkenai (HUMP nos. 26200, 26201), Hokkaido; Miyata (AKMG-7109, 7248, 7249, 7406), Akita Pref.; Goshō (IAGI No. 61090), Iwate Pref.; Nenoshiroishi (IGPS-60501, 60570, 60596, 60981), Miyagi Pref.; Oguni (GSJ nos. 4589, 4590), Yamagata Pref.; Kabutoiwa (RSG nos. 1221, 1222), Gunma Pref.; Omi, Nagano Pref.; Akashi, Hyogo Pref.; Mitoku (GSJ nos. 4182, 4183) and Tatsumitoge (NSM-PP-16052; GSJ no. 4779), Tottori Pref.; Hamjindong (IGPS-59755), North Korea; Korf Bay (IV-AN no. 511/26), Kamchatka.

Acer uemurae Tanai et Ozaki

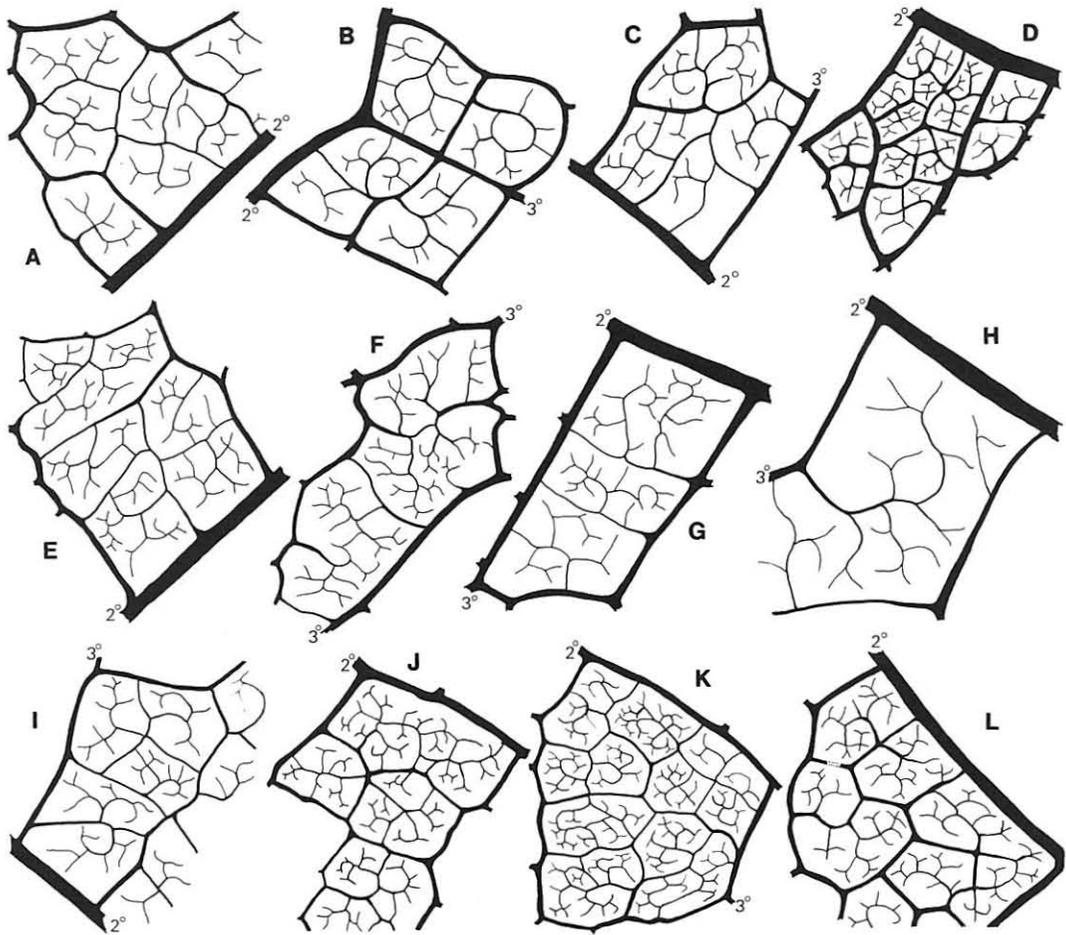
(pl. 5, fig. 11)

Acer uemurae Tanai et Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4], 17 (4): 579. pl. 5. f. 3, 4, 9; text-f. 2-B.D.

Type: Holotype, TPM-293; Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Pref.

Discussion: This species represented only by leaves, is uncommon in the Neogene of Japan. These five-lobed leaves are characterized by the following features: each lobe is acuminate at apex, with a long tip; margin is compoundly double-serrate with large, obtuse principal teeth which are clefted by angular sinus; the ultimate veinlets are thin but well-developed, and are ramified 3 or 4 times within four- to five-sided areoles. As already discussed in detail, *A. uemurae* is closely related to the extant *A. micranthum* S. et Z. and *A. tchonoskii* Maxim. of Japan, especially to the former.

Occurrence and Collections: Tatsumitoge (TPM-293, -484; NSM-PP-16067), Tottori Pref.



Text-fig. 4. The Details of Venation Characters of Fossil *Acer* — (1) all figures $\times 15$.

- A. *Acer palaeorufinerve* Tanai et Onoe. HUMP no. 26201 (pl. 5, f. 10)
- B. *Acer arcticum* Heer, SMNH collection (Heer, 1876: pl. 22, f. 1).
- C. *Acer arcticum* Heer. SMNH collection, Lectotype (Heer, 1876: pl. 22, f. 7).
- D. *Acer arcticum* Heer, HUMP no. 26205 (pl. 2, f. 3).
- E. *Acer uemurae* Tanai et Ozaki. Holotype TPM-293 (pl. 5, f. 11).
- F. *Acer oishii* Tanai. HUMP no. 26206 (pl. 4, f. 7).
- G. *Acer oishii* Tanai. Holotype HUMP no. 25986 (pl. 2, f. 6)
- H. *Acer subukurunduense* N. Suzuki. Holotype HUMP no. 25918 (pl. 4, f. 2)
- I. *Acer nordenskiöldi* Nathorst. SMNH collection, Lectotype (Nathorst, 1883: pl. 11, f. 4)
- J. *Acer nordenskiöldi* Nathorst. NSM-PP 16065 (Tanai & Ozaki, 1977: pl. 1, f. 2)
- K. *Acer protomatsumurae* Tanai. Holotype GSJ no. 4777 (pl. 3, f. 5)
- L. *Acer protojaponicum* Tanai et Onoe. HUMP no. 25037 (Tanai & N. Suzuki, 1960: pl. 5, f. 6)

Section *Distyla* Ogata
Acer protodistylum Endo
 (pl. 3, fig. 4)

Acer protodistylum Endo. 1950. Short Papers IGPS. (1): 12. pl. 3. f. 2.

Acer subpictum auct. non Saporta. Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 128. pl. 111. f. 5.
Type: Holotype, IGPS-60988; Fushun coal-bearing Formation (Late Eocene or Lower Oligocene); Fushun, Liaoning, China.

Discussion: This species is based on a single well-preserved samara from the Paleogene of the Fushun coal field. This samara is characterized by a rather small and subglobose seed, somewhat slender and oblanceolate wing, and acute angle (about 26°) between the outer margin of wing and contact scar of seed. These features well accord with those of the extant *Acer distylum* Sieb. et Zucc. of Japan as suggested by Endo (1950). Endo's original figure was later illustrated as *A. subpictum* in the book, Cenozoic plants of China (Acad. Sinica, 1978), but the original specimen is distinctly different from samaras of *A. mono* group in seed character as far as reinvestigated by me.

Two samaras from the Miocene of Hokkaido which were once referred to *A. protodistylum* (Tanai & N. Suzuki, 1960), were confirmed to belong to other sections by my reinvestigation. No fossil leaf referable to *A. protodistylum* has been yet known in the Tertiary of East Asia. A single leaf of *A. kryshstofovichii* from the Oligocene of Sakhalin (Borusk, 1965) has a ovate form similar to that of *A. distylum*, but it is too ill-preserved to determine.

Occurrence and Collection: Fushun (IGPS-60988), China.

Section *Spicata* Pax
Acer arcticum Heer
 (pl. 1, figs. 1-4; pl. 2 figs. 1, 3, 4)

Acer arcticum Heer. 1876 (part). Kgl. Sv. Vet. Akad. Handl. 14(5): 86. pl. 22. f. 1-7; pl. 23. f. 1-4a, 5-9; pl. 24. f. 1, 2a; pl. 25. f. 1-3 (excluding pl. 30. f. 6).

Nathorst. 1888. Palaeont. Abhandl. 4 (3): 11. pl. 3. f. 1.

Konstantow. 1914. Mem. Comite Geol. n. ser. 113: 8. pl. 4. f. 1.

Endo. 1942. Bull. Cent. Natl. Mus. Manch. (3): 40. pl. 16. f. 11; pl. 17. f. 10.

Oishi & Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 87. pl. 9. f. 1-5.

Tanai. 1961. ditto. 11(2): 356. pl. 26. f. 8, 9; pl. 27. f. 6.

Endo. 1963 (part). Trans. Proc. Palaeont. Soc. Jap. N.S. (50): 60. pl. 10. f. 5.

Kryshstofovich & Baikovskaya. 1966. Selected Works of Kryshstofovich. 3: 298. text-f. 15.

Endo. 1968 (part). Bull. Natl. Sci. Mus. 11 (4): 436. pl. 5. f. 5; pl. 12. f. 5.

Tanai. 1970. J. Fac. Sci., Hokkaido Univ. [4]. 14 (4): 488. pl. 14. f. 3, 7.

Acad. Sin. 1978. Cenozoic Plants of China. p. 124. pl. 108. f. 3, 4; pl. 115. f. 5.

Acer thulense Heer. 1876. Kgl. Sv. Vet. Akad. Handl. 14 (5): 88. pl. 24. f. 3.

Type: Lectotype, SMNH Palaeobot. Section collection (Heer, 1876; pl. 22. f. 7); the Cape Lyell, Spitzbergen.

Discussion: A number of leaves from the Paleogene of Hokkaido and northern Honshu are referable to *Acer arcticum*, which was originally described from the "Paleocene" of Spitzbergen by Heer (1876). The fossil leaves of Spitzbergen were grouped in-

to the following five types by Heer, based on foliar shape and lobation characters: (1) leaves wider than the length, trilobed with distinct lateral lobes, and deeply cordate at the base, (2) leaves longer than the width, trilobed but indistinct in lateral lobation, deeply cordate at the base, (3) leaves longer than the width, nearly rounded at the base, (4) leaves longer than the width, unlobed, and dentate with big teeth on the margin, (5) leaves coarsely wavy on the margin. My collection includes also these five leaf types, while many intermediate forms indicate that there is an intergradation in the morphological characters defined by Heer.

So far as investigated in detail by me, all the Heer's original specimens stored at Stockholm, both illustrated and unillustrated, show the similar venation and marginal characters, although variable in size, shape and lobation. *A. arcticum* is characterized by the features that the margin is coarsely dentate with round, retusely-tipped teeth, and that the freely-ending veinlets are ramified more than twice within the quadrangular or pentagonal areoles. Japanese fossil leaves correspond well with Spitzbergen specimens in all morphological characters, including the venation.

A. arcticum has been frequently misused by many authors for cordate to pentagonal leaves with tri- or five-plinervation which occurred from the Paleogene of the Northern Hemisphere; some of these leaves are probably referable to *Populus* and some genera of the Vitaceae, whose leaves are easily distinguishable from *A. arcticum* in glandular margin and veinlet characters.

There are no leaves of any extant maple which well match with *A. arcticum* in all characters. Considering the foliar shape, well-defined tertiary veins, ultimate veinlets and large-toothed margin, *A. arcticum* probably to the section *Spicata*, whose extant species are living in East Asia and eastern North America. Of three extant species of this section North American *A. spicatum* Lam. is most similar to *A. arcticum* in general appearance. Despite of abundant occurrence of leaves referable to *A. arcticum*, no fossil winged seed corresponding to this species has been unfortunately found in the Paleogene of Hokkaido. Regarding the winged seeds of *A. arcticum* it is necessary to note that the original specimens (Heer, 1876: pl. 22, fig. 2b, 2c.) were invalidly illustrated. So far as examined by me, these samaras are hidden by rocks at its lower part, and are not clear in the contact scar of seed.

Occurrence and Collections: Shimizusawa (HUMP nos. 9355, 9356; NSM 10458), Bibai (HUMP nos. 9352-9354, 26202-26204), Reisui-zan (HUMP no. 26205), Kamui, Danma-nosawa (GSJ no. 4299), Harutori (HUMP nos. 25984, 25985), Tokomuro and Shiranuka, Hokkaido; Uchigo, Ibaraki Pref.; Shinminato (HUMP nos. 25259, 25260), Sasebo, Nagasaki Pref.; Fushun, China; Breja, Ussuri.

Acer oishii Tanai

(pl. 2, figs. 2, 5, 6; pl. 4, fig. 7)

Acer oishii Tanai. 1970. J. Fac. Sic., Hokkaido Univ. [4], 14(4): 490. pl. 14. f. 1, 4, 5; pl. 20. f.4.

Acer sp. Oishi & Huzioka. 1943. ditto. 7: 97. pl. 14. f. 1.

Type: Holotype, HUMP no. 25986; Harutori Formation (Early Oligocene); Harutori

coal mine, Kushiro, Hokkaido.

Discussion: This species was originally described by many, medium to large leaves and a poorly-preserved samara from the Oligocene of eastern Hokkaido. The well-preserved leaves referable to this species are also found from the Eocene and Oligocene of the Ishikari coal field. All of these leaves are characterized by 3-lobed shape with deep sinus, coarsely serrate margin with large, acute or acuminate teeth which are accompanied by one or two smaller subsidiary teeth, and irregularly percurrent but well-defined tertiary veins. The ultimate veinlets of these foliage specimens including the holotype, are more than thrice ramified within the comparatively large areoles.

A. oishii was first compared with the extant *A. rubrum* Linne of North America by the superficial resemblance (Tanai 1970). However, the above-noted characters, especially of the venation, indicate that *A. oishii* is not related to the section Rubra but to the section Spicata. Of three extant species of the section Spicata, leaves of the East Asian *A. ukurunduense* Trauv. et Mey. are usually 5-lobed, rarely 7-lobed, while those of the North American *A. spicatum* Lam. and the Himalayan *A. caudatum* Wall. are usually 3-lobed or sometimes slightly 5-lobed. It is very interesting that *A. oishii* is more closely related *A. spicatum* rather than other two Asiatic species, considering the lobation together with the marginal character. Leaves referable to *A. oishii* are somewhat variable in shape, but some leaves closely resemble those of *A. alaskanum* Tanai & Wolfe which was recently established from the Paleocene of Alaska (Tanai & Wolfe, MS). *A. oishii* may be a descendant of *A. alaskanum*, which appears to have migrated to East Asia across the Beringia.

Occurrence and Collections: Harutori (HUMP nos. 9357, 25986), Reishui-zan (HUMP no. 26206) and Shimizusawa (AKMG-6309), Hokkaido.

Acer subukurunduense N. Suzuki

(pl. 4, fig. 2)

Acer subukurunduense N. Suzuki, 1963. J. Fac. Sci., Hokkaido Univ. [4], 11 (4): 690. pl. 1. f. 1.

Huzioka & Uemura. 1974. Bull. Natl. Sci. Mus. 17 (4): 354. pl. 8. f. 4-6.

Chelebaeva. 1978. Miocene floras of E. Kamchatka. p. 82. pl. 18. f. 6; text-f. 30-2.

Acer sp. N. Suzuki. 1963. J. Fac. Sci., Hokkaido Univ. [4], 11 (4): 692. pl. 2. f. 4.

Type: Holotype, HUMP no. 25918; Komatsuzawa Formation (Early Pliocene); Yongosen, Rubeshibe-machi, Hokkaido.

Discussion: This species is represented by comparatively large leaves, which are double-serrate with acute, well-defined teeth at the margin, irregularly-spaced secondary veins on each lobe and deeply cordate at the base. The reinvestigation of the holotype specimen reveals that the ultimate veinlets are ramified somewhat irregularly and usually more than three times within the large, four-sided areoles. So far as observable, the holotype specimen is pubescent on the undersurface as well as is in the extant *A. ukurunduense* Traut. et Mey., which is closely related analogue of *A. subukurunduense*.

Leaves of the extant *A. ukurunduense* are generally five to seven lobed, while those

of *A. subukurunduense* are usually five lobed. This fossil species, although rare in occurrence, is confined to northern Japan and northward, and it seems to have adapted to cool-temperate forest as doing by its modern analogue.

Occurrence and Collections: Rubeshibe (HUMP nos. 29918, 25920), Hokkaido; Sanzugawa (AKMG no. 7578; NSM-PP 6007a, 15276), Akita Pref.; Korf (IV-AN 513/2), Kamchatka.

Section Palmata Pax
Acer nordenskiöldi Nathorst
(pl. 3, figs. 1, 2)

- Acer nordenskiöldi* Nathorst. 1883. Kgl. Sv. Vet. Akad. Handl. 20 (2): 60. pl. 11. f. 10-16.
Miki. 1937. Jap. J. Bot. 8: 322. pl. 9A; text-f. 8 P-Q.
Hu & Chaney 1938. Palaeont. Sinica. [A]. (1): 60. pl. 34. f. 1, 6.
Tanai & Onoe. 1961. Geol. Surv. Jap. Rept. (187): 47. pl. 15. f. 1.
Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 358. pl. 28. f. 6.
Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 64.
Huzioka & Takahashi. 1973. Bull. Natl. Sci. Mus. 6 (1): 140.
Huzioka & Uemura. 1973. ditto. 16 (4): 719. pl. 14. f. 9.
Baikovskaya. 1974. Late Miocene floras of S. Primorye. p. 85. pl. 19. f. 3, 8-10; pl. 29. f. 8; text-f. 17.
Ina. 1974. Bull. Mizunami Fossil Mus. (1): 346. pl. 108. f. 2, 3.
Hayashi. 1975 (part). Fossils from Iki Island. p. 26. pl. 21. f. 5.
Tanai. 1976. J. Fac. Sci., Hokkaido Univ. [4], 17 (2): 330. pl. 7. f. 4, 8; pl. 8. f. 7; pl. 9. f. 4; text-f. 7-h, i.
Tanai & Ozaki. 1977 (part). J. Fac. Sci., Hokkaido Univ. [4], 17 (4): 580. pl. 1. f. 1-3, 5, 6, 8, 9; text-f. 3. A-D; text-f. 4. B-D, F.
Acad. Sinica. 1978. Cenozoic plants of China. p. 127. pl. 110. f. 2; pl. 111. f. 8; pl. 134. f. 2.
Ina. 1981. Monogr. Mizunami Mus. 2. pl. 28. f. 1, 2, 4-6.
Acer cf. nordenskiöldi Nathorst. Ina. 1977. Geol. & Palaeont. Kani Town. p. 83. pl. V-22. f. 4, 5.
Acer palmatum auct. non Thunb. Florin. 1920. Kgl. Sv. Vet. Akad. Handl. 61 (1): 23 & 36. pl. 4. f. 1-4.
Kryshstofovich. 1930. Ann. Russ. Palaeont. Soc. 8: 22 & 27. pl. 3. f. 34.
Miki. 1941. Jap. J. Bot. 11: 283. text-f. 17. B-CD.
Takahashi. 1954. Mem. Fac. Sci., Kyushu Univ. [D]. 5 (1): 60. pl. 7. f. 5-7a, b.
Acer palmatum Thunb. subsp. *megamoenum* Murai. 1963. Rept. Tech., Iwate Univ. 16 (1): 99. pl. 11. f. 6a-b; pl. 16. f. 5.
Acer ornatum auct. non Carr. Tanai. 1952. Trans. Proc. Palaeont. Soc. Jap. N.S. (8): 234. pl. 22. f. 10, 11.
Acer debilum Huzioka et K. Suzuki. 1954. ditto. (14): 140. pl. 16. f. 11, 12.
Huzioka & Uemura. 1973. Bull. Natl. Sci. Mus. 16 (4): 718. pl. 13. f. 2.
Acer florinii auct. non Hu et Chaney. Hayashi. 1975 (part). Fossils from Iki isl. p. 26. pl. 20. f. 5.
Acer ablaevii Akhmetjev et Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 87. pl. 10. f. 1; text-f. 1-12.
Acer sp. Chelebaeva. 1979. Stratigr. and Floras. p. 79. pl. 3. f. 14, 15; pl. 8. f. 23.
Liquidambar europaeum auct. non Al. Braun. Florin. 1920. Kgl. Sv. Vet. Akad. Handl. 61 (1): 20. pl. 3. f. 5.
Type: Lectotype, SMNH Palaeobotany Section collection (Nathorst, 1883: pl. 11. f. 14); Mogi plant-bearing Formation (Early Pliocene); Mogi, Nagasaki City, Nagasaki Prefecture.

Discussion: This species was first established by several leaves from the Pliocene of North Kyushu (Nathorst, 1883), all of which are closely related to the extant *Acer palmatum* Thunb. of Japan. Thereafter a number of specimens from the Neogene of East Asia have been referred to *A. nordenskiöldi* by various authors. Although some authors proposed to distinguish some leaf forms from the original specimens, *A.*

nordenskioidi includes various forms in lobation, lobe shape and marginal serration as similarly displayed by the extant "*A. palmatum*" group.

As already discussed (Tanai, 1976; Tanai & Ozaki, 1977), the original specimens are 7-lobed with acute sinus and are rather coarsely serrate on the margin; each tooth in which the secondary veins end, is often accompanied by one or two subsidiary minute teeth on its basal side.

As far as reinvestigated, all the leaf specimens listed in the above synonymy are 5 or 7 lobed and are finely to coarsely serrate at the margin. These leaves are roughly grouped into the following two types by the marginal characters, although they are highly variable in lobe shape, and depth and angles of sinus.

(1) margin is serrate with fine teeth, accompanied by one or two subsidiary teeth; main teeth are densely arranged.

(2) margin is serrate with fine to coarse teeth, accompanied by one or two subsidiary teeth; main teeth are remotely arranged.

These two types of the serration often include many intermediate forms, and also do not show any special stratigraphic distribution. Generally speaking, the 7-lobed leaves with remotely serrate teeth are common in the Lower Miocene, while the 5-or 7-lobed leaves with densely serrate teeth are common since the Middle or Late Miocene. Because the above two types of leaves have no strict base for separation by foliar characters and venation, all the specimens listed above are included in *A. nordenskioidi*.

Compared with common occurrence of leaves, samaras referable to *A. nordenskioidi* have been uncommon. They are closely similar to samaras of *A. protojaponicum*, but are distinguishable by somewhat outwardly bulged seed and smaller size. *Occurrence and Collections*: Miyata (AKMG-7111), Akita Pref.; Kamigo, Obayashi and Takamine, Yamagata Pref.; Shiotsubo, Fukushima Pref.; Hiramaki, Mizunami and Tokitsu, Gifu Pref.; Seto, Aichi Pref.; Omi, Nagano Pref.; Ningyotoge, Mitoku (GSJ no. 4173) and Tatsumitoge (TPM-471; NSM-PP 16020, 16021, 16025, 16027, 16040; GSJ no. 4783a), Tottori Pref.; Akashi, Hyogo Pref.; Shimonoseki, Yamaguchi Pref.; Mogi (GSJ nos. 4728a-4730), Oya and Chojabaru (HUMP no. 26207), Nagasaki Pref.; Amakusa, Kumamoto Pref.; Yeonil, South Korea; Tongcheon and Hamjindong (IGPS-92370), North Korea; Shanwang, China; Udugou, Rettikhovska, Nagaeva, Nexhino and Uglovoe (DBGI-AN no. 70054), Primorye.

Acer protojaponicum Tanai et Onoe

(pl. 3, figs. 8-10)

- Acer protojaponicum* Tanai et Onoe. 1959. Geol. Surv. Jap. Rept. 10 (4): 21. pl. 6. f. 5, 7, 8.
 Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4], 10 (3): 565. pl. 5. f. 6; pl. 9. f. 18, 19.
 Tanai. 1961. Ditto. 11 (2): 362. pl. 26. f. 4; pl. 27. f. 8.
 Tanai & N. Suzuki. 1963. Tertiary floras of Japan. p. 141.
 Suzuki, N. 1963. J. Fac. Sci., Hokkaido Univ. [4], 11 (4): 688. pl. 4. f. 5; pl. 5. f. 4.
 Huzioka. 1964. J. Min. Coll., Akita Univ. [A], 3 (4): 92. pl. 15. f. 6.
 Ishida. 1970. Mem. Fac. Sci., Kyoto Univ. [geol. & Min.], 37 (1): 96. pl. 15. f. 16.
 Tanai & N. Suzuki. 1972. J. Fac. Sci. Hokkaido Univ. [4], 15 (1-2): 336.

- Huzioka. 1972. J. Min. Coll., Akita Univ. [A], 5 (1): 65.
 Hojo. 1973. Mem. Fac. Sci., Kyushu Univ. [D], 22 (2): 31. pl. 9. f. 13.
 Hayashi. 1975. Fossils from Iki Isl. p. 26. pl. 21. f. 7, 8.
 Tanai & Ozaki. J. Fac. Sci., Hokkaido Univ. [4], 17 (4): 581. pl. 2. f. 2; pl. 5. f. 1, 2.
Acer paxi auct. non Franch. Nathorst. 1888. Palaeont. Abhandl. 4 (3): 26. pl. 11. f. 13.
Acer japonicum auct. non Thunb. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 134. pl. 24. f. 7.
 Murai. 1963. Rept. Tech., Iwate Univ. 17 (1): 104. pl. 17. f. 2.
Acer miojaponicum Huzioka et Nishida. 1960. Sado Mus. Publ. (3): 19. pl. 5. f. 5.
Acer iwaii K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 81. pl. 18. f. 5.
Acer protosieboldianum Tanai et Onoe. 1961. Geol. Surv. Jap. Rept. (187): 50. pl. 15. f. 5.
 Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 363.
Acer pseudocarpinifolium auct. non Endo. N. Suzuki. 1963 (part). ditto. 11 (4): 698. pl. 3. f. 2.
Acer subpictum auct. non Saporta. N. Suzuki. 1963 (part). ditto. 11 (4): 690. pl. 5. f. 1, 2.
 Onoe. 1974. Geol. Surv. Jap. Rept. (253): 51. pl. 11. f. 8.
Acer ezoanum auct. non Oishi et Huzioka. Huzioka et Uemura. 1973 (part). Bull. Natl. Sci. Mus. 16 (4): 718.
 pl. 14. f. 7.
Acer sp. Oishi et Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 98. pl. 14. f. 5.

Type: Holotype, GSJ no. 4038; Shichiku Formation (Early Miocene); Shichiku, Yotsukura-machi, Iwaki, Fukushima Prefecture.

Discussion: This species was first established on the basis of well-preserved samaras and a single fragmentary leaf (Tanai & Onoe, 1959), and was later supplemented by nearly complete leaves (Tanai & N. Suzuki, 1960; Tanai, 1961). These leaves are somewhat variable in shape and size: they are 9 to 11 lobed, deeply cordate at the base, and are of medium to large size. Each lobe is shallowly dissected with acute sinus, and is double serrate with acute teeth at the margin. The areolar venation is composed of irregular-sized, four- to six-sided areoles, in which the fine veinlets branch more than three times. These venation characters well match those of the extant *Acer japonicum* Thunb. living in Japan. The fossil samaras are characterized by a comparatively small-sized, thick and globose seed, and angles of 55° to 90° between the outer margin of wing and contact scar of seeds. Both lower margins of wing reach the base of seed or the contact scar; the seed is kept within the wing width.

So far as reinvestigated, all the leaf and samara specimens listed in the above synonymy are included in *A. protojaponicum*. Although they were based on well-preserved leaves or samaras similar to *A. japonicum*, *A. miojaponicum* and *A. iwaii* are the later synonyms to *A. protojaponicum*. A single complete leaf described as *A. protosieboldianum* from the Pliocene of western Honshu (Tanai & Onoe, 1961) is unseparable from *A. protojaponicum*. The samaras of *A. protojaponicum* and *A. nordenskiöldi* are generally similar in the sense of small size, globular seed and divergent angles of wings; however, the latter is smaller on the average, and is characterized by outwardly bulged seed.

Occurrence and Collections: Yoshioka (HUMP nos. 25037, 25039), Abura (HUMP nos. 9346, 25038), Wakamatsu, Kudo, Kaminokuni (HUMP no. 25259), Shanabuchi (HUMP nos. 25262, 25763, 25765), Rubeshibe (HUMP nos. 25902, 25912, 25913) and Bifuka (HUMP no. 26208), Hokkaido; Gomyojin (IAGI-61022), Iwate Pref.; Miyata (AKMG-7257), Akita Pref.; Oguni (GSJ no. 4591), Yamagata Pref.; Shichiku (GSJ nos. 4038, 4039; IGPS-78142—78144; AKMG-5078), Fukushima Pref.; Seki (AKMG-3309, 3310), Niigata Pref.; Noroshi (JC 88-490), Ishikawa Pref.; Hiyoshi,

Gifu Pref.; Fugenji, Shimane Pref.; Ningyotoge (GSJ no. 4184) and Tatsumitoge (TMP-217, 231, 480), Tottori Pref.; Chojabaru, Iki Isl., Nagasaki Pref.; Shonai, Oita Pref.; Hamjindong (HUMP no. 9319; IGPS-92368), North Korea.

Acer protomatsumurae Tanai sp. nov.

(pl. 3, figs. 3, 5)

Acer ornatum auct. non Carr. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 20 (2): 60. pl. 11. f. 10-16.

Acer nordenskiöldi auct. non Nathorst. Tanai & Ozaki. 1977 (part). J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 580. pl. 1. f. 4, 7; text-f. 4, A, E.

Type: Holotype, GSJ no. 4777; Tatsumitoge Formation (Late Miocene); Tasumitoge, Saji-mura, Tottori Prefecture.

Description: Leaves incomplete but medium in size, palmately seven or nine lobed, cordate at base; length probably 5.5 to 6 cm and width about 7 cm. Margin double serrate, with large, acute teeth which are distinct by acute sinus; principal teeth concave at apical side, while convex at basal side where one or two smaller teeth exist. Each lobe deeply dissected by narrow, wedged-shaped sinus, lanceolate in shape, attenuate with caudate tip at apex; two lower pairs of lobes smaller than others, especially a basal pair smallest. Primary veins stout, palmately emerging from the base, nearly straight, ending in lobe apex; secondary veins distinct, opposite to subopposite, more than 7 pairs, emerging from the primaries at angles of 60° to 70°, gently curving up, entering principal teeth; intersecondary veins often developing but slender; tertiaries random reticulate or weakly percurrent; quaternary and higher order veins forming polygonal areoles; the highest order vein sixth; the ultimate veinlets thin but well-developed, two or three times branching. Petiole missing.

Discussion: This new species is based on two incomplete leaves, which were once included in *Acer nordenskiöldi*. However these two leaves are distinguishable by distinctly double-serrate margin with acute sinus, although similar in foliar shape and venation. Some leaves of *A. nordenskiöldi* also show double-serrate in margin, but their principal teeth are not so much conspicuous as in *A. protomatsumurae*.

A. protomatsumurae is closely related to the extant *A. palmatum* Thunb. var. *matsumurae* Koidz. which is living in central and northern Honshu.

Occurrence and Collections: Tatsumitoge (GSJ nos. 4777, 4778), Tottori Pref.; Keumkwandong (HUMP no. 9326), South Korea.

Section Arguta Rehder

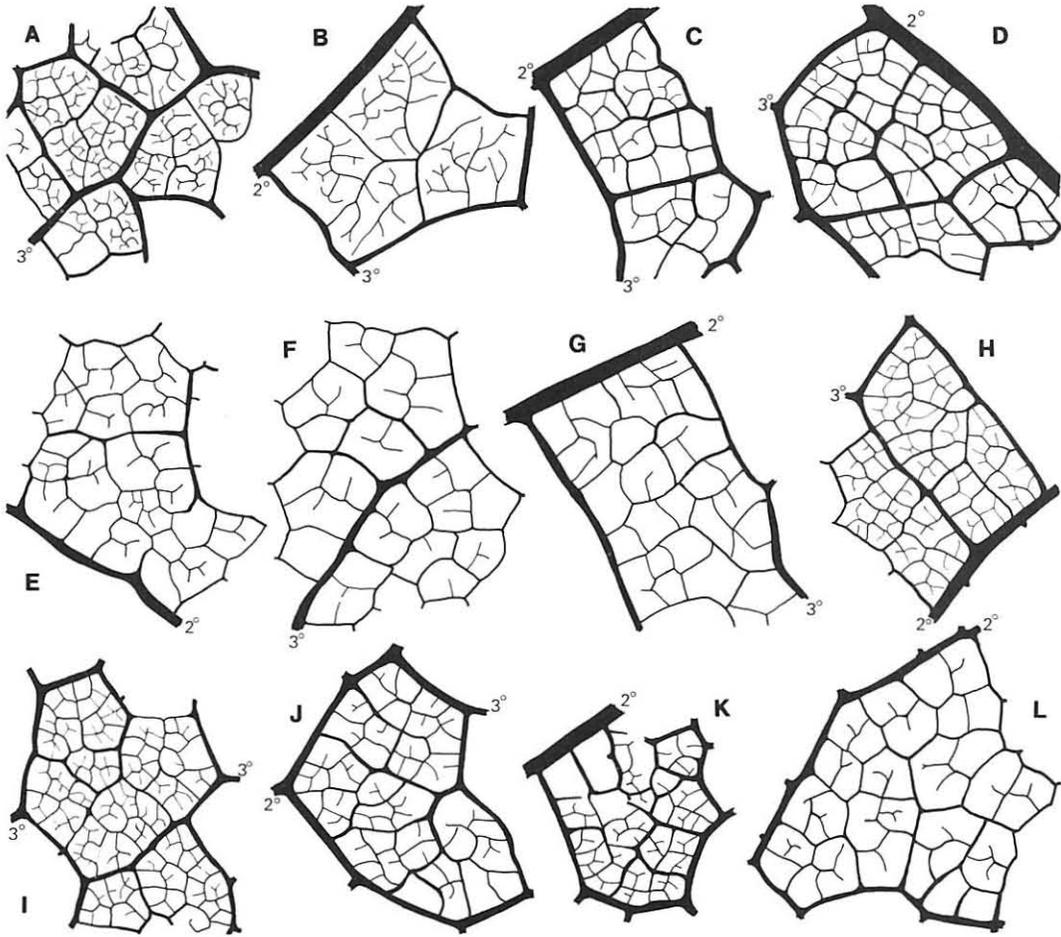
Acer tottoriense Tanai et Ozaki

(pl. 3, figs. 6, 7)

Acer tottoriense Tanai et Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 582. pl. 3. f. 2-6.

Acer midavidii auct. non Hu et Chaney. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 99. pl. 9. f. 5; text-f. 1-3.

Type: Holotype, TPM-235, Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Prefecture.



Text-fig. 5. The Details of Venation Characters of Fossil *Acer* — (2) all figures $\times 15$.

- A. *Acer protonegundo* Tanai. Holotype HUMP no. 25004 (pl. 5, f. 4)
- B. *Acer endoanum* Huzioka. GSJ no. 4056 (pl. 4, f. 6)
- C. *Acer ezoanum* Oishi et Huzioka. HUMP no. 26217 (pl. 6, f. 6)
- D. *Acer ezoanum* Oishi et Huzioka. Dr. Ina's collection (pl. 7, f. 5)
- E. *Acer tricuspidatum* Bronn. TPM-280 (Tanai & Ozaki, 1977: pl. 2, f. 7)
- F. *Acer tricuspidatum* Bronn. HUMP no. 25896 (N. Suzuki, 1963: pl. 2, f. 2)
- G. *Acer tricuspidatum* Bronn. ETH collection (Hantke, 1965: pl. 10, f. 7)
- H. *Acer chiharae* Huzioka. Paratype AKMG no. 3313 (pl. 10, f. 2)
- I. *Acer chiharae* Huzioka. AKMG no. 3318 (Huzioka & Nishida, 1960: pl. 6, f. 2)
- J, K. *Acer protomiyabei* Endo. HUMP no. 25010 (Tanai & N. Suzuki, 1960: pl. 2, f. 2)
- L. *Acer rotundatum* Huzioka. NSM-PP 16065 (Tanai & Ozaki, 1977: pl. 2, f. 4)

Discussion: This species is uncommonly known from the Neogene of Japan, and is represented by a single leaf and several samaras which are closely similar to the extant *Acer argutum* Maxim. of Japan. Although a leaf specimen is ill-preserved, the foliar shape with a prominent central lobe, double serrate margin and well-defined tertiary venation of *A. tottoriense* match well those of *A. argutum*, excepting for deep sinus of lobation. The fossil samaras also resemble those of the extant relative: the seeds are thick, orbiculate and are somewhat wrinkled on surface; the angles between the contact scar of seeds and outer margin of wing are 70° to 75°.

Occurrence and Collections: Tatsumitoge (TPM-235; NSM-PP 16168, 16202, 16213), Tottori Pref.; Amgu River (GIN-AN 3802/381), Prymorie, USSR.

Section Negundo (Boehm.) Maxim.

Acer protonegundo Tanai

(pl. 5, figs. 2-4)

Acer protonegundo Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 362. pl. 27. f. 2, 4, 5.

Acer crataegifolium (Knowlton) auct. non Lamotte. Tanai & N. Suzuki. 1960. ditto. 10 (3): 555. pl. 8. f. 1-4; pl. 11. f. 6, 11.

Ina. 1981. Monogr. Mizunami Fossil Mus. (2). pl. 29. f. 4.

Acer miohenryi auct. non Hu et Chaney. Tanai & N. Suzuki. 1963. Tertiary Floras Japan. p. 141. pl. 25. f. 4, 8.

? Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 91. pl. 15. f. 3.

? Huzioka. 1972. ditto. 5 (1): 64

Tanai & N. Suzuki. 1972. J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 336. pl. 6. f. 10.

Acer arcticum auct. non Heer. Ina. 1977. Geol. & Paleont. Kani Town. p. 83. pl. V-22. f. 11.

Acer sp. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 136. pl. 23. f. 2.

Type: Holotype, HUMP no. 25004; Yoshioka Formation (late-Early Miocene); Yoshioka, Fukushima-cho, Hokkaido.

Discussion: This species is represented by trifoliate leaves or detached single leaflets and samaras, which are closely similar to those of the extant *Acer negundo* Linn. of North America and *A. henryi* Pax of China. These samaras that are characterized by oblong seeds, narrow wings and rather short contact scar of two seeds, are easily distinguishable from those of other fossil maples. The fossil leaflets are inequilateral, especially in the laterals, and are coarsely serrate with large teeth on the margin. The ultimate venation is more than twice ramified within rather small, four- or five-sided areoles. The fine venation characters show that the fossil leaves are more akin to *A. negundo* than *A. henryi*, because the Chinese extant species is usually more than twice larger in the areoles and more complicately branching in the ultimate veinlets than the North American species.

After some meanders in the specific name for this Tertiary boxelder of East Asia, we have recently adopted the epithet "*miohenryi*", whose species was established by the detached leaflets from the Shangwang flora of China (Hu & Chaney, 1938). However, all these specimens of Shanwang are very doubtful to be referable to *Acer*: some of them are transferred to *Zelkova ungeri* as already pointed out by Brown (1946), while one specimen may be referred to the Rosaceae in the foliar shape and marginal character. Only one remaining specimen (Hu & Chaney, 1938: pl. 33, fig. 1)

is also questionable to belong definitely to *Acer*; although it shows a superficial resemblance to some leaflets of *A. henryi*, the fine venation character needs to be confirmed. Thus, I prefer to use the epithet “*protonegundo*” based on a complete and doubtless type specimen in order to avoid future confusion. The above-noted fine venation character is based on the type specimens of Yoshioka locality.

So far as reinvestigated, the leaflets and samaras listed in the above synonymy are included in *A. protonegundo*. These leaflets are distinguishable by the freely-ending veinlets from those of *A. heterodentatum* (Chaney) MacGinitie that was recently reported from the Miocene flora of Alaska (Wolfe & Tanai, 1980), although the fossil samaras of both species are somewhat difficult to be separated. *A. protonegundo* closely related to North American boxelder, is uncommon in the Tertiary of East Asia, but it seems to have dispersed from North America by Early Miocene time.

Occurrence and Collections: Yoshioka (HUMP nos. 25001-25005), Abura (HUMP no. 25006), Wakamatsu (HUMP 26159), Hokkaido; Seki (AKMG no. 3287), Sado Isl., Niigata Pref.; Hiramaki, Gifu Pref.; Yongdong (HUMP no. 9323), North Korea.

Section *Cissifolia* Koidz.

Acer endoanum Huzioka

(pl. 4, figs. 4-6)

Acer endoanum Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 63. pl. 14. f. 5.

Acer palaeodiabolicum auct. non Endo. Tanai. 1952. Trans. Proc. Palaeont. Soc. N.S. (8). pl. 22. f. 12.

Acer miohenryi auct. non Hu et Chaney. Tanai & Onoe. 1959. Bull. Geol. Surv. Japan. 10 (4). pl. 6. f. 11.

Acer cf. *pseudocarpinifolium* auct. non Endo. Tanai & Onoe. 1961. Geol. Surv. Japan Rept. (187): 51. pl. 15. f. 3.

Acer subpicutum auct. non Saporta. Huzioka & Uemura. 1973 (part). Bull. Natl. Sci. Mus. 16 (4): 720. pl. 13. f. 4.

Acer pseudocarpinifolium auct. non Endo. Tanai & Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 583. pl. 4. f. 8.

Acer sp. Huzioka. 1943. ditto. 7 (1): 136. pl. 22. f. 6.

Acer sp. Huzioka & K. Suzuki. 1954. Trans. Proc. Palaeont. Soc. Japan N.S. (14): 141. pl. 16. f. 13.

Type: Holotype, HUMP no. 9350; Hamjindong Formation (late-Early Miocene); Hamjindong, Hamg'yeong-bukdo, North Korea.

Supplementary Description: Leaflet elliptical in general outline, more than 3 cm long and 1.3 cm wide; apex missing, base inequilaterally cuneate; margin serrate with large and slightly acuminate teeth which are rarely accompanied by a subsidiary tooth. Venation pinnate; midvein thick, nearly straight; secondaries more than 5 pairs, subopposite, emerging from the midvein at acute angles, ending in marginal teeth; tertiary veins of intercostal area coarsely percurrent, somewhat retroflexed or forking to form reticulum; a tertiary vein from the secondaries branching near the margin, sometimes ending at the bottom of sinus; fourth and higher order veins random reticulate; the highest order vein fifth; areolation four- or five-sided, comparatively large; freely ending veinlets irregularly branching more than three times. Petiolule thick, 5 mm long.

Discussion: The wide elliptic seed with three longitudinal low keels, narrow angles of 15° between the contact scar of seeds and outer margin of wing, and a short contact

scar (2-3 mm) indicate that the type specimen is closely similar to samaras of the extant *Acer cissifolium* (S. et Z.) K. Koch living in Japan, although Huzioka (1972) compared the type specimen with the extant *A. ginnala* Maxim. or *A. nugundo* L. The samaras listed in the above synonymy are included in *A. endoanum* by the above-noted characters. *A. endoanum* is closely similar to *A. protonengundo* in the keels of the seed and narrow divergent angles of wings, but it is distinctly different in seed shape.

A single detached leaflet reported as *A. miohenryi* from the Miocene of north-eastern Honshu (Tanai & Onoe, 1959), is confirmed to be closely similar to the extant *A. cissifolium* in its slender shape, areolation and fine venation characters, as far as reinvestigated, and this specimen is considered to represent a lateral leaflet of *A. endoanum*. This leaflet is easily distinguishable from *A. protonengundo* in larger areoles and irregularly branching veinlets, although similar in foliar shape. A single fragmentary leaf described as *Acer* cf. *cissifolium* from the Upper Miocene of Akita (Huzioka & Uemura, 1973) may represent an fragmentary lobe of *A. nordenskiöldi*, because it is different from those of *A. cissifolium* in marginal serration.

Occurrence and Collections: Miyata (AKMG-7152, 7415), Akita Pref.; Shiotsubo and Schichiku (GSJ no. 4056), Fukushima Pref.; Tatsumitoge (NSM-PP 16054 and Mitoku GSJ no. 4189), Tottori Pref.; Yeonil, South Korea; Hamjindong (HUMP no. 9350), North Korea.

Section Trilobata Pojarkova

Acer subginnala Guo

(pl. 1, figs. 5, 6)

Acer subginnala Guo. 1980. Act. Palaeont. Sinica. 19 (5): 409. pl. 1. f. 2, 2a.

Acer ginnala auct. non Maxim. Endo. 1951. Short Papers IGPS. (3): 57. pl. 8. f. 8.

? Murai. 1963. Rept. Tech., Iwate Univ. 16 (1): 106. pl. 17. f. 5.

? *Acer* cf. *ginnala* auct. non Maxim. Akhmetjev & Schmidt. 1976. Geol. Paleont. Rept. Far East. p. 89. pl. 10. f. 9; text-f. 1-18.

? *Acer* sp. Hori. 1976. Fossil Plants from Kobe. p. 132. text-F. 137.

Type: Holotype, NIGP PB-6114; Zekog, Qinghai, China.

Discussion: This species was recently established on the basis of a well-preserved samara from the Miocene of Qinghai. A specimen described as *A. ginnala* Maxim. from the Miocene of Kobe (Endo, 1951) is identical to *A. subginnala*. The oblong seed, abruptly incurving veins of wing and narrow angles (10°—20°) between the contact scar of seed and outer margin of wing of these samaras accord well with samaras of the section Trilobata.

A. subginnala has been rarely known in the Tertiary of East Asia. Many samaras from the Miocene of Japan were once reported as those similar to the extant *A. ginnala*, but all of them are quite different in seed shape. The fragmentary leaves described as *A. ginnala* from the Miocene of Japan (Murai, 1963) and Sikhote-Alin (Akhmetjev & Schmidt, 1976) are somewhat similar to leaves of the extant relative, but they need to be reinvestigated in the venation.

Occurrence and Collections: Kobe (IGPS-60599), Hyogo Pref.; Zekog (NIGP

PB-6114), China.

Section Rubra Pax

Acer ezoanum Oishi and Huzioka

(pl. 4, fig. 1; pl. 6, figs. 1, 4-6; pl. 7, figs. 1-3, 5-8)

- Acer ezoanum* Oishi et Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 89. pl. 10. f. 1-3; pl. 11. f. 1-4; pl. 12. f. 1, 2.
- Ina. 1981 (part). Monogr. Mizunami Mus. (2). pl. 30. f. 2.
- Acer yabei* Endo. 1950. Short Papers IGPS. (1): 13. pl. 3. f. 7.
- Suzuki, N., 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 691. pl. 4. f. 4, 6.
- Tanai & N. Suzuki. 1965 (part). Palaeont. Soc. Japan, Spec. Paper. (10): 39. pl. 10. f. 10; pl. 13. f. 4.
- Huzioka & Uemura. 1973. Bull. Natl. Sci. Mus., 6 (4): 720. pl. 14. f. 1.
- Acer* cf. *kokangense* auct. non Endo. Tanai & Onoe. 1959. Geol. Surv. Jap. Bull. 10 (4): 23. pl. 6. f. 9.
- Acer macrosamarum* Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 90. pl. 14. f. 12.
- Acer palaeoplatanoides* Endo var. *macroptera* Akhmet. & Schmidt. 1966. Geol. Palaeont. Rep. from Far East. p. 97. pl. 9. f. 2; text-f. 1-23.
- Acer pseudomiyabei* Baikov. form. *dissecta* Baikovskaya. 1974. Late Miocene flora of South Primorye. p. 85. pl. 19. f. 6, 7.
- Acer protopalmatum* auct. non K. Suzuki. Ina. 1977. Geol. & Palaeont. Kani Town. p. 83. pl. V-22, f. 7.
- Acer grahamensis* auct. non Knowlton et Cockerell. Chelebaeva. 1978. Miocene floras of eastern Kamchatka. p. 79. pl. 17. f. 9; pl. 19. f. 1-4.
- Acer* sp. cf. *A. ezoanum* auct. non Oishi et Huzioka. Baikovskaya. 1974 (part). Late Miocene floras of S-Primorye. p. 82. pl. 19. f. 1, 2.
- Acer* sp. cf. *A. osmontii* auct. non Knowlton. Baikovskaya. 1974 (part). ditto. p. 115. pl. 40. f. 6, 7.
- Acer* sp. Hojo. 1973. Mem. Fac. Sci., Kyushu Univ. [D]. 22 (1): 32. pl. 9. f. 14.
- Acer* sp. Ina. 1977. Geol. & Palaeont. Kani Town. p. 85. pl. v. 23. f. 3, 4.
- Acer* sp. Ina. 1977. ditto. p. 86. pl. V-24. f. 1, 2.
- Acer* sp. Ina. 1981. Monogr. Mizunami Mus. (2). pl. 27. f. 1-5.
- Acer* sp. Ina. 1981. ditto. pl. 31. f. 2.
- Platanus* sp. Ina. 1977. Geol. & Palaeont. Kani Town. p. 75. pl. V-17. f. 4; pl. V-18. f. 1.

Type: Lectotype, HUMP no. 9360; Shiritori coal-bearing Formation (Early Miocene); Shiritori coal mine, Shiritori (Makarov), South Sakhalin.

Emended Description: Leaves five-palmately lobed, highly variable in shape and size, 2.6 to 11 cm long and 3.1 to 12 cm wide, length/width ratio 0.8 to 0.9; base broadly to deeply cordate. Each lobe deeply dissected by narrowly acute sinus; central lobe somewhat larger or sometimes considerably larger than the upper laterals, and these three lobes oblanceolate to narrow obovate; basal lobes smallest, ovate to narrow ovate; margin variably dentate, from a few dents accompanied by smaller or minute acute teeth to less dents represented by sharply pointed teeth; larger dents especially conspicuous in central lobe, and sometimes with attenuate tips. Primary veins stout, nearly straight or slightly curving, emerging from base and ending in lobe apex, in some case a basal pair of the primaries emerging exmedially from the lower portion of lateral primaries; secondary veins more than 7 pairs, opposite to subalternate, emerging from the primaries at variable angles from 40° to 90°, curving upward, entering dentate teeth or forming large loops with superadjacent secondaries or intersecondaries; intersecondary veins often developing; tertiary veins at intercostal area random reticulate or weakly percurrent; tertiaries at marginal area forming small loops or entering small

teeth; quaternary and higher order veins well forming polygonal networks; the highest order vein seventh; freely-ending veinlets linear-single or lacking within quadrangular areoles. Petiole stout, more than 2 cm long but missing in most specimens.

Samaras usually large, oblong to oblanceolate in general outline, 4.8 to 11 cm long and 1.4 to 2.2 cm wide, length/wide ratio 2.9 to 5.8. Wing rounded at apex, markedly narrowed near the base; outer margin nearly straight or slightly curved; inner margin gently convex, terminating at the upper portion of seed part; veins numerous, dichotomizing more than three times, considerably curving inward, nearly perpendicular to outer margin. Seeds thick, ellipsoidal in shape, 11 to 24 mm long and 5 to 11 mm wide, length/width ratio 2.2 to 3.1; contact scar distinct, 5 to 10 mm long; angles between outer margin of wing and contact scar of seed less than 10° ; the base of seed part often pointed as a beak.

Discussion: A single incomplete samara originally described as *A. yabei* by Endo (1950) is closely similar to the extant *A. saccharinum* L. of North America, although its modern relationship was unknown at that time. Later, supplemented by well-preserved samaras from northeastern Hokkaido, this modern relationship was pointed out by N. Suzuki (1963), but he erroneously redesignated *A. yabei* to combine these samaras with fossil leaves similar to the extant *A. rubrum* L. These large samaras are usually distinguishable from others by a thick spindle-shaped seed, very narrow angles of the wing divergence and distinct contact scar. Excepting for somewhat longer contact scar of seeds, the above-described characters of samara well accord with those of *A. saccharinum*.

My recent reinvestigation of all the original specimens of *A. ezoanum* from the Miocene of Sakhalin (Oishi and Huzioka, 1943) reveals that most of them are not similar to the extant *A. miyabei* Maxim. but to *A. saccharinum* L. in their marginal characters though unfortunately not preserved in the fine venation: the original specimens including types have two or three minute teeth on the basal side of large dents, whose minute teeth the tertiary veins from the secondary end in. So far as reinvestigated, six leaves illustrated as *Acer* sp. from the Miocene of central Honshu (Ina, 1977, 1981) are closely similar to some types of leaves of *A. saccharinum* in their foliar shape, margin and even in the venation characters, and they are conspecific with leaves of Sakhalin. These leaf specimens from the Miocene of Sakhalin and Central Honshu are very variable in the foliar shape and marginal dentation, but their variation is well consistent with that of the extant relative.

A. yabei doubtlessly represents the samara of *A. ezoanum*, and is a later synonym of *A. ezoanum*. Though samara is of characteristic features, *A. yabei* (here transferred to *A. ezoanum*) has been uncommonly found in the Tertiary of Japan; its past distribution was formerly limited to northern Japan. Although incomplete, samaras described as *A. cf. kokangense* (Tanai & Onoe, 1959), *A. macrosamarum* (Huzioka, 1964) and *A. palaeoplatanoides* var. (Akhmetjev et al., 1966) from Japan or Primorye are included in *A. yabei* by their large size and seed shape. Several well-preserved, large samaras were recently reported as *A. grahamensis* from the Miocene Kamchatka (Chelebaeva, 1978); all of them are identical with *A. yabei* in their characteristic seeds.

Compared with a wide occurrence of such characteristic samaras, few leaves referable to *A. ezoanum* have been known in the Tertiary of East Asia. This may be partly due to the fact that leaves related with *A. saccharinum* are highly variable in shape and margin, and that they are not always easily distinguishable from other maples such as *A. tricuspidatum* and *A. grahamense* only by gross characters. Recently I could find several leaves identical to the redefined *A. ezoanum*, accompanied by many samaras in the Middle Miocene of north-central Hokkaido. Leaves reported under the various names of *A. pseudomiyabei* var. *dissectum*, *A. cf. ezoanum* and *A. cf. osmontii* from southern Primorye (Baikovskaya, 1974) are also referable to *A. ezoanum* here redesignated.

A. ezoanum, represented by both leaves and samaras, is closely similar to *A. osmontii* Knowlton, which is one of the common maples in the Tertiary of the western United States. It is very interesting for phytogeographic history that two species related to *A. saccharinum* were once widely distributed in East Asia and western North America bordering the northern Pacific, although *A. saccharinum* is now missing in both regions.

Occurrence and Collections: Shanabuchi (HUMP no. 26917), Rubeshibe (HUMP no. 26916), and Bifuka (HUMP nos. 26217-26220, 26346a, b), Hokkaido; Nenoshiroishi (IGPS-60992), Miyagi Pref.; Miyata (AKMG-7420) and Aniai (AKMG-3933), Akita Pref.; Shichiku (GSJ no. 4043), Fukushima Pref.; Kani, Gifu Pref.; Suki, Oki Isl., Shimane Pref.; Dembi (GIN-AN no. 3803/884a) and Botchi, Primorye; Korf Bay (IV-AN nos. 514/66, 86a/13, 513/12A, 514/90, 514/150), Kamchatka; Nexhino and Udugou, Primorye; Old Due Mine, Sernyi Cape, Shiritori (HUMP nos. 9359, 9360), Nayoshi (HUMP nos. 9425, 9426) and Taihei coal mine (9403a-b, 9428), Sakhalin.

Acer ishikariense Tanai sp. nov.

(pl. 5, figs. 1, 8, 9)

Acer arcticum auct. non Heer. Endo. 1963 (part). Trans. Proc. Palaeont. Soc. Japan. N.S. (50): 66. pl. 10. f. 4.

Endo. 1968 (part). Bull. Natl. Sci. Mus. 11 (4): 437. pl. 12. f. 6.

Type: Holotype, HUMP no. 26209; paratype, HUMP no. 26210; Ikushunbetsu Formation (Early Oligocene); Reisui-zan, Yubari, Hokkaido.

Description: Samaras oblanceolate in general outline, 26 to 36 mm long and 8 to 10 mm wide; length/width ratio 3.3 to 3.8. Wing rounded at apex, gradually narrowed toward base; outer margin straight and inner margin gently convex; both margins of wing ending just in the upper part of seed. Seeds thick, ellipsoidal, somewhat bulged outwardly, 6 to 7 mm long and 2.5 to 3.5 mm wide, length/wide ratio 2 to 2.8; finely anastomosing veins developing on seed surface; longitudinal axis of seed slightly oblique with very acute angles; contact scar of seed usually short, 2 to 2.5 mm. in length; angles between the contact scar and outer margin of wing 18° to 20°.

Discussion: This species is based on a number of well-preserved samaras from the Paleogene of the Ishikari coal field of Hokkaido. The ellipsoidal seed that is covered by

finely anastomosing veins, acute divergent angles of wings and short contact scar of seed, indicate that this species is closely related to the extant *Acer rubrum* L. and *A. pycnanthum* K. Koch. which are the vicariant species in eastern North America and Japan. However, *A. ishikariense* is usually larger on the average than that of the extant relatives. Although the samaras were commonly found, no fossil leaves referable to *A. ishikariense* have been yet known in the Paleogene of Hokkaido. A single samara described as *A. arcticum* from the Paleogene of Hokkaido (Endo, 1963, 1968) was invalidly illustrated. My reinvestigation of this specimen is identical with *A. ishikariense*, although it lacks the lower part of seed.

Occurrence and Collections: Reisui-zan (HUMP nos. 26209-26212), Shimizusawa (NSM no. 10488; HUMP no. 26213), Shikanotani (HUMP no. 26214) and Mayachi (HUMP no. 26215), Yubari; Takinosawa (HUMP no. 26216), Bibai, Hokkaido.

Acer tricuspidatum Bronn

(pl. 8, figs. 5, 7, 8)

- Acer tricuspidatum* Bronn. 1838. Lethaea Geogn. 2. pl. 35. f. 10a. b.
Walth. 1968. Monatsb. Deutsch. Acad. Wiss. 10 (8): 636. pl. 2. f. 1-3 (see discussion).
- Acer trilobatum* auct. non Sternberg. Heer. 1878. Mem. Acad. Imp. St. Petersb. [7]. 25 (7): 48. pl. 13. f. 9.
- Acer trilobatum* (Sternb.) auct. non Al. Braun. Oishi & Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 96. pl. 12. f. 4.
Huzioka. 1963. Tertiary floras of Japan. p. 209. pl. 37. f. 2.
Tanai. 1971. Mem. Natl. Sci. Mus. (4): 163. pl. 11. f. 4.
Tanai & Ozaki. 1977. J. Fac. Sci., Hokkaido Univ., [4]. 17 (4): 584. pl. 2. f. 5-7; text-f. 5, A, B.
- Acer trilobatum* (Sternb.) Al. Br. var. *productum* auct. non Al. Br. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ., [4]. 7 (1): 132. pl. 23. f. 8.
Endo. 1951. Short Papers IGPS, (3): 54. pl. 8. f. 6.
Huzioka. 1972. J. Min. Coll. Akita Univ. [A]. 5 (1): 67. pl. 9. f. 3.
- Acer* cf. *trilobatum* Al. Br. auct. non Kryshstofovich. 1921. Rec. Geol. Commit. Russ. Far East. (15): 9. pl. 3. f. 3.
- Acer miocaudatum* Hu et Cheney. 1938. Palaeont. Sin. [A]. (1): 57. pl. 32. f. 4, 6.
Akhmetjev & Schmidt. 1976. Geol. Paleont. Rept. from Far East. p. 84. pl. 9, f. 7; text-f. 1-20.
Acad. Sin. 1978. Cenozoic plants of China. p. 125. pl. 108. f. 2; pl. 109. f. 2.
- Acer rubrum* L. var. *lignitum* Miki. 1941. Jap. J. Bot. 11: 283. text-f. 17-A.
- Acer pseudocarpinifolium* Endo. 1950. Short Papers IGPS (1): 14. pl. 3. f. 6.
Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 92. pl. 15. f. 7, 8.
- Acer yabei* auct. non Endo. N. Suzuki. 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 691. pl. 4. f. 3.
Tanai and N. Suzuki. 1965 (part). Palaeont. Soc. Jap. Spec. Pap. (10): 39. pl. 10. f. 2.
- Acer yoshiokaense* auct. non Tanai et N. Suzuki. Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 94. pl. 15. f. 14.
Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. from Far East. p. 100. pl. 10. f. 11; text-f. 1-14.
- Acer palaeodiabolicum* auct. non Endo. N. Suzuki. 1963 (part) J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 687. pl. 2. f. 2.
Tanai & N. Suzuki. 1965. Palaeont. Soc. Jap. Spec. Pap. (10): 37. pl. 10. f. 3.
Onoe. 1974. Geol. Surv. Jap. Rept. (253): 51. pl. 11. f. 9.
- Acer lebedevii* Akhmetjev et Schmidt. 1976. Geol. Palaeont. Far East. p. 81. pl. 9. f. 13; text-f. 1-27.
- Acer anguenum* Akhmetjev et Schmidt. 1976. ditto. p. 93. pl. 10. f. 12; text-f. f-6.
- Acer aldanense* Iljinskaja. 1976. Trans. Inst. Geol. Geophy. 233: 119. pl. 26. f. 5; pl. 28. f. 1, 2; pl. 29. f. 6; etc.
- Acer rubrum* L. var. *pycnanthum* auct. non Makino. Hori. 1976. Fossil Plants from Kobe. p. 132. text-f. 130.

- Acer tigilensis* Chelebaeva. 1976. Red. Ban. Lab. Geol. Inst. Trans. (294): 192. pl. 24. f. 3-5; pl. 39, f. B-D; pl. 40. f. A, B.
 Chelebaeva. 1978. Miocene floras of eastern Kamchatka. pl. 81. pl. 20. f. 2; pl. 25. f. 8; text-f. 32-1.
 Fotjanova & Sinelynikova. 1982. New Informations on Stratigr. & Palaeont. p. 99. pl. 10. f. 3; pl. 12. f. 2; pl. 13. f. 1.
Acer vassilijevii Akhmetjev et Schmidt. 1979 (part). Palaeont. & Stratigr. Far East. p. 105. pl. 13. f. 6; text-f. 1-d.
Acer ezoanum auct. non Oishi et Huzioka. Schvareva & Baranova. 1979. Continental Tertiary deposits. p. 95. pl. 7. f. 1.
Acer sp. Huzioka et Nishida. 1960. Sado Mus. Publ. (3): 20. pl. 6. f. 6, 7.
Acer sp. Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 67. pl. 9. f. 2.
Acer sp. Akhmetjev et Schmidt. 1976. Geol. Palaeont. Rept. from Far East. p. 96. pl. 9. f. 1; text-f. 1-2.
Acer sp. Chelebaeva. 1978. Miocene floras of eastern Kamchatka. p. 80. pl. 17. f. 8.

Type: Neotype, SLG DAW no. 59; Salzhausen, near Nidda, Hesse, West Germany [the original specimens by Bronn (1838) were lost].

Discussion: This species is originally based on Tertiary leaves of Europe, which are closely related to the extant *Acr rubrum* L. of eastern North America and *A. pycnanthum* K. Koch of Japan. Leaves of *A. tricuspdatum* are highly variable in shape and margin as in the extant relatives: the lobes are from three to five with acute or caudate apex, although a basal pair is usually very small in the case of five-lobed leaves; the margin is from largely dentate to remotely serrate, with or without a pair of large dents on central lobe; the divergence of lateral lobes is very variable in angles. These variable foliar characters have frequently resulted in the misidentification or in dividing into many species by various authors. However, all the Tertiary leaves from East Asia are well in accords with the fine venation and foliar variation displayed by the extant relatives: the areoles are regularly well-developed and are mostly quadrangular; the freely-ending veinlets are single or lacking.

Regarding application of specific name to such leaves which are closely related to the extant *A. rubrum*, two opinions have been in controversy in Europe. Although I summarized briefly this problem (Tanai & Ozaki, 1977), it was based on misunderstanding, due to lacks of bibliographic survey. Hantke (1965) claimed to conserve the epithet "*trilobatum*", while Kvacek (1965) and Walther (1968) discussed in detail to adopt "*tricuspdatum*". As noted by the latter, the conservative name should be confined to the genus and family (the Article 14 of the International Code of Botanical Nomenclature, 1972). Although there were proposed many specific names since Sternberg (1820), the oldest epithet "*tricuspdatum*" is considered to have been validly published (the Article 44 of ICBN).

Fossil samaras similar to *A. rubrum* or *A. pycnanthum* have been also common in the Tertiary of Europe; they were described as *A. cyclopermum* Goepfert, *A. tricuspdatum*, *A. trilobatum* and others. These samaras should be included in *A. tricuspdatum* which was redesignated by Walther (1972). Compared with considerable variation in foliar shape, samaras referable to *A. tricuspdatum* in East Asia are usually characterized by thick, ellipsoidal or obovate seeds, comparatively short contact scar of seed and narrow acute angles of the wing divergence. These fossil samaras are mostly larger on the average than those of the extant relatives.

As far as determined, all the specimens in the above list are included in *A.*

tricuspidatum. Based on many well-preserved leaves, *A. tigilensis* was proposed from the Tertiary of eastern Kamchatka (Chlebaeva, 1976), but it is unseparable from *A. tricuspidatum*. From leaves of *A. miocaudatum* from the Shanwang flora are also identical with the dentate margined leaves of *A. tricuspidatum*, though they are somewhat incomplete. *A. aldanense* from the Miocene of Mamatova Gora (Iljinskaya, 1976) probably represent larger leaves of *A. tricuspidatum*.

Occurrence and Collections: Kayanuma (HUMP no. 9362), Sakipenpetsu (HUMP no. 26047), Rubeshibe (HUMP no. 25897-25906, 25916), Bifuka and Shanabuchi (HUMP no. 25767), Hokkaido; Aniai (AKMG-3928) and Utto (AKMG-3137), Akita Pref.; Oguni (GSJ no. 4588), Yamagata Pref.; Nenoshiroishi (IGPS-44246), Miyagi Pref.; Seki (AKMG-3325), Niigata Pref.; Shichiku (AKMG-5084), Fukushima Pref.; Chausuyama (IGPS-60982), Nagano Pref.; Seto, Aichi Pref.; Tokitsu and Hiyoshi (AKMG-5156), Gifu Pref.; Tatsumitoge (GSJ. no. 4826; TPM-208; NSM-PP-16163), Tottori Pref.; Kilyu (HUMP no. 9341), Kungshim (IGPS-92367) and Kogeonweon (IGPS-92365), North Korea; Shanwang, China; Uglovoe (DBGI-AN nos. 700/1, /2, 24), Belikaja Kema (GIN-AN no. 3820/555a), Amgu River (GIN-AN no. 3802/45), Rettikovka (GIN-AN no. 410/1500) and Shakterskoe (DBGI-AN no. 655/3b), Primorye; Mamatova Gora, Aldan Region, Siberia; Tigil River (IV-AN nos. T60/68, /72, /77), Kolpakov River (PI-AN nos. 4039/71, /72) and Korf (IV-AN nos. 511/77, 5170/2, M610/1A, M614/13), Kamchatka; Due, Sakhalin.

Section Platanoidea Pax

Acer chiharae Huzioka et Nishida

(pl 9, figs. 4, 5a, pl. 10, figs. 1-5)

Acer chiharae Huzioka et Nishida. 1960. Sado Mus. Publ. (3): 18. pl. 5. f. 6-8.

Tanai et N. Suzuki. 1963. Tert. floras Japan. p. 137. pl. 14. f. 7; pl. 25. f. 6.

Huzioka. 1964. J. Min. Coll., Akita Univ. [4], 3 (4): 88. pl. 14. f. 5.

Tanai. 1971. Mem. Natl. Sci. Mus. (4): 162. pl. 10. f. 4.

Acer imaii Huzioka et Nishida. 1960. Sado Mus. Publ. (3): 18. pl. 6. f. 1, 2.

Huzioka. 1964. J. Min. Coll., Akita Univ. [4]. 3 (4): 90. pl. 14. f. 11.

Huzioka. 1974. ditto. 5 (2): 103. pl. 5. f. 7.

Acer subpictum auct. non Saporta. Oishi et Huzioka. 1943 (part). J. Fac. Sci., Hokkaido Univ. [4]. 7: 93. pl. 13. f. 1-3.

Tanai et N. Suzuki. 1960 (part). ditto. 10 (3): 567. pl. 4. f. 2, 3; pl. 7. f. 6.

Acer juanii Chaney et Chuang. 1968. Geol. Soc. China. (11): 16. pl. 1. f. 3.

Acer pseudomonoides Chelebaeva. 1978. Miocene floras of eastern Kamchatka. p. 80. pl. 17. f. 6, 7; pl. 18. f. 2-5; text-f. 27-5; text-f. 28-1; text-f. 29-2.

Acer sp. Acad. Sinica 1978. Cenozoic Plants of China. p. 130. pl. 116. f. 4.

Type: Holotype, AKMG no. 3312; Suginoura Formation (Early Miocene); Seki, Aikawa-machi, Sado Isl., Niigata Prefecture.

Discussion: This species that is represented by five to seven lobed leaves is generally similar to *Acer rotundatum* described later, but it is distinguishable by lanceolate lobes whose margin is usually remotely serrate with small, obtuse teeth. *A. chiharae* was originally compared with the extant *A. chingii* Hu of southwestern China (Huzioka, 1964), which belongs to the section Palmata. However, my reinvestigation of the type

specimens reveals that the ultimate veinlets are lacking or single within the four- or five-sided areoles. Considering the venation character together with leaf shape, *A. chiharae* belongs to the section *Platanoidea*, and is closely related to the extant *A. mono* Maxim.

The extant related species, *A. mono*, has many varieties and form species, showing several leaf shapes or marginal characters. The most typical leaves of *A. mono* have deltoid lobes and entire margin, but some leaves have a few minute teeth on the upper margin of lobes as in the case of *A. mono* var. *marmoratum* (Nichols.) Hara and *A. mono* var. *mayrii* (Schwerin) Sugimoto. Compared with the abundant occurrence of *A. rotundatum* through the Tertiary of East Asia, leaves referable to *A. chiharae* are not common. *A. chiharae* may represent a variety of *A. rotundatum* as seen in leaves of the extant *A. mono*. However, *A. chiharae* is here treated as an independent species, emphasizing the minutely serrate margin.

As far as reinvestigated, all the specimens listed in the synonymy are included in *A. chiharae*. Leaves of *A. imaii* described from the same locality of the Seki flora of Sado Island are conspecific with *A. chiharae*, because the fine venation character is quite similar. *A. pseudomonoides* from the Miocene of the Korf Bay, Kamchatka is also unseparable from *A. chiharae*, although it includes several large leaves with 7 lobes attaining 20 cm length. Many large leaves with a few minute teeth are also found from the Upper Miocene of north-central Hokkaido, accompanied by many normal-sized leaves of *A. chiharae*; all of these leaves show similar venation characters including the areolar shape and fine veinlets excepting for some difference of areole size.

A. hilgendorfi Nathorst based on a single leaf of the Mineralogical Museum of Berlin (Nathorst, 1883), is probably identical with *A. chiharae*, and the epithet “*hilgendorfi*” has a nomenclature priority for such remotely minute-toothed leaves similar to *A. mono*. However, the original specimen was unfortunately lost in the Museum, and also we cannot select a neotype for “*hilgendorfi*”, because the original specimens are unknown in the exact locality.

Occurrence and Collections: Sakipenpetsu (HUMP nos. 9335-9337, 25045), Kaminokuni (HUMP nos. 25049, 25050, 25054), and Bifuka (HUMP nos. 26221-26224), Hokkaido; Seki, (AKMG nos. 3311-3313, 3317, 3318), Niigata Pref.; Daibo (AKMB no. 5917), Yamaguchi Pref.; Jiggu, Yunnan, China; Shihti, Taiwan, China; Korf Bay (IV-AN nos. 511/100B 514/20B, /23, /59, /70, /104, /102, /154), Kamchatka.

Acer huziokae Tanai sp. nov.

(pl. 11, fig. 2)

Acer pictum auct. non Thunb. Nathorst. 1883 (part). Kgl. Sv. Vet. Akad. Handl. 20 (2): 60. pl. 12. f. 2.

Okutsu. 1940 (part). Saito Ho-on Kai Mus. Res. Bull. (19): 163. pl. 8. f. 4.

Acer uweharae auct. non Konno. K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 77. pl. 17. f. 10.

Acer florinii auct. non Hu et Chaney. Huzioka & Uemura. 1973. Bull. Natl. Sci. Mus. 16 (4): 718. pl. 13. f. 8.

Tanai & Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 586. pl. 4. f. 3; text-f. 4-K.

Guo. 1978. Acta Palaeont. Sin. 17 (3): 343. pl. 1. f. 8.

Acer miofranchetii auct. non Hu et Chaney. Acad. Sin. 1978 (part). Cenozoic Plants of China. p. 126. pl. 109. f. 1.

? *Acer* sp. cf. *A. stonolobum* Bell. Akhmetjev & Schmidt. 1976. Geol. Paleont. Rept. Far East. p. 94. pl. 9. f. 4; text-f. 1-9.

Type: Holotype, TPM-400; Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Prefecture.

Description: Leaves trilobed, variable in size, 3.6 to 9.5 cm long and 4.2 to 9.7 cm wide; base rounded to broadly cordate; margin entire. Lobes trigonal to narrowly trigonal, separated by broadly opened, obtuse sinus; central lobe somewhat larger than the laterals; apex of each lobe acuminate to attenuate, sometimes with a caudate tip. Primary veins three, strong, radiating from the base, entering the lobe apex; secondary veins more than 6 pairs, opposite to subopposite, diverging from the primaries at acute angles, gently curving upward, then joining the superadjacent secondary at nearly right angles, random reticulate; the highest venation order sixth; areolation moderate in size, four- or five-sided by fourth and fifth order veins; freely ending veinlets lacking or single. Petiole thick but incomplete, more than 2 cm long.

Discussion: This species is distinguishable from the entire margined specimens of *Acer prototrifidum* Tanai by the larger areoles, thin venation and no presence of a fimbrial vein.

The entire margin and venation characters indicate that *A. huziokae* is akin to the extant *A. mono* Maxim., although leaves of the extant relative are mostly 5 to 7 in lobation. Of many varieties of *A. mono*, there is known *A. mono* var. *glaucum* (Koidzumi) Kitamura living in northeastern Honshu, whose leaves are usually 3 to 5 in lobation. *A. huziokae* may be included in *A. rotundatum* that is closely similar to the extant *A. mono* in all the characters, but it is better to treat as an independent species, emphasizing the trilobed character.

This new species is named in the honour of Professor Kazuo Huzioka who has excellently worked on Cenozoic paleobotany of Japan.

Occurrence and Collections: Miyata (AKMG-7400), Akita Pref.; Fujitoge (IGF no. 5345), Fukushima Pref.; Nenoshiroishi, Miyagi Pref.; Tatsumitoge (TPM-400), Tottori Pref.; Mogi, Nagasaki Pref.; Shungpan, Schuan (NIGP-PB no.6130) and Shanwang, China.

Acer palaeoplatanoides Endo

(pl. 9, figs. 1-3, 6)

Acer palaeoplatanoides Endo. 1950. Short Papers IGPS, (1): 11. pl. 3. f. 1, 9.

Tanai & Onoe. 1959 (part). Bull. Geol. Surv. Jap. 10 (4): 21. pl. 6. f. 4, 10.

Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 563. pl. 9. f. 8.

Tanai & N. Suzuki. 1963. Tert. Floras Japan. p. 139.

Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 65. pl. 8. f. 9, 9a.

Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 96. pl. 10. f. 2; text-f. 1-17. 21.

Acer pictum Thunb. subvar. *savatieri* auct. non Pax. Endo. 1950. Short Papers IGPS. (1): 15. pl. 3. f. 12.

Acer subpictum auct. non Saporta. Suzuki, N. 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 690. pl. 5. f. 5.

Tanai & N. Suzuki. 1965. *Palaeont. Soc. Jap. Spec. Paper.* (10): 39. pl. 2. f. 1a.

Ishida. 1970. *Mem. Fac. Sci., Kyoto Univ. [Geol. & Min.]*. 37 (1): 96. pl. 15. f. 15.

Tanai & N. Suzuki. 1972 (part). *J. Fac. Sci., Hokkaido Univ.* [4]. 15 (1-2): 337. pl. 7. f. 6; pl. 8. f. 2.

Hayashi. 1975. *Fossils Iki Island*. p. 26. pl. 18. f. 3, 4, 10.

Acer submayrii acut. non Tanai et Onoe. Tanai & N. Suzuki. 1960. *J. Fac. Sci., Hokkaido Univ.* [4]. 10 (3): 568. pl. 9. f. 9.

Acer sp. Florin. 1920. *Kgl. Sv. Vet. Akad. Handl.* 61 (1): 32. pl. 6. f. 7, 8.

Acer sp. Oishi & Huzioka. 1943. *J. Fac. Sci., Hokkaido Univ.* [4]. 7 (1): 98. pl. 11. f. 5.

Acer sp. Huzioka, 1943. ditto. 7 (1): 136. pl. 23. f. 1, 3.

Acer sp. Akhmetjev. 1973. *Acad. Sci. USSR. Geol. Inst. Trans.* 247: 76. pl. 15. f. 5; pl. 26. f. 2.

Type: IGPS-60987: Hamjindong Formation (late-Early Miocene); Hamjindong, Hamg'yeong-bukdo, North Korea.

Supplementary Description: Samaras oblong to oblanceolate in general outline, 24 to 45 mm long, 7 to 14 mm wide; length/width ratio 2.1 to 3.2. Wing slightly narrowed toward base, rounded at apex; outer margin nearly straight or slightly concave; inner margin broadly convex, reaching the contact scar of seed; veins fine, numerous, dichotomizing more than three times, curving gently inward. Seeds thin, flattened, orbicular to suborbicular, 6 to 10 mm long and 5 to 9 mm wide; length/width ratio 1 to 1.3; contact line of seeds distinct, 5 to 9 mm long; angles between outer margin of wing and contact scar of seeds 60° to 90°.

Discussion: The thin, flattened seeds with an orbicular to suborbicular shape and general shape of wings indicate that these samaras are closely similar to those of the extant *Acer mono* Maxim. of East Asia. As discussed later, the samaras described in the above list show usually wider divergent angles (120°-180°) of wings. Most of these samaras have been referred to *A. subpictum* Saporta or *A. palaeoplatanoides* Endo by many authors.

The epithet "*subpictum*" is doubtlessly a nomen nudum as already discussed by me (Tanai, 1976: p. 330). Although the holotype specimen of *A. palaeoplatanoides* (Endo, 1950) is somewhat incomplete in the preservation of the contact scar of seed, the divergent angles of wings show more than 120°. Thus, the epithet "*palaeoplatanoides*" is adopted for the samara specimens having wider divergent angles (120°-180°) of wings, which are similar to some of the extant *A. mono*.

Compared with abundant occurrence of samaras of *A. rotundatum*, *A. palaeoplatanoides* redesignated here have not been always common in the Neogene of East Asia.

Occurrence and Collections: Yoshioka (HUMP no. 25033), Wakamatsu (HUMP no. 25099), Kudo (HUMP no. 27133), Garo (HUMP no. 27077), Abura (HUMP no. 9363a), Shanabuchi (HUMP no. 25776a) and Rubeshibe (HUMP no. 25803c), Hokkaido; Shichiku (GSJ nos. 4036, 4054), Fukushima Pref., Noroshi (JC-88-501), Ishikawa Pref.; Chojabaru (HUMP nos. 26225, 26226), Iki Isl. and Mogi, Nagasaki Pref.; Yeonil (HUMP no. 26227), South Korea; Kilyu (HUMP no. 9321) and Hamjindong (IGPS-60987, HUMP no. 9439), North Korea; Shakterskow and Botchi, Sikhote-Alin.

Acer rotundatum Huzioka

(pl. 11, figs. 1, 3, 6)

- Acer rotundatum* Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 129. pl. 24. f. 1-3; pl. 25. f. 2.
 Oishi & Huzioka. 1943. ditto. 7 (1): 93. pl. 12. f. 3.
 Huzioka & Nishida. 1960. Sado Mus. Publ. (3): 19. pl. 5. f. 4.
 Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 93. pl. 15. f. 10.
 Huzioka. 1972. ditto. 5 (1): 66. pl. 14. f. 2.
- Acer pictum* auct. non Thunb. Nathorst. 1883 (part). Kgl. Svens. Vet. Akad. Handl. 20(2): 60. pl. 12. f. 3-8.
 Florin. 1920. ditto. 61 (1): 24. pl. 4. f. 5.
 Kryshstofovich. 1930. Ann. Russ. Palaeont. Soc. 8: 24, 26, 27. pl. 3. f. 30.
 Okutsu. 1940 (part). Saito Ho-on Kai Mus. Res. Bull. (19): 163. pl. 7. f. 3; pl. 8. f. 1-3.
 Okutsu. 1955. Sci. Rept., Tohoku Univ. [2]. 26: 103. pl. 7. f. 1, 2, 8.
- Acer subpictum* auct. non Saporta. Hu & Chaney. 1938. Palaeont. Sinica. [A]. (1): 61. pl. 34. f. 3-5, 7;
 pl. 35. f. 1.
 Oishi & Huzioka. 1943 (part). J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): pl. 13. f. 4; pl. 14. f. 3, 4.
 Huzioka. 1943. ditto. 7 (1): 129. pl. 24. f. 4-6; pl. 25. f. 3.
 Tanai. 1952. Jap. J. Geol. Geogr. 22: 131. pl. 4. f. 7.
 Tanai & N. Suzuki. 1960 (part). J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 567. pl. 4. f. 1, 4; pl. 7.
 f. 3-5.
 Tanai & Onoe. 1961. Geol. Surv. Jap. Rept. (187): 51. pl. 16. f. 4-6.
 Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 365. pl. 27. f. 1; pl. 28. f. 2.
 Tanai & N. Suzuki. 1963. Tertiary floras of Japan. p. 142. pl. 21. f. 7, 9.
 Huzioka. 1963. ditto. p. 209. pl. 37. f. 1.
 Suzuki, N. 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 690. pl. 5. f. 3.
 Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 93. pl. 15. f. 11-13.
 Tanai. 1971. Mem. Natl. Sci. Mus. (4): 163. pl. 10. f. 3, 7.
 Tanai & N. Suzuki. 1972 (part). J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 337. pl. 7. f. 9.
 Huzioka & Takahashi. 1973. Bull. Natl. Sci. Mus. 16 (1): 140.
 Huzioka & Uemura. 1973 (part). ditto. 16 (4): 720. pl. 13. f. 1-3.
 Ozaki. 1974. Sci. Rept., Yokohama Natl. Univ. [III]. (21): 18. pl. 3. f. 7.
 Huzioka & Uemura. 1974. Bull. Natl. Sci. Mus. 17 (4): 354. pl. 8. f. 1.
 Huzioka. 1974. J. Min. Coll., Akita Univ. [A]. 5 (2): 104. pl. 5. f. 3.
 Hori. 1976. Fossil Plants from Kobe. p. 132. text-f. 131.
 Ina. 1977. Geol. Palaeont. Kani Town. p. 84. pl. V-22. f. 3; pl. V-23. f. 1, 2.
 Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 128. pl. 100. f. 4; pl. 101. f. 4; pl. 105. f. 3;
 pl. 106. f. 4; pl. 108. f. 1; pl. 111. f. 3, 7. pl. 112. f. 3; pl. 113. f. 2, 3. pl. 114; pl. 115. f. 1-3;
 pl. 116. f. 1.
 Ina. 1981 (part). Monogr. Mizunami Mus. 2. pl. 29. f. 1, 2.
- Acer miyagiense* Endo. 1950. Short Papers IGPS (1): 16. pl. 3. f. 14.
- Acer mayrii* auct. non Schwerin. Endo. 1951. ditto. (3): 57. pl. 8. f. 2.
- Acer monoides* Shaparenko. 1956. Palaeobotanika. 1: 34. pl. 51. f. 1b, 2, 3; pl. 52. f. 3, 4; text-f. 62-64.
 Chelebaeva. 1968. Bot. Jour. 53 (6): 746. pl. 4. f. 6; text-f. 4-d.
 Baikovskaya. 1974. Late Miocene flora of S. Primorye. p. 84. pl. 20. f. 10; pl. 24. f. 11.
 Baikovskaya. 1974. ditto. p. 115. pl. 38. f. 2; text-f. 39.
 Chelebaeva. 1976. Red. Ban. Lab. Geol. Inst. Trans. 294: 192. pl. 38. f. D.
- Acer matsuii* Tanai et Onoe. 1959. Geol. Surv. Jap. Bull. 10 (4): 22. pl. 6. f. 1, 13.
- Acer protodistylum* auct. non Endo. Tanai & N. Suzuki. 1960 (part). J. Fac. Sci., Hokkaido Univ. [4].
 10 (4): 564. pl. 9. f. 4.
- Acer submayrii* Tanai et Onoe. 1961. Geol. Surv. Jap. Rept. (187): 50. pl. 17. f. 5.
 Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 365. pl. 26. f. 7.
- Acer konnoi* Murai. 1963. Rept., Tech., Iwate Univ. 16 (1): 108. pl. 13. f. 3, 5.
- Acer florinii* auct. non Hu et Chaney. Huzioka, 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 89. pl. 14. f. 10.
- Acer palaeoplatanoides* auct. non Endo. Huzioka. 1964 (part). J. Min. Coll., Akita Univ. [A]. 3 (4): 91.
 pl. 15. f. 5.

- Acer palaeodiabolicum* auct. non Endo. Ishida. 1970. Mem. Fac. Sci., Kyoto Univ. [Geol. & Min.]. 37 (1): 96. pl. 17. f. 17.
- Acer prototataricum* auct. non Tanai et N. Suzuki. Tanai & N. Suzuki. 1972. J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 337. pl. 6. f. 9.
- Acer yoshiokaense* auct. non Tanai et N. Suzuki. Tanai & N. Suzuki. 1972 (part). ditto. 15 (1-2): 338. pl. 6. f. 13.
- Acer integerrimum* auct. non (Viviani) Massalongo. Tanai. 1976. J. Fac. Sci., Hokkaido Univ. [4]. 17 (2): 329. text-f. 7-K.
Tanai & Ozaki. 1977. ditto. 17 (4): 588. pl. 2. f. 1, 3, 4; text-f. 4-G, H.
- Acer macrophylla* auct. non Franch. Gen. ex Acad. Sin. 1978. Cenozoic Plants of China. p. 125. pl. 111. f. 1; pl. 112. f. 2.
- Acer* sp. Florin. 1920. Kgl. Svens. Vet. Akad. Handl. 61 (1): 24. pl. 4. f. 6.
- Acer* sp. K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 78. pl. 17. f. 8.
- Acer* sp. Huzioka. 1963. Tert. Floras Japan. p. 210. pl. 37. f. 4.

Type: Lectotype, HUMP no. 9339b; Changgi Group (Early Miocene): Keumkwandong, Kyongsangbuk-do, South Korea.

Discussion: This species is represented by a number of leaves and samaras that have been commonly found in the Neogene of East Asia. These specimens have several features indicating a close relationship to the extant *Acer mono* Maxim. of East Asia: leaves are shallowly to deeply and 5 to 7 lobed with entire margin; the apex of each lobe is acute to acuminate, sometimes, with a caudate tip; the freely ending veinlets are lacking or single within the quadrangular areoles; seeds are thin and flattened, with an orbiculate to suborbiculate shape. These specimens are very variable in the foliar shape or lobation and the divergent angles of wings as done by the extant related *A. mono*, which is classified into several varieties. It is difficult to separate these fossil leaves, based only by foliar shape, excepting for 3 lobed or weakly toothed-margin leaves. Although the fossil samaras are also variable in the angles between the outer margin of wing and the contact scar of seeds, such character is separable into two clusters by angles: 30°-45° and 60°-90°. Thus, the 5-7 lobed leaves with entire margin and samaras with less than 100° of the divergent angles of wings are treated as an independent fossil species that is similar to *A. mono* group.

As described in the above list, various specific names have been used or proposed for the leaves and samaras of East Asia similar to *A. mono*, but *A. integerrimum* was recently used by me (Tanai, 1976). According to Walther (1972), an European Tertiary species, *A. integerrimum*, includes various leaves; from 3 to 5 lobed and from quite entire to weakly toothed in the margin. Huzioka (1943) proposed *A. rotundatum* for 5-lobed, entire margined leaves with a rounded base and caudate apex of lobe from the Miocene of Korea, but these Korean leaves are unseparable from most Tertiary leaves similar to *A. mono*. The epithet "*rotundatum*" has a nomenclatural priority for leaves and samaras of the "*mono*"-type which is here redesignated. *A. rotundatum* was widely distributed in East Asia since Early Miocene time, corresponding with the fact that the extant *A. mono* is widely living in Northeast Asia with several varieties.

Occurrence and Collections: Sakipenpetsu (HUMP nos. 9406, 26036b, 26046; NSM-PP-5356), Abura (HUMP no. 9327, 9361), Yoshioka (HUMP nos. 25047, 25048, 25051-25053), Wakamatsu (HUMP no. 26158), Kudo (HUMP nos. 27136, 27139), Kaminokuni (HUMP no.25054), Nukabira (HUMP no. 25261), Rubeshibe (HUMP

no. 26913), and Kayanuma, Hokkaido; Miyata (AKMG-7105, 7112; NSM-PP-6272), Sanzugawa (AKMG-7583), Utto (AKMG-3138, 3141) and Aniai (AKMG-3915, 3931), Akita Pref.; Gosho (IAGI nos. 61096, 61097), Iwate Pref.; Aburado (AKMG-5022) and Kamigo, Yamagata Pref.; Shichiku (GSJ no. 4042; AKMG-5081; IGPS-78145), Fukushima Pref.; Seki (AKMG-3308), Niigata Pref.; Nenoshiroishi (IGPS-60598, 60997), Miyagi Pref.; Omi and Kita-aigi, Nagano Pref.; Hiyoshi, (GSJ no. 4301), Mizunami (GYNU-CMP-1020) and Hiramaki, Gifu Pref., Noroshi (JC88-484), Ishikawa Pref., Mitoku (GSJ no. 4185), Ningyo-toge (GSJ nos. 4186-4188) and Tatsumitoge (NSM-PP-16065; TPM-362, 383), Tottori Pref.; Onbara, Okayama Pref., Yamane (AKMG-5908), Daibo and Shimonoseki, Yamaguchi Pref.; Mogi (GSJ no. 4727) and Chojabaru, Nagasaki Pref.; Amakusa, Kumamoto Pref.; Shanwang, China; Keumkwandong (HUMP no. 9339a, b), South Korea; Yongdong (HUMP nos. 9338a, b; 9345a, b), Kilyu (HUMP no. 9346) and Hamjindong (HUMP no. 9343), North Korea; Nayoshi (HUMP no. 9334) and Sernyi Cape, Sakhalin; Tigil River, Pirozhnikovaya River (IV-AN nos. 6036/32, /42), Kamchatka; Kedrvki, Mduogou and Nexhino, Primorye.

Acer shanwangense Tanai sp. nov.

(pl. 8, fig. 4)

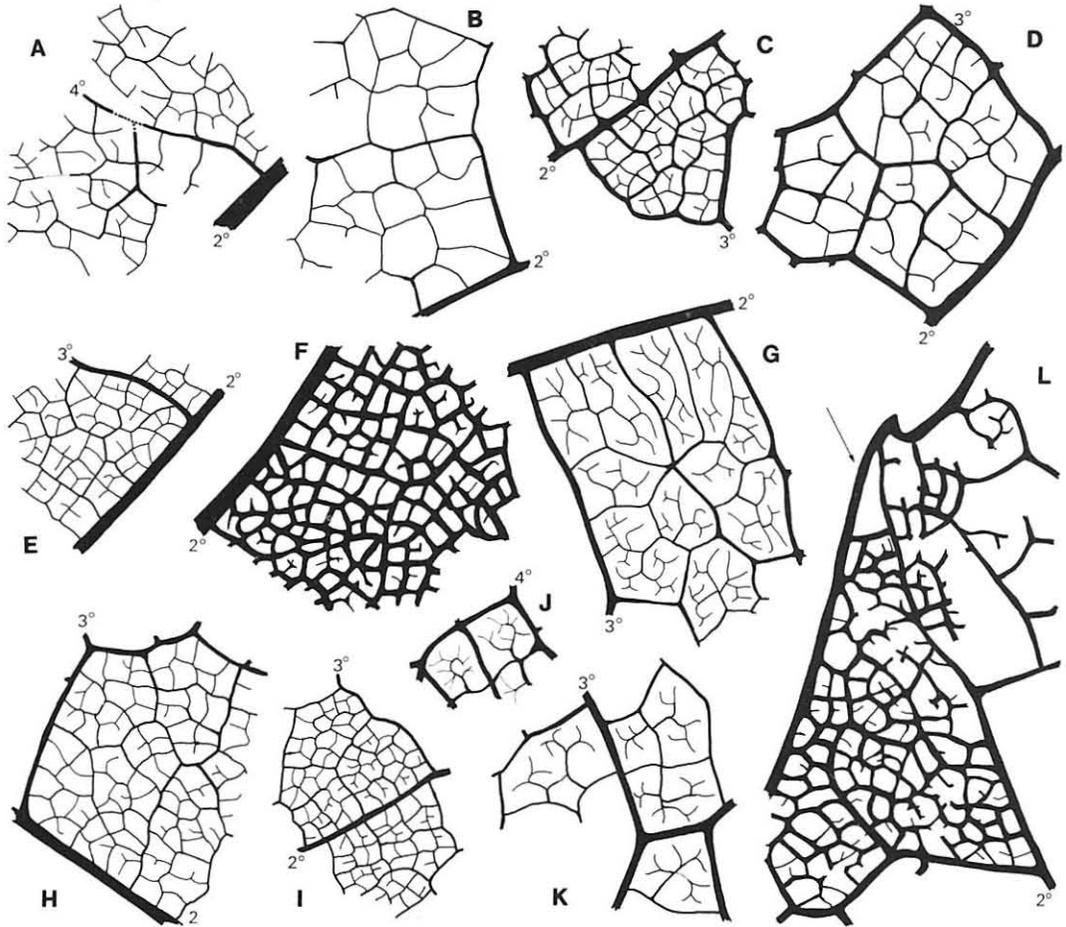
Acer subpictum auct. non Saporta. Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 128. pl. 106. f. 1 (only).

Kalopanax acerifolium (Nath.) auct. non Hu et Chaney. Acad. Sinica. 1978 (part). ditto. p. 137. pl. 124. f. 1; pl. 126. f. 1.

Type: Holotype, NIGP, Palaeobotany collection (Acad. Sinica, 1978: pl. 106, f. 1; Shanwang Group (Early-late Miocene); Shanwang, Shandong, China.

Description: Leaves five to seven lobed, cordate to broadly cordate at base, 8 to 12 cm (estimated) long and 8.5 to 12.5 cm (estimated) wide; length/width ratio 0.94 to 0.96; petiole stout, more than 3-6 cm long. Lobes oblong to obovate in general outline, separated by narrowly deep or broadly opened sinus; apex of each lobe attenuate with a long, caudate tip; margin of lobes irregularly dentate excepting the basal pair, usually with large teeth which are gently concave on the upper side and nearly straight or slightly convex on the lower side; the dentate teeth having long tip, one or two on each margin of lobes. Primary veins palmately 5 to 7 at the base, entering lobe apex; secondary veins distinct, more than 7 pairs, irregularly spaced, emerging from the primaries at angles of 45° to 55°, slightly curving upward, then ending in marginal dents or forming a large loop near the margin; intersecondary veins sometimes developing, slender, nearly parallel to the secondaries; the venation lower than the third order not well observed.

Discussion: A single leaf described as *Acer subpictum* Saporta from the Miocene Shanwang flora, is distinguishable from the *A. mono* group by the conspicuously dentate margin of lobes. Judging from the attenuate-tipped dentation, this Shanwang specimen closely resembles leaves of the extant *A. platanoides* Linne. of Europe and *A. truncatum* Bunge of northeast Asia, especially similar to the latter in the shape of central



Text-fig. 6. The Details of Venation Characters of Fossil *Acer* — (3) all figures $\times 15$.

- A. *Acer kushiroanum* Tanai. Holotype HUMP no. 25990 (pl. 11, f. 4)
 B. *Acer huziokae* Tanai. Holotype TPM-400 (pl. 11, f. 2)
 C. *Acer yamanae* Tanai et Ozaki. Holotype NSM-PP 16022 (pl. 12, f. 6)
 D. *Acer rotundatum* Huzioka. HUMP no. 25912 (N. Suzuki, 1963: pl. 5, f. 3)
 E. *Acer yamanae* Tanai et Ozaki. GSJ no. 4298 (Tanai, 1961: pl. 26, f. 6)
 F. *Acer prototrifidum* Tanai. IGPS no. 7725 (pl. 17, f. 1)
 G. *Acer subcarpinifolium* Tanai. HUMP no. 26340 (pl. 14, f. 3)
 H. *Acer subnikoense* Tanai et Ozaki. Holotype NSM-PP 16017 (pl. 17, f. 3)
 I. *Acer palaeodiabolicum* Endo. GSJ no. 4177 (pl. 13, f. 1)
 J. *Acer fatsiaefolium* Huzioka. Holotype HUMP no. 9342 (pl. 16, f. 6)
 K. *Acer grahamense* Knowlton et Cockerell. USNM 208475 (Wolfe & Tanai, 1980: pl. 19, f. 2)
 L. *Acer prototrifidum* Tanai. Neotype HUMP no. 26229 (pl. 15, f. 1). The arrow indicates the fimbrial vein along the margin.

lobe. The both sides of margin of central lobe are nearly parallel in *A. platanoides*, while they are apically opened in *A. truncatum* as done by this fossil specimen.

Two large leaves described as *Kalopanax acerifolium* (Nathorst) Hu & Chaney from the Miocene of Shanwang are included in *A. shanwangense* by the dentate margin and attenuate apex of lobes, although these two leaves are 7 lobed. The extant related species, *A. truncatum*, are usually 5 to 7 lobed.

Occurrence: Shanwang, Shandong, China.

Section Campestria Pax
Acer kushiroanum Tanai
(pl. 11, fig. 4, 5, 7)

Acer kushiroanum Tanai. 1970. J. Fac. Sci., Hokkaido Univ. [4]. 14 (4): 489. pl. 20. f. 1.

Type: Holotype, HUMP no. 25990; Yubetsu Formation (Early Oligocene); Nakanosawa, Yubetsu, Akan-cho, Hokkaido.

Supplementary Description: Samara large but unknown in general outline; outer margin of wing nearly straight, ending in the top of seed, while inner margin concave in the lower part, reaching near the contact scar; veins numerous, ramified more than three times, considerably curving inward; seed thick, depressed-orbulate, bulged outwardly, 8 mm long and 10 mm wide; contact scar distinct, 13 mm long; angles between contact scar of seed and outer margin of wing about 85°.

Discussion: This species was based on a single leaf from the Oligocene of eastern Hokkaido (Tanai, 1970), which was compared with the extant *Acer miyabei* Maxim. of Japan in its foliar shape and irregular dentation of lobe margin. I could recently confirm such modern relationships of *A. kushiroanum* by the fine venation: the areoles are medium-sized, quadrangular to pentagonal; the ultimate veinlets are lacking or single; venation is composed of fifth orders.

A. kushiroanum has been very few in the Paleogene of Hokkaido, although I have extensively collected many plant fossils. A single leaf illustrated as *A. shimokawarae* Huzioka (MS) from the Eocene of central Hokkaido (Huzioka & Kobayashi, 1961) is probably included in *A. kushiroanum* by its foliar shape and marginal character, but its fine venation is unfortunately not preserved. A single incomplete samara from the Eocene of central Hokkaido shows a close resemblance to that of the section Campestria as described in the above, and it may represent a samara of *A. kushiroanum*. *A. protomiyabei*, one of common Miocene maples, is closely similar to *A. kushiroanum* in general appearance, but is distinguishable by more irregularly large dents of lobe margin.

Occurrence and Collections: Yubetsu (HUMP no. 25990), Akan-cho, Hokkaido; Shimizusawa (HUMP no. 26228; AKMG-6254), Yubari, Hokkaido.

Acer protomiyabei Endo

(pl. 6, figs. 2, 3; pl. 7, fig. 4; pl. 8, figs. 1-3, 6)

- Acer protomiyabei* Endo. 1950. Short Papers IGPS (1): 15. pl. 3. f. 11.
 Huzioka & Nishida. 1960. Sado Mus. Publ. (3): 20. pl. 5. f. 9, 10.
- Acer ezoanum* auct. non Oishi et Huzioka. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 130. pl. 23. f. 6.
 Tanai. 1952. Jap. J. Geol. Geogr. 22: 130. pl. 4. f. 8.
 Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 556. pl. 1. f. 1, 2; pl. 2. f. 1, 2; pl. 3. f. 1-4; pl. 9. f. 20-25.
 Tanai. 1961. ditto. 11 (2): 356. pl. 26. f. 1, 2, 5.
 Tanai & N. Suzuki. 1963. Tertiary floras of Japan p. 137.
 Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 89. pl. 14. f. 6-9.
 Ishida. 1970. Mem. Fac. Sci., Kyoto Univ. [Geol. & Min.]. 37 (1): 95.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 63. pl. 8. f. 2.
 Tanai & N. Suzuki. 1972. J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 335. pl. 7. f. 1-5.
 Huzioka & Uemura. 1973 (part). Bull. Natl. Sci. Mus. 16 (4): 718. pl. 14. f. 8.
 Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. from Far East. p. 80. pl. 9. f. 12; text-f. 1-1.
 Wolfe & Tanai. 1980. U.S. Geol. Survey Prof. Paper 1105: 40. pl. 17. f. 1-3, 5; pl. 19. f. 2, 5.
- Acer miyabei* auct. non Maxim. Endo. 1950. Short Papers IGPS. (1): 13. pl. 3. f. 5, 8.
 Endo. 1951. ditto. (3): 52. pl. 8. f. 3.
- ? *Acer meisenene* Endo. 1950. Short Papers IGPS (1): 12. pl. 3. f. 4.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 64. pl. 8. f. 7.
- Acer fatsiaefolia* auct. non Huzioka. Tanai & N. Suzuki. 1960 (part). J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 559. pl. 7. f. 1, 2.
- Acer* cf. *ezoanum* Oishi et Huzioka. Huzioka & Nishida. 1960. Sado Mus. Publ. (3): 18. pl. 6. f. 3.
- Acer subpictum* auct. non Saporta. Acad. Sin. 1978 (part). Cenozoic plants of China. p. 128. pl. 101. f. 3.
- Acer* sp. Oishi & Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 98. pl. 10. f. 4; pl. 11. f. 6.
- Acer* sp. Huzioka. 1943. ditto. 7 (1): 136. pl. 23. f. 5; pl. 25. f. 4.

Type: Holotype, IGPS-60994; Tongencheon Formation (late-Early Miocene); Tongecheon, Kangweon-do, North Korea.

Emended Description: Leaves pentagonal in general outline, five-palmately lobed, variable but generally large in size, 6 to 11 cm long and 6 to 14 cm wide, length/width ratio 0.72 to 1.23; base broadly to deeply cordate; margin dentate. Middle and upper lateral lobes oblong in outline, abruptly acuminate at apex, sometimes with caudate tip, having 2 or 3 pairs of dentate teeth with acuminate tip on each side, of whose dents the lowest pair is larger and prominent but is often unequal-sized on both sides; basal pair of lobes acute to acuminate at apex, nearly entire at apical margin and coarsely serrate at basal margin. Primary veins stout nearly straight or slightly curving, emerging from the base and ending in lobe apex; secondary veins 5 to 7 pairs in each lobes, opposite to subopposite, diverging from the secondary at angles of 30° to 45°, nearly straight or gently curving up, some of them entering marginal dents, while some arising up along the margin to connect with superadjacent secondary; slender intersecondaries sometimes developing; tertiaries at intercostal area coarsely percurrent, often forking at the middle to form reticulum; quaternary and higher order veins forming polygonal networks; the highest order veins sixth; freely-ending veinlets mostly lacking and rarely single linear/or curved within four- or five-sided areoles. Petiole thick, incomplete but more than 3.5 cm long.

Samaras oblong in outline, sometimes slightly falcate, generally medium in size, 1.8

to 3.5 cm long an 0.7 to 1.1 cm wide, length/width ratio 2.8 to 3.4. Wing rounded at apex, straight to incurved at outer margin and nearly straight to gently convex at inner margin; veins numerous, dichotomizing more than three times, curving inward. Seed large in comparison with wing size, thick, orbiculate to depressed orbiculate, bulged outwardly beyond the width of wing, 0.7 to 1.2 cm in diameter; contact scar distinct, 6 to 10 mm long; angles between outer margin and contact scar 90° to 135° .

Discussion: A number of leaves and samaras from the Miocene of East Asia and Alaska which are similar to the extant *A. miyabei* and *A. campestre* L., have been referred to *A. ezoanum*. As already discussed in the earlier pages (section Rubra), all the original specimens of *A. ezoanum* are distinguishable from leaves of Campestria in having minute teeth on the basal side of dents, and they are transferred to section Rubra. However, most of other leaves and samaras which are reported as *A. ezoanum* are doubtlessly related to the section Campestria, especially to *A. miyabei*, although fossil leaves have usually acuminate dents at the lobe margin in comparison of the extant relative. The venation characters of fossil leaves, including the areolation and veinlets, are well consistent with those of *A. miyabei*, excepting that some leaves are sometimes smaller in areole size than the extant leaves.

The epithet "*protomiyabei*" has the nomenclatural priority for Miocene leaves and samaras which are related to the extant *A. miyabei*. My reinvestigation indicates all the specimens of the above synonymy are included in *A. protomiyabei*. Samaras of this species are readily distinguishable from any other fossil samaras by the characteristic features such as seed shape and divergent angles of wings. Compared with the common occurrence of samaras, leaves of the section Campestria have not been always common in the Tertiary of East Asia. This is mainly due to the fact that leaves of Campestria are sometimes indistinguishable from those of Saccharina and Macrophylla in incomplete or ill-preserved specimens. Actually leaves of *A. protomiyabei* are frequently difficult to distinguish superficially from those of *A. honshuense* and *A. fatsiaefolium* without examination of the fine venation. The latter two species belonging to Macrophylla have usually smaller areoles, within which the freely-ending veinlets are more than twice branching. Two leaves described as *A. fatsiaefolium* from the Miocene of Hokkaido (Tanai & N. Suzuki, 1960) are included in *A. protomiyabei* by their fine venation.

Leaves of *A. protomiyabei* having the acuminate dentate margin are sometimes difficult to separate from those of *A. saccharum* group such as *A. yamanae*. Although the fine venation is closely similar each other, *A. protomiyabei* is generally larger in areole size than *A. yamanae*. Another distinction is in the margin of basal part: *A. protomiyabei* is coarsely serrate in basal margin of the lowest lobes, while *A. yamanae* is entire. However, these distinctions may include any exceptions, and a further investigation needs to exclude leaves of Saccharina from *A. protomiyabei*.

Occurrence and Collections: Yoshioka (HUMP no. 25007-25020, 25022, 25023), Wakamatsu, Abura (HUMP no. 9633), Kudo (HUMP nos. 26114b, 26128, 26130-26132), Sakipenpetsu (HUMP no. 9332) and Kayanuma, Hokkaido; Miyata (AKMG-7413), Aniai (AKMG-3920, 3922, 3926b) and Iwadate, Akita Pref.; Aburdo (AKMG-5065), Yamagata Pref.; Seki (AKMG 3314-3316; IGPS-60991), Niigata

Pref.; Shichiku, Fukushima Pref.; Nenoshiroishi (IGPS-60510), Miyagi Pref.; Noroshi, Ishikawa Pref.; Hiyoshi (GSJ nos. 4296, 4297), Gifu Pref.; Yeonil and Keumkwandong, South Korea; Hamjindong (IGPS-60990; HUMP no. 9340), Tongcheon (IGPS-60994) and Yongdong (HUMP nos. 9320, 9349), North Korea; Shanwang, China; Buy (GIN-AN no. 3804/6), South Primorye.

Section *Saccharina* Pax
Acer pseudoginnala Tanai et Onoe
(pl. 5, figs. 5-7)

- Acer pseudoginnala* Tanai et Onoe. Geol. Surv. Jap. Bull. 10 (4): 22. pl. 6. f. 2.
Tanai & N. Suzuki. 1960 (part). J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 566. pl. 9. f. 14-16a, b.
Tanai. 1961. ditto. 11 (2): 365. pl. 26. f. 3.
Tanai & N. Suzuki. 1963. Tert. floras Japan. p. 140.
Huzioka. 1964. J. Min. Coll., Akita Univ. [A]. 3 (4): 93. pl. 15. f. 9.
Huzioka. 1972 (part). ditto. 5 (1): 66.
Tanai & N. Suzuki. 1972. J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 337. pl. 6. f. 14, 15.
Acer prototataricum Tanai et N. Suzuki. 1960 (part). ditto. 10 (3): 566. pl. 9. f. 12.
Acer yoshiokaense Tanai et N. Suzuki. 1960. ditto. 10 (3): 568. pl. 2. f. 5, 6.
Tanai & N. Suzuki. 1963. Tert. floras Japan. p. 142.
Tanai & N. Suzuki. 1972 (part). J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 338. pl. 6. f. 11, 12.
Acer protodistylum auct. non Endo. Tanai & N. Suzuki. 1960 (part). ditto. 10 (3): 564. pl. 9. f. 3.
Tanai. 1963. Tert. floras Japan. p. 141.
Tanai & N. Suzuki. 1972. J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 336. pl. 6. f. 8.
Acer miofranchetii auct. non Hu et Chaney. Acad. Sinica. 1978 (part). Cenozoic plants of China. p. 126.
pl. 112. f. 4.
Acer sp. Oishi & Huzioka 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 98. pl. 13. f. 5.

Type: Holotype, GSJ no. 4040; "Shichiku" Formation (Early Miocene); Shichiku, Iwaki City, Fukushima Prefecture.

Discussion: This species which is represented only by samaras, is characterized by the following features: seed part is large, compared with the wing; seed is thick and suborbiculate to wide ovate in shape; the wing is abruptly narrowed toward the seed part, often constricted near the seed; angles between the contact scar of seed and outer margin of wing are 10° to 22°. Although the original specimen was compared with the extant *Acer ginnala* Maxim., the above characters are indicative of the section *Saccharina* whose living species are confined to eastern North America. Although the specific taxonomy of the section *Saccharina* may be yet in controversy, this section contains 5 or 6 living species. Judging from the seed shape and divergent angles of two wings, *A. pseudoginnala* is closely related to *A. saccharum* Marsh. or *A. nigrum* Michx., especially to the former.

As listed in the above synonymy, many samaras reported under the various names from the Miocene of Japan, Korea and China are included in *A. pseudoginnala*. Despite of common occurrence of this species, there have been yet no leaves similar to the extant *A. saccharum* in the Tertiary of East Asia.

Occurrence and Collections: Yoshioka (HUMP nos. 25035, 25041, 25044-25046, 25056, 25057), Abura (HUMP no. 25040), Wakamatsu (HUMP nos. 25042, 25043, 27517, 27160, 27169), Kudo (HUMP nos. 27137, 27138), and Sakipenpetsu (HUMP no.

9333), Hokkaido; Shichiku (GSJ no. 4040), Fukushima Pref.; Aniai (AKMG-3894b), Akita Pref.; Shanwang, China; Paektodong (IGPS-92359), North Korea.

Acer yamaanae Tanai et Ozaki

(pl. 12, figs. 1-3, 6)

- Acer yamaanae* Tanai et Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 558. pl. 3. f. 1, 7-11; text-f. 5-F, G; text-f. 6-E, F.
- Acer miyabei* auct. non Maxim. Okutsu. 1940. Saito Ho-on Kai Mus. Res. Bull. (19): 162. pl. 8. f. 5, 6. Murai. 1958. Rept. Tech., Iwate Univ. 11: 18. pl. 1. f. 4. Murai. 1963. ditto. 16 (1): 107. pl. 15. f. 8.
- Acer palaeodiabolicum* auct. non Endo. Tanai & Onoe. 1959. Bull. Geol. Surv. Jap. 10 (4). pl. 6. f. 6. Tanai & Onoe. 1961 (part). Geol. Surv. Jap. Rept. (187): 48. pl. 15. f. 2, 4; pl. 16. f. 1; pl. 17. f. 1-3. Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 359. pl. 28. f. 5. Murai. 1963. Rept. Tech., Iwate Univ. 16 (1): 107. pl. 16. f. 6; pl. 17. f. 1.
- Acer pseudoginnala* auct. non Tanai et Onoe. Tanai & N. Suzuki. 1960 (part). J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 566. pl. 9. f. 13.
- Acer fatsiaefolium* auct. non Huzioka. Tanai. 1961. ditto. 11 (2): 357. pl. 26. f. 6.
- Acer diabolicum* auct. non Blume. Murai. 1963. Rept. Tech., Iwate Univ. 16 (1): 100. pl. 12. f. 7.
- Acer subpictum* auct. non Saporta. Tanai & N. Suzuki. 1972 (part). J. Fac. Sci., Hokkaido Univ. [4]. 15 (1-2): 337. pl. 7. f. 7, 8.
- Acer honshuence* Tanai et Ozaki. 1977 (part). ditto. 17 (4): 598. pl. 5. f. 7.
- Acer vassiljevii* Akhmetjev et Schmidt. 1979 (part). Palaeont. Stratigr. Far East. p. 105. pl. 13. f. 2, 4; text-f. 1-v, -g.
- Acer ezoanum* auct. non Oishi et Huzioka. Ina. 1981 (part). Monogr. Mizunami Mus. 2. pl. 29. f. 7; pl. 30. f. 1.
- Acer* sp. Huzioka. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 136. pl. 24. f. 6.
- Acer* sp. Akhmetjev. 1973. Acad. Sci. USSR Geol. Inst. Trans. 247: 75. pl. 19. f. 6.
- Acer* sp. Hori. 1976. Fossil plants from Kobe. p. 132. pl. 13. f. 4; text-f. 134. 135.
- Acer* sp. Ina. 1977. Geol. & Palaeont. Kani Town. p. 86. pl. V-24. f. 3.
- Acer* sp. Ina. 1981. Monogr. Mizunami Mus. 2. pl. 29. f. 3.

Type: Holotype, NSM-PP 16022; Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Prefecture.

Discussion: This species is represented by both leaves and samaras, which are related to those of the section *Saccharina*. As already discussed by Tanai and Ozaki (1977), these five-lobed leaves with attenuate, long tips are characterized by the following features: the irregularly undulate margin, often with obtuse, large dents; the deeply cordate base; the comparatively small, four-sided areoles within which the freely-ending veinlets are mostly lacking or rarely single. The samaras have thick, globular seeds, and the angles between the contact scar of seeds and outer margin of wing are 30° to 45°. Of the extant species of the section *Saccharina*, *A. yamaanae* is closely similar to *A. nigrum* Michx., *A. leucoderme* Small and *A. barbatum* Michx., judging the above-noted characters of leaves and samaras.

Leaves of this species are somewhat variable in margin, from irregularly undulate to obtusely dentate, as in leaves of the related extant species, but are distinguishable from those of the extant *A. saccharum* Marsh. that is more conspicuously dentate with acuminate tips in margin. Samaras of *A. yamaanae* are also separable from those of *A. saccharum* by globose seeds and wider divergent angles of two wings.

The fossil leaves and samaras described in the above list are included in *A.*

yamanae. Two leaves of *A. vassiljevii* from southern Primorye are unseparable from *A. yamanae* in foliar shape and margin. Although these leaves were illustrated as trilobed (Akhmetjev et al., text-fig. 1-v, -g), they seem to have a pair of small lobes or larger dents as in the holotype (Tanai & Ozaki, 1977: pl. 3. fig. 8). Leaves of the extant relatives, *A. nigrum* and *A. barbatum*, are also variable from 3 to 5 in lobation.

Occurrence and Collections: Wakamatsu (HUMP no. 25042) and Kudo (HUMP nos. 27134, 27135), Hokkaido; Gomyojin (IAGI nos. 61020, 61023) and Gosho (IAGI nos. 61090, 61095), Iwate Pref.; Nenoshiroishi (IGPS-60510), Miyagi Pref.; Shichiku (GSJ. no. 4054), Fukushima Pref.; Motojuku (RSG no. 1234), Gunma Pref.; Hiramaki and Hiyoshi (GSJ no. 4298), Gifu Pref.; Tatsumitoge (NSM-PP 16022, 16081, 16202, 16216; GSJ nos. 4800b, 4827, TPM-457), Onbara and Mitoku (GSJ nos. 4175-4180), Tottori Pref.; Hamjindong (HUMP no. 9324), North Korea; Botchi and Uglovoe, Shikhote-Alin.

Section Oblonga (Hu et Cheng) Delendick

Acer prototrifidum Tanai

(pl. 15, figs. 1-8; pl. 17, fig. 1)

- Acer prototrifidum* Tanai. 1952. Trans. Proc. Palaeont. Soc. Japan. N.S. (8): 234. pl. 22. f. 13.
 Tanai. 1961. J. Fac. Sci., Hokkaido Univ. [4]. 11 (2): 364. pl. 25. f. 2.
 Hojo. 1971. Prof. Matsushita Mem. vol. p. 152. pl. 11. f. 2-5; pl. 12. f. 1, 2.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 66.
 ? Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 90. pl. 10. f. 10; text-f. 1-13.
Acer pictum auct. non Thunb. Takahashi. 1954. Mem. Fac. Sci., Kyushu Univ. [D]. 5 (1): 60. pl. 7. f. 3, 4a-b.
Acer florinii auct. non Hu et Chaney. Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 560. pl. 5. f. 3.
 Tanai & N. Suzuki. 1963. Tertiary floras of Japan. p. 138.
 Hojo. 1971. Prof. Matsushita Mem. vol. p. 152. pl. 10. f. 1-5; pl. 11. f. 1; pl. 12. f. 4.
 Huzioka. 1974. J. Min. Coll., Akit Univ. [A]. 5 (2): 103. pl. 5. f. 8.
 Hayashi. 1975 (part). Fossils from Iki Isl. p. 26. pl. 18. f. 11; pl. 20. f. 6, 7; pl. 21. f. 6.
 Acad. Sin. 1978 (part). Cenozoic Plants of China. 125. pl. 105. f. 1; pl. 113. f. 4; pl. 115. f. 6.
Acer cf. *parviflorum* auct. non F. & S. Takahashi. 1954. Mem. Fac. Sci., Kyushu Univ. [D]. 5 (1): 51. pl. 7. f. 1a-b.
Acer trilobatum (Sternb.) auct. non Al. Braun. Hojo. 1971. Prof. Matsushita Mem. vol. p. 153. pl. 12. f. 3, 5.
 Hayashi. 1974 (part). Fossils from Iki Isl. p. 26. pl. 19. f. 5; pl. 20. f. 1, 2, 4; pl. 21. f. 1.
Acer nordenskiöldi auct. non Nathorst. Hayashi. 1975 (part). ditto. p. 26. pl. 18. f. 2; pl. 19. f. 9; pl. 21. f. 9.
Acer miofranchetii auct. non Hu et Chaney. Acad. Sin. 1978 (part). Cenozoic Plants of China. p. 126. pl. 109. f. 1.
Acer sp. Hori. 1976. Fossil plants from Kobe. p. 133. text-f. 132, 133.
Acer sp. Ina. 1977. Geol. Paleont. Kani Town. p. 84. pl. V-22. f. 6.
Acer sp. Ina. 1981. Monogr. Mizunami Mus. 2. pl. 28. f. 3.

Type: Holotype, Paleobotany collection of the University of Tokyo (Tanai, 1952: pl. 22, f. 13); Yeonil Group (late-Early Miocene); Yeonil, Kyongsang-bukdo, South Korea. (This type specimen was lost). Neotype, HUMP no. 26229; "Wakamatsu" Formation (late-Early Miocene); Chojabaru, Tagawa-cho, Iki Isl, Nagasaki Prefecture.

Supplementary Description: Leaves palmately trilobed, much variable in general outline and margin; length 2.6 to 9 cm, width 3.6 to 10.5 cm, length/width ratio 0.72 to 1.04 (mostly about 0.9); base broadly obtuse to nearly truncate, rarely broadly cordate; margin variable from quite entire to remotely serrate with minute teeth. Lobes trigonal to narrowly trigonal, separated by broadly opened sinus; central lobe nearly same as or somewhat larger than the laterals; apex of each lobe attenuate, often with long, caudate tip. Primary veins three, stout, radiating from the base, nearly straight, entering the apex; secondary veins distinct, more than 7 pairs, opposite to subopposite, diverging from the primaries at about 60°, curving up near the margin; in the toothed leaves the secondaries ending directly in the teeth or forking near the margin, and one entering teeth and another one joining superadjacent secondary; in the entire-margined leaves the secondaries forming large loops just near the margin; intersecondary veins often developing, nearly parallel to the secondaries; tertiaries moderate thick, emerging from the secondaries at various angles, random reticulate and merging with the irregularly reticulate venation of higher order; higher order venation relatively thick, forming a reticulum; highest venation order fifth; freely-ending veinlets lacking or single within quadrangular areoles; ultimate marginal venation hemmed by a thick fimbrial vein. Petiole thick, more than 2.4 to 3.2 cm long, although the specimens are incomplete. Texture firm.

Samara small, 14 to 18 mm long and 4 to 4.5 mm wide; length/width ratio 3.2 to 4. Wing oblanceolate in general outline, rounded at the apex; outer margin nearly straight, inner margin convex; veins numerous, curving inward conspicuously, forking about three times. Seeds ovate, thick, 3 mm wide and 4-5 mm long; contact scar of seeds 2.5 to 4 mm long; angles between outer margin and contact scar 30° to 40°.

Discussion: The trilobed leaves described under the names of *Acer florinii* Hu et Chaney or *A. prototrifidum* Tanai from the Tertiary of East Asia, are a complex of leaf architectural types that could not have occurred within a species. These leaves are very variable in shape and marginal characters. So far as reinvestigated these specimens, some of the serrate-margined leaves are transferred to the genus *Liquidambar* by the glandular toothed margin as discussed later. The remaining leaves referable to *Acer*, are classified into two types: leaves of one type are characterized by thick venation of higher order, the distinct fimbrial vein along the margin and the smaller areoles intruded mostly by single veinlets, although they are entire or toothed on margin; those of another type are usually entire on the margin with no fimbrial vein, generally thin in higher order venation and comparatively larger in the areoles that are intruded by once branching veinlets. These venation characters reveal that the former type is close to leaves of the extant *A. buergerianum* Miq. and *A. paxi* Franch., and the latter type is similar to trilobed leaves of the extant *A. mono* Maxim.

The epithet "*florinii*" has a nomenclature priority for the fossil trilobed maple leaves, if the Shanwang specimens have distinct fimbrial vein along the margin. However, according to the personal communication from Dr. Guo Shuang-xing of Nanking Institute of Geology and Palaeontology, the original specimens from Shanwang are not clear in such vein, due to the ill-preservation. On the one hand, a single

type specimen of *A. prototrifidum* from Yeonil of Korea is doubtlessly related to the section *Oblonga*, but it was unfortunately lost in the Museum of the University of Tokyo. Thus, a neotype for *A. prototrifidum* is here chosen from the well-preserved leaf and samara specimens which were commonly found in the Miocene of Iki Island, Kyushu.

Leaves of the extant *A. buergerianum* are variable in the foliar shape, lobe and margin: leaves of the old or fully matured trees are mostly shallowly trilobed with entire margin and obtuse lobe apex, while those of young trees have usually toothed-margined lobes with somewhat long tip. Leaves of *A. prototrifidum* redesignated here match well the above-noted variation of the extant species, but are markedly distinguishable in longer caudate tips of lobes and the averaged larger size.

The trilobed leaves of *A. trilobatum* (Sternb.) A1. Braun are sometimes similar to the toothed leaves of *A. prototrifidum* in general appearance as misidentified by some authors, but are distinguishable by no presence of a fimbrial vein, larger double-serrate teeth and thin reticulate venation. *A. prototrifidum* belonging to the sect. *Oblonga*, is confined to East Asia as well as the extant three species.

Occurrence and Collections: Yoshioka (HUMP no. 25026), Hokkaido; Noroshi, Ishikawa Pref.; Hiramaki, Gifu Pref.; Yamane (AKMG-8118), Tateishi (AKMG-8096), Yamaguchi Pref.; Mogi (IGPS-7725), Chojabaru (HUMP nos. 26229-26233), Iki Isl., and Oya, Nagasaki Pref.; Yeonil, Pohang, South Korea; Tongcheon, (IGPS-92363), Kungshim (IGPS-92362), North Korea; Shanwang, (Nat. Geol. Surv. China, nos. 28, 29), Shandong, China; Dembi (GIN-AN no. 3803/827), Sikhote-Alin.

Section *Trifoliata* Pax
Acer subnikoense Tanai et Ozaki
(pl. 17, fig. 3)

Acer subnikoense Tanai et Ozaki. 1977. J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 594. pl. 4. f. 1, 2, 4-7; text-f. 6-c.

? *Acer subpictum* auct. non Saporta. Ina. 1981 (part). Monogr. Mizunami Mus. 2. pl. 29. f. 5.

Type: Holotype, NSM-PP 16017; Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Prefecture.

Discussion: This species is represented by the trifoliate leaves and detached leaflets. Excepting for its more distinct dentation of margin and short-petiolule of lateral leaflets, these specimens closely coincide with those of the extant *A. nikoense* Maxim. of Japan in the foliar shape and venation. The freely-ending veinlets are lacking or rarely single within the four- to five-sided areoles as in the extant analogue.

A. subnikoense resembles *A. protonegundo* in general appearance, but is distinguishable by obtuse or rather rounded tip of marginal teeth and no branching veinlets. Although the extant *A. nikoense* is peculiar in seed character, no fossil samaras referable to *A. subnikoense* have been yet known up to the present.

Occurrence and Collections: Tatsumitoge (NSM-PP 16007, 16012, 16015, 16017; GSJ no. 4796; TPM-487), Tottori Pref.

Acer trifoliatum Geng

(pl. 17, fig. 4)

- Acer trifoliatum* Geng. Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 129. pl. 105. f. 5; pl. 110. f. 1; pl. 111. f. 6; pl. 112. f. 5; pl. 113. f. 1; text-f. 64.
 ? *Acer* sp. Akhmetjev. 1973. Acad. Sci. USSR Geol. Inst. Trans. 247: 75. p. 21. f. 6; pl. 25. f. 6.
 ? *Acer* sp. cf. *A. mandshuricum* Maxim. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 99. pl. 1. f. 6; text-f. 1-19.

Type: Lectotype, Palaeobotany Collection, Institute of Botany, Academia Sinica (Acad. Sin., 1978: pl. 112. f. 5); Shanwang Group (late-Early Miocene); Shanwang, Shandong, China.

Discussion: The trifoliate leaves and detached leaflets from the Shanwang flora doubtlessly resemble those of the section Trifoliata in general outline and gross venation feature. These leaflets are characterized by several features: the margin is coarsely serrate with acute teeth that are variable from minute to large; the base is cuneate to obliquely rounded; the apex is acute to acuminate; lateral leaflets have a short petiolule. Judging from these characters, *A. trifoliatum* is most closely related to the extant *A. triflorum* Komarov living in northeast China and Korea as described by Geng. The extant *A. mandshuricum* Maxim. of northern China is also similar to this fossil species, but it is distinguishable by the sessile character of lateral leaflets.

A single samara illustrated as *A. trifoliatum* from Shanwang (Acad. Sinica, 1978: pl. 102, f. 5) seems to be different from those of *A. trifoliatum* in wing shape and seed character, and it is doubtful to be included in *A. trifoliatum*. *A. trifloriformis* described from the Miocene of Sikhote-Alin (Akhmetjev, 1973) is similar to big-toothed leaflets of *A. trifoliatum*, and the epithet "*trifloriformis*" may have a priority for the fossil leaflets similar to the extant *A. triflorum*. I prefer, however, to use the epithet "*trifoliatum*" in order to avoid future confusion, because a single leaflet of Sikhote-Alin lacks the lower half of its blade. *A. trifoliatum* resembles at a glance *A. subnikoense* described in the preceding page, but it is easily distinguishable by acute toothed margin. Some samara specimens from Primorye (Akhmetjev, 1973 and others) are close to those of Trifoliata in thick seed, distinct contact scar and divergent angles of wings, and they may be included in *A. trifoliatum*.

Occurrence: Shanwang, Shandong, China.

Section Lithocarpa Pax

Acer miofranchetii Hu et Chaney

(pl. 13, fig. 2)

- Acer miofranchetii* Hu et Chaney. 1938 (part). Palaeont. Sinica. new ser. A. (1): 58. pl. 33. f. 3b.
 Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 126. pl. 104. f. 2, 4; pl. 107. f. 5.
Acer diabolicum auct. non Blume. Acad. Sinica. 1978. ditto. p. 124. pl. 99. f. 1, 6; pl. 105. f. 4; pl. 107. f. 6; pl. 108. f. 5; pl. 109. f. 3.
Acer miohenryi auct. non Hu et Chaney. Acad. Sinica. 1978 (part). ditto. p. 127. pl. 100. f. 3.

Type: Holotype, Nat. Geol. Surv. China no. 183b: Shanwang Group (late-Early Miocene); Shanwang, Shandong, China.

Discussion: Of three specimens that were originally described by Hu and Chaney (1938), two leaves are transferred to *Liquidambar*, but a remaining samara is doubtlessly related to that of the section *Lithocarpa* in the following features: subglobular seed; contact scar of seed distinct and long; longitudinal axis of seed nearly perpendicular to the outer margin of wing; angle between the outer margin of wing and contact scar very narrow (about 12°). Furthermore, the seed is markedly exposed out of wing which is considerably contracted toward the seed. These features indicate that *A. miofranchetii* is more closely related to the extant *A. franchetii* Pax of central China than *A. diabolicum* Bl. of Japan.

Six leaves described as *A. diabolicum* from Shanwang (Acad. Sinica, 1978) are rather more similar to *A. franchetii* in shape of central lobe, and they are included in *A. miofranchetii*. The central lobe of these fossil leaves are deltoid in shape as in *A. franchetii*, while it is oblong or elliptic in *A. diabolicum*. *A. miofranchetii* is closely similar to *A. palaeodiabolicum* in general appearance, but is distinguishable in the above-described characters of samara and leaf. A single samara described as *A. miohenryi* from Shangwang (Acad. Sinica, 1978) is identical with *A. miofranchetii* in its seed character.

Occurrence and Collection: Shanwang, Shandong, China.

Acer palaeodiabolicum Endo

(pl. 13, fig.s 1, 4-7)

- Acer palaeodiabolicum* Endo 1950. Short Papers IGPS. (1): 161. pl. 13. f. 4.
 Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 562
 Tanai & Onoe. 1961 (part). Geol. Surv. Jap. Rept. (187): 48. pl. 16. f. 1; pl. 17. f. 4.
 Suzuki, N. 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 687. pl. 2. f. 1.
 Tanai & N. Suzuki. 1963. Tert. floras Japan p. 140.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 65. pl. 8. f. 8, 8a.
 Huzioka & Uemura. 1973. Bull. Natl. Sci. Mus. 16 (4): 719. pl. 14. f. 2-6.
 Huzioka & Uemura. 1974. ditto. 17 (4): 353. pl. 8. f. 7.
 Hayashi. 1975. Fossils Iki Isl. p. 26.
Acer diabolicum auct. non Bl. Okutsu. 1940. Saito Ho-on Kai Mus. Res. Bull. (19): 161. pl. 7. f. 7.
Acer pseudoginnala auct. non Tanai et Onoe. N. Suzuki. 1963. J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 689. pl. 3. f. 4.
 Tanai & N. Suzuki. 1965. Palaeont. Soc. Jap. Spec. Pap. (10): 38. pl. 10. f. 9.
Acer trilobatum auct. non (Sternb.) Al. Br. Hayashi. 1975 (part). Fossils Iki Isl. p. 26. pl. 19. f. 2-4, 6, 7.
 ? *Acer protodiabolicum* K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 82. pl. 17. f. 9.

Type: Holotype, IGPS no. 60989; Hamjindong Formation (late-Early Miocene); Kilju, Hamg'yeong-bukudo, North Korea.

Emended Description: Leaves pentagonal in outline, five palmately lobed, narrowly to broadly cordate at base, 8.3 to 11 cm long and 8.5 to 13.4 cm wide; the height longer than the width in most case; petiole thick, more than 9 cm long. Lobes shallowly dissected by acute sinus; lateral lobes of an upper pair usually inequilateral, larger in ex-medial side; the basal pair smaller than others, often inconspicuous; margin of lobes irregularly dentate with 2 or 3 obtusely pointed tips, of whose dents the lowest is especially large. Primary veins palmately 5 at the base, stout, entering the lobe apex;

secondary veins distinct, 5 to 7 pairs, irregularly spaced, emerging from the primaries at acute angles, gently curving up, then ending in marginal dents of forming large loops near the margin; slender intersecondary veins sometimes developing; the tertiaries at intercostal areas conspicuous, rather thick, emerging from the both sides of the secondaries at acute angles, irregularly percurrent; quaternary and higher order venation forming a reticulum; highest order venation sixth; freely-ending veinlets mostly single or once branching; areolation medium in size, quadrangular to pentagonal.

Samaras oblanceolate in general outline, 29 to 41 mm long and 8 to 12 mm wide; length/width ratio 2.6 to 4.4. Wing rounded at apex, gradually narrowed toward base; outer margin nearly straight; inner margin gently convex, ending in the upper part of seed. Seed thick, globular to subglobular in shape, irregularly sutured and often hairy on surface; length 5 to 10.6 mm and width 5 to 7.5 mm, length/width ratio 1.1. to 1.7; contact scar distinct, 7.5 to 11 mm long; angles between the outer margin of wing and contact line of seeds 8° to 17° ; style persisted as a spine on the upper-dorsal corner of seed.

Discussion: This species was first based on a single samara from the Miocene of North Korea (Endo, 1950), which is similar to that of the extant *Acer diabolicum* Blume living in Japan. Later *A. palaeodiabolicum* was supplemented by leaves from the Neogene of Honshu and Hokkaido (Tanai & Onoe, 1961; N. Suzuki, 1963), while several leaves similar to the extant relative were described as *A. diabolicum*, *A. proto-diabolicum* or others from the Neogene of northeastern Honshu (Okutsu, 1940; K. Suzuki, 1961 and others). However, these fossil leaves sometimes included those unrelated to *A. diabolicum*, because the comparison was based on only the gross features. In actual, it is often difficult to distinguish these five-lobed leaves with coarsely dentate margin without checking the fine venation.

As far as determined by my reinvestigation, all the leaves and samaras described in the above synonymy are included in *A. palaeodiabolicum* which is here redesignated. Leaves of *A. palaeodiabolicum* are especially characterized by the following features: marginal dentation of each lobe is less conspicuous with obtuse dents; the lateral lobes of an upper pair are markedly inequilateral; the tertiary veins are prominently developed, and irregularly percurrent; the ultimate veinlets are single or once branching. Samaras are characterized by globose seeds with irregular suture and very acute extension angles of wings. It is interesting to find firm hairs on the seed surface and a persisted style at the upper dorsal side of seed in the well-preserved specimens. These characters of leaves and samaras well coincide with those of the extant *A. diabolicum* Blume of Japan and also of *A. franchetii* Pax of central China. However, *A. palaeodiabolicum* is distinguishable from these two extant species by the facts that each lobe apex is generally more longer with caudate tip, and that the seeds are often subglobular on the average.

A. palaeodiabolicum is known from the Neogene of Japan and Korea, especially common from the Upper Miocene and Pliocene of Japan. It is noteworthy that this species has not been yet recorded in Primorye, Sakhalin and Kamchatka.

Occurrence and Collections: Yoshioka (HUMP nos. 25031, 25032), Abura, Wakamatsu

and Rubeshibe (HUMP nos. 25895-25897, 25908), Hokkaido; Miyata (AKMG-7252, 7410) and Sanzugawa (NSM-PP 15315), Akita Pref.; Nenoshiroishi (IGPS-60508), Miyagi Pref.; Fujitoge (IGF-5190), Fukushima Pref.; Omi, Nagano Pref.; Mitoku (GSJ no. 4188), Tottori Pref.; Onbara (GSJ nos. 4177, 4181), Okayama Pref.; Hiramaki, Gifu Pref.; Chojabaru (HUMP nos. 26334, 26335), Iki, Nagasaki Pref.; Kilyu (IGPS-60989), North Korea.

Section Macrophylla (Pojark.) Momotani

Acer fatsiaefolium Huzioka

(pl. 16, figs. 1, 2, 5, 6)

- Acer fatsiaefolium* Huzioka. 1934. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 131. pl. 23. f. 1.
 Tanai & N. Suzuki. 1960 (part). ditto. 10 (3): 559. PL. 6. f. 1.
 Tanai & N. Suzuki. 1963. Tertiary floras Japan. p. 138.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 63.
 Huzioka. 1974. ditto. 5 (2): 103. pl. 5. f. 1.
Acer kokangenense Endo. 1950. Short Papers IGPS (1): 14. pl. 3. f. 10.
 Huzioka. 1972. J. Min. Coll., Akita Univ. [A]. 5 (1): 63. pl. 8. f. 3.
Acer cf. *miofranchetii* auct. non Hu et Chaney. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East p. 98. pl. 10. f. 7; text-f. 1-26.

Type: Holotype, HUMP no. 9342; Changgi Group (Early Miocene); Keumkwandong, Yeong'il, Kyongsang-bukdo, South Korea.

Discussion: This species was originally based on a large, five-lobed leaf with dentate margin from the Miocene of South Korea. Thereafter several leaf specimens from Sakhalin, Hokkaido and Honshu were referred to this species by several authors. These leaves closely resemble superficially those of *A. protomiyabei* which is common in the Miocene of East Asia. Compared with *A. protomiyabei*, typical leaves of *A. fatsiaefolium* are narrowly elongate in each lobe dissected by deeper sinus, and are dentate with more sharply pointed teeth which are apically directed. That such distinction is not always clear between these two species, sometimes resulted in their misidentification.

In general appearance leaves of *A. fatsiaefolium* are similar to some types of leaves of the extant *A. miyabei* Maxim, *A. saccharum* Marsh. and *A. macrophyllum* Pursh; these three extant species belong to different sections respectively. The holotype specimen is unfortunately ill-preserved in the fine venation; as far as determined, its leaf is imperfect in areolar development, and the freely-ending veinlets are thin and irregularly ramified more than two or three times. Considering these fine venation characters together with the foliar shape, *A. fatsiaefolium* is doubtlessly related to *A. macrophyllum*, although its marginal teeth are acute and more pointed than those of the living species. The leaves which are listed above as *A. fatsiaefolium* from Hokkaido and western Honshu, are not unfortunately preserved in the fine venation; but they are closely similar to the type specimen in their foliar shape and marginal dentation, and are probably included in *A. fatsiaefolium*. On the one hand, a single leaf described as *A. fatsiaefolium* from the Miocene of central Honshu (Tanai, 1961: pl. 26, fig. 6) shows well-developed areolation within which the veinlets are lacking or single, and it is

transferred to *A. yamanae*. It may be in most case difficult to separate *A. fatsiaefolium* from other species having five-lobed leaves with dentate margin, without checking the fine venation.

A single samara which was described as *A. kokangense* from the Tertiary of North Korea (Endo, 1950) has remained uncertain in its modern relationship because of the poor illustration of the original specimen. My recent reinvestigation of the original specimen and its counterpart reveals that they are closely related to the extant *A. macrophyllum* in the following features: the base of samara is acute and pointed; the seed is rather thick and semicircular in shape as being truncately cut; the contact scar of seeds are long with about 1 cm; the angle between the contact line and the outer margin is rather narrow (26°). No fossil samaras identical to *A. kokangense* have been known from Japan, but a single samara which was described as *A. cf. franchetii* from Primorye (Akhmetjev et al., 1976) is referable to *A. kokangense* in its seed characters.

Although *A. fatsiaefolium* and *A. kokangense* have not yet been found in a same locality, these two species are closely related to the leaf or samara of the extant *A. macrophyllum*. Accordingly, I prefer to include *A. kokangense* in *A. fatsiaefolium*, representing the samara of the latter species.

A. fatsiaefolium redesignated here is the first record of a Tertiary maple from East Asia most closely similar to North American *A. macrophyllum*. *A. fatsiaefolium* is closely similar in the both features of leaf and samara to *A. oregonianum* Knowlton, which is one of the common maples through the Tertiary of western North America. A further study may show that *A. fatsiaefolium* should be combined with *A. oregonianum*, when more specimens with well-preservation will be collected in East Asia.

Occurrence and Collections: Yoshioka (HUMP no. 25021), Hokkaido; Daibo (AKMG-5911), Yamaguchi Pref.; Keumkwandong (HUMP no. 9342; IGPS-30990), South Korea; Kogeonweon (IGPS-60993a, b), North Korea; Buy (GIN AN no. 3804/72a), Dembi and Rettikhovskae, Primorye.

Acer grahamense Knowlton et Cockerell

(pl. 14, fig. 6)

Acer grahamense Knowlton et Cockerell. 1919. U.S. Geol. Survey Bull. 696: 50.

Acer palaeoplatanoides auct. non Endo. Tanai & Onoe. 1959 (part). Geol. Surv. Jap. Bull. 19 (14): 21. pl. 6. f. 3..

Huzioka. 1964 (part). J. Min. Coll., Akita Univ. [A]. 3 (4): 91. pl. 15. f. 4.

Acer megasamarum Tanai et N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 560. pl. 5. f. 1, 2.

Tanai. 1961. ditto. 11 (2): 358. pl. 29. f. 3.

Tanai & N. Suzuki. 1963. Tert. floras Japan. p. 139.

Acer meisenense auct. non Endo. Tanai & N. Suzuki. 1960. J. Fac. Sci., Hokkaido Univ. [4]. 10 (3): 561. pl. 9, f. 1, 2.

Acer prototataricum Tanai et N. Suzuki. 1960 (part). ditto. 10 (3): 566. pl. 9. f. 7.

Tanai & N. Suzuki. 1963. Tert. floras Japan. p. 140.

Acer grandisamarum Huzioka et Nishida. 1960 (part). Sado Mus. Publ. (3): 19. pl. 6. f. 5.

Acer oknensis Chelebaeva. 1978. Miocene floras of E. Kamchatka. p. 82. pl. 19. f. 5; text-f. 30-1.

Acer sp. cf. *A. osmontii* auct. non Knowlton. Kryshtofovich. 1934. Trans. Far East Geol. Prosp. Trust. 62: 19. pl. 5. f. 27.

Acer sp. Huzioka. 1963. Tert. floras Japan. p. 209. pl. 37. f. 3.

Type: Lectotype, Collection of Swedish Museum of Natural History (Heer, 1869: pl. 9, f. 8); Tyonek Formation (late-Early Miocene); Seldovia Point, Kenai Peninsula, Alaska, U.S.A.

Discussion: Although this species was originally based on the incomplete specimens, the specific characters were recently supplemented on the basis of better specimens from the original locality of Alaska (Wolfe & Tanai, 1980). This species is especially characterized by large samaras with globose to suborbiculate seeds, which are considerably swelling outwardly from the width of wing. The angles between the contact scar of seeds and outer margin of wing are from 26° to 35° in the Alaskan specimens.

All the large samaras of the East Asian Tertiary described in the above list are identical with *Acer grahamense* in the seed characters, although they are slightly wider in the divergent angles of wings than the North American specimens. An incomplete large leaf from the Miocene Utto flora (Huzioka, 1963) is included in *A. grahamense* by its foliar shape, lobation, more than once branching veinlets and smaller areolation as far as reinvestigated by me. A large leaf of *A. oknensis* from Kamchatka is probably conspecific with *A. grahamense* in its similar foliar shape and marginal dentation, although the fine venation needs to be studied. As already discussed by Wolfe & Tanai (1980), *A. grahamense* is related to the extant *A. macrophyllum* Pursh living in western North America.

Occurrence and Collections: Korf Bay, Kamchatka; Yoshioka (HUMP no. 25040) and Abura (HUMP nos. 25029, 25039), Hokkaido; Shichiku (GSJ no. 4037), Fukushima Pref.; Seki (AKMG no. 3324), Niigata Pref.; Utto (AKMG-3140), Akita Pref.

Acer honshuense Tanai et Ozaki

(pl. 16, figs. 3, 4)

Acer honshuense Tanai et Ozaki. 1977 (part). J. Fac. Sci., Hokkaido Univ. [4]. 17 (4): 598. pl. 5. f. 5, 6, 8; text-f. 6-I.

? *Acer diabolicum* auct. non Blume. K. Suzuki. 1959. Mongr. Assoc. Geol. Collab. Japan. (9): 40. pl. 4. f. 7.

? *Acer ezoanum* auct. non Oishi et Huzioka. Murai. 1969. Tech. Rept., Iwate Univ. 4: 63. pl. 4. f. 2, 4. Hori. 1976. Fossil plants from Kobe. p. 131. text-f. 129.

Type: Holotype, TPM-382; Tatsumitoge Formation (Late Miocene); Tatsumitoge, Saji-mura, Tottori Prefecture.

Discussion: This species was recently established by a single leaf and several samaras from the Upper Miocene of western Honshu. This leaf is related to that of *Acer macrophyllum* Pursh. of western North America in its foliar shape and venation characters, especially in the areolation and veinlets. The samaras of *A. honshuense* are characterized by a compressed globular and hairy seed, and a distinct contact scar. Although *A. honshuense* is common in many characters of foliage and samara of *A. macrophyllum*, it is distinguishable by having long-caudate tip of lobe apex and dents, and also wider divergent angles of samara wings.

Of three samaras originally described, a single specimen (Tanai & Ozaki, 1977: pl. 5.

fig. 7) is transferred to *A. yamanae*, because its wing is considerably constricted in the lower part of the inner margin. *A. honshuense* has been rarely known in the Upper Miocene of Japan. Several leaves described as *A. diabolicum* (K. Suzuki, 1959) from the Upper Miocene of northern Honshu, closely resemble *A. honshuense* in foliar shape; they may be ascertained to be conspecific if the fine venation will be investigated. *A. honshuense* is closely similar to leaves and samaras of *A. grahamense* excepting for long-caudate tips of lobes, and it represents a descendant of *A. grahamense*.

Occurrence and Collections: Tatsumitoge (TPM-382, 486; NSM-PP 16215), Tottori Pref..

Section Indivisa Pax

Acer subcarpinifolium Tanai sp. nov.

(pl. 9, fig. 5b; pl. 12, figs. 4, 5; pl. 13, figs. 3, 8; pl. 14, figs. 1-5)

Acer pseudocarpinifolium auct. non Endo. N. Suzuki. 1963 (part). J. Fac. Sci., Hokkaido Univ. [4]. 11 (4): 689. pl. 3. f. 3.

Tanai & N. Suzuki. 1965. Palaeont. Soc. Jap. Spec. Paper. (10): 38. pl. 10. f. 8; pl. 11. f. 1.

? Ina. 1974. Bull. Mizunami Fossil Mus. (1): 346.

Guo. 1980. Acta Palaeont. Sin. 19 (5): 409. pl. 1. f. 3, 3a.

Type: Holotype, HUMP no. 26336; Paratype, HUMP no. 26342; Ote Formation (Late Miocene); South of Tamagawa, Bifuka-cho, Hokkaido. Paratype, HUMP no. 25909; Komatsuzawa Formation (Early Pliocene); Yongosen, Rubeshibe, Hokkaido.

Description: Leaves symmetrical, narrow elliptic to elliptic in general outline, 5.2 to 18 cm long and 2.6 to 9 cm wide; length/width ratio 1.6 to 2.2; apex long acuminate to attenuate; base acute to rounded, often slightly cordate. Margin double serrate, with acute or acuminate teeth; principal teeth having mostly smaller teeth on their both sides: in the upper part of blade one or two on the basal side and one on the apical, while in the middle and lower parts more than two on basal side and none on the apical; especially in the lower part, between the bigger principal teeth there are one to three large teeth accompanied by a single in many instances subsidiary tooth on basal side. Venation pinnate, simple craspedodromous; midvein stout, straight; secondary veins in 12 to 18 pairs, thick, opposite to subopposite, regularly spaced and parallel each other excepting for a basal pair, diverging at 40° to 45°, nearly straight or slightly curving upward; the lower secondaries provided with outer branches ending in subsidiary teeth; a pair of secondaries emerging at or just above the base, curving upward along the basal margin; tertiary veins originating at right angles on either side of the secondaries, irregularly percurrent, retroflexed in course, sometimes merging into the higher order reticulum, fourth- and fifth-order veins forming oblong-quadrangular areoles of irregular size; veinlets highly irregular in ramification, twice to several times branching with gradually thinning tips.

Samara large, oblanceolate in general outline, 4.4 to 5.8 cm long and 1.2 to 1.5 cm in the widest part of wing; length/width ratio 3.2 to 4.8. Wing gradually narrowed toward base, rounded at apex; outer margin nearly straight, inner margin broadly

convex; veins fine, numerous, dichotomizing more than three times, curving abruptly inwards, then nearly perpendicular to inner margin. Seeds narrow ovate, thin, 15 to 18 mm long and 6 to 8 mm wide; contact scar of seeds 3.5 to 5 mm long; angles between outer margin and contact scar of seeds somewhat variable, 30° to 40°.

Discussion: This new species is represented by well-preserved leaves and samaras from the Upper Tertiary of Hokkaido. These leaves resemble at a glance those of the Betulaceae, especially of *Carpinus* or *Ostrya*, but are distinctly distinguishable by the following features: the large oblong-guadrangular areoles of irregular size within which the freely-ending veinlets are irregularly ramified twice to several times, the characteristics of double serrate margin, and a pair of the slender basal secondaries extending along the basal margin. These features, especially fine venation, of fossil leaves match well with those of the extant *Acer carpinifolium* S. et Z. living in Japan, although the modern leaves are more acuminate with longer tips in the marginal teeth than are in the fossil leaves.

Many samaras were associated with leaves of *A. subcarpinifolium* from the same localities of north-central Hokkaido; these samaras are closely similar to those of the extant *A. carpinifolium* in general shape, narrow ovate and thin seeds and a distinct contact scar of seeds, although they are somewhat narrower in angles of two wings and bigger on the average.

There have been some confusions regarding the specific name for the Tertiary leaves and samaras that are closely similar to the extant *A. carpinifolium*. Most of these fossils have been referred to *A. pseudocarpinifolium*, which was originally described on the basis of samara (Endo, 1951). Judging from the original illustration, Tanai and Ozaki (1977) transferred the original specimen to the section *Cissifolia*, because the type specimen is narrower in angles of two wings and seed shape than the samaras of *A. carpinifolium*. However, the recent reinvestigation of Endo's type specimen reveals that it is rather similar to the samaras of the extant *A. rubrum* L. in seed shape and the coarsely anastomosing venation developing on the seed surface, and is referable to *A. tricuspdatum*.

Up to the present, the reliable occurrence of *A. subcarpinifolium* is confined to the Neogene of Hokkaido, however a cautious investigation would probably yield leaves and samaras of this species in Honshu and elsewhere in the future.

Occurrence and Collections: Rubeshibe (HUMP nos. 25909, 25910), Shanabuchi (HUMP no. 25766), Bifuka (HUMP nos. 26336-26342), Utanobori, Shibiutan and Honhorobetsu, Hokkaido; Zekog (NIGP-PB no. 6115), Qinghai, China.

Doubtful Species of *Acer*

The following species were described on the basis of the superficial resemblance to some leaves of the extant maples by some authors. However, I could find on definite characters in these specimens to be referable to or to be rejected from the genus *Acer*.

Acer kryshstofovichii Borsuk

Acer kryshstofovichii. 1956. Trans. All Union Prosp. Invest. n. ser. 12: 67. pl. 18. f. 1.

Discussion: This species was based on a single ovate leaf from the Paleogene of western coast of Sakhalin. It was compared with leaves of the extant *A. distylum* Sieb. et Zucc., but it appears to be rather similar to leaves of *A. davidii* Franch. in its termination feature of the secondary veins. However, this leaf specimen lacks a definite character assignable to *Acer*, and it needs to reinvestigate in detail.

Occurrence: Brodyazheskaya valley, Sakhalin.

Acer miohenryi Hu et Chaney

Acer miohenryi Hu et Chaney. 1938 (part). Palaeont. Sinica. [A]. (1): 59. pl. 33. f. 1.

Acad. Sinica. 1978 (part). Cenozoic Plants of China. p. 100. pl. 109. f. 4.

Discussion: Of five leaflets originally described as *A. miohenryi*, four specimens are transferred to other families. The remaining leaflet is doubtful whether or not it is related with the extant *A. henryi* Pax, because this leaflet is somewhat different in the marginal dentation.

Occurrence: Shanwang, China.

Acer pliocenicum Chaney

Acer pliocenicum Chaney. 1933. Bull. Geol. Soc. China. 12 (2): 135. pl. 1. f. 10, 11.

Guo. 1978. Acta Palaeont. Sin. 17 (3): 348. pl. 2. f. 4.

Discussion: These leaves from the Pliocene or Lower Pleistocene of central China are superficially similar to leaflets of *A. henryi* Pax as described by Chaney (1933), but they also resemble leaves of *Zelkova*. We need a further investigation to ascertain their generic assignments by venation character.

Occurrence: Taigu, Shansi and Sunga, Sichuan, China.

Acer sugawarae Endo

Acer sugawarai Endo. 1951. Short Papers, IGPS. (3): 56. pl. 8. f. 7.

Discussion: No living leaf of *Acer* is comparable to this small, five-lobed leaf, which lobes are entire at the margin and rounded at the apex. This fossil leaf may be an abnormal leaf of *Acer mono* group, for instance of *A. rotundatum*, because the fine veinlets are lacking or single within four-sided areoles.

Occurrence: Kawasaki-machi, Miyagi Prefecture.

Acer sp. cf. *A. oishii* Tanai

Acer sp. cf. *A. oishii* Tanai. Akhmetjev & Schmidt. 1966. Geol. Palaeont. Rept. Far East. p. 95. text-f. 1-24.

Discussion: This incomplete leaf is unable to ascertain its generic assignment, because it was poorly illustrated. As far as judged from its figure, this specimen is different

from *A. oishii* in the marginal character.

Occurrence: Sonye, Khabarovsk.

Acer sp.

Acer sp. Heer. 1871. Vid. Medd. Naturhist. Foren Kjob. (23-35): 34. pl. 8. f. 4.

Discussion: A five-lobed leaf from Sakhalin is too incomplete to make its specific identification, because it is not clear in the marginal character.

Occurrence: Sertuny, Sakhalin.

The Specimens of *Acer* indeterminable to any Section

The following specimens are unfortunately difficult to determine their sections because of ill-preservation or without the reinvestigation of the original specimens, although they may be probably referable to the genus *Acer* in some superficial characters.

Acer ambiguum Heer. 1878. Mem. Acad. Imp. Sci. St. Petersburg. [7]. 25 (7): 50. pl. 13. f. 5-7. [Mgratsch, North Sakhalin]

These five-lobed leaves with coarsely denate margin are similar in general appearance to those of *A. grahamense* Knowlton et Cockerell, *A. fatsiaefolium* Huzioka and *A. protomiyabei* Endo. But it is impossible to determine their relationship with the above Tertiary species without checking the ultimate venation.

Acer arsenjevii Akhmetjev et Schmidt. 1979. Paleont. & Stratigr. Far East. p. 104. pl. 13. f. 1; text-f. 1-b. [Uglovoe, Primorye]

These five-lobed leaves with large dentate margin are superficially similar to leaves of the section *Acer* such as *A. trauvetterii* Medw. and *A. heldreichi* Orph. as pointed out by Akhmetjev & Schmidt (1979). However, leaves of the above two extant species are thicker and more prominent in the secondary veins than those shown by the figures of *A. arsenjevii*. Judging from the original figures (pl. 13, figs. 1, 2), each large dent of lobes seems to be accompanied by one or two minute teeth on its basal side, although these minute teeth were not shown in the sketches (text-f. 1-a, -b). *A. arsenjevii* is also similar to the extant *A. saccharinum* L. in the foliar shape and marginal characters, and it may be included in *A. ezoanum*, which is redesignated by both leaves and

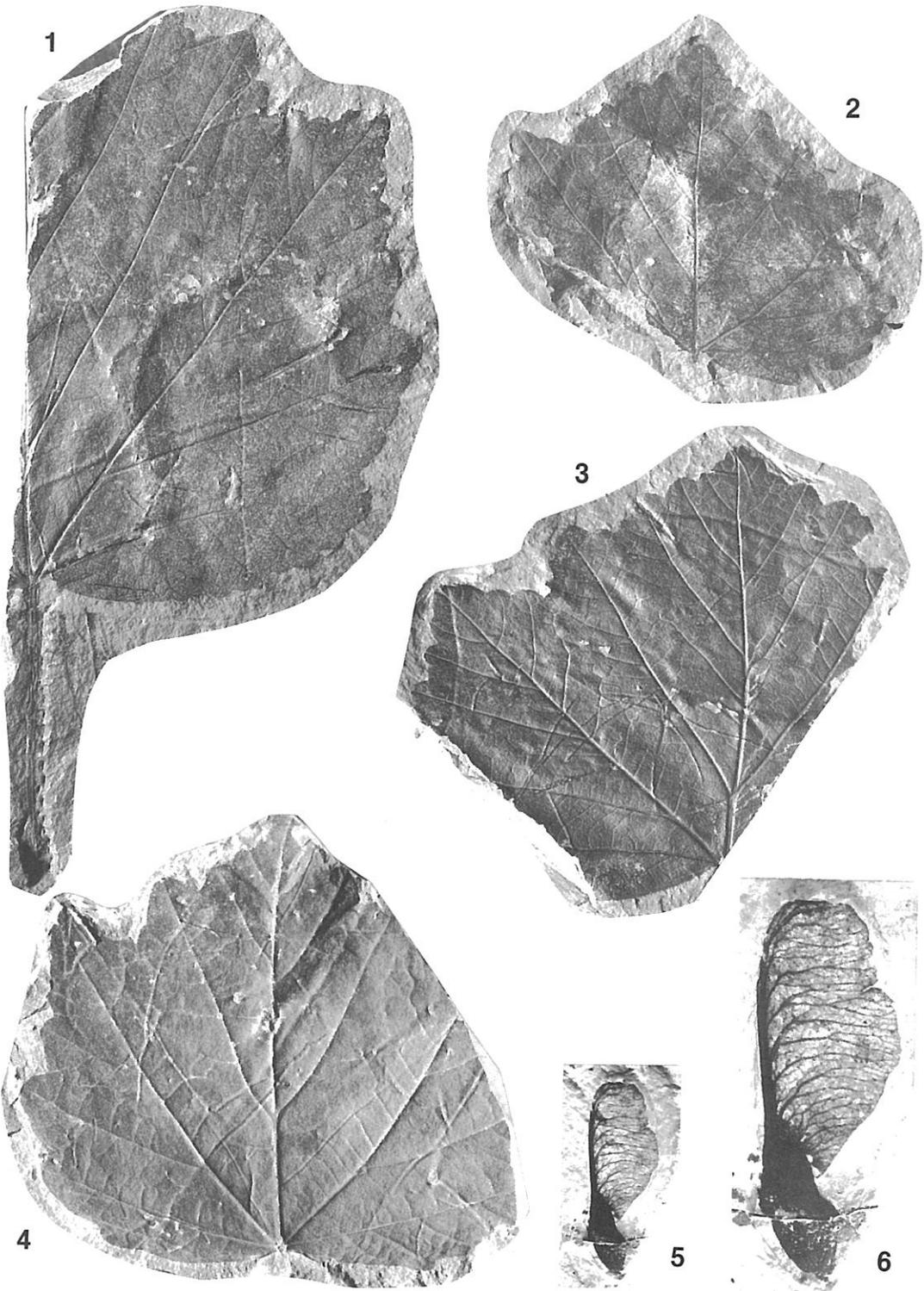
Explanation of Plate I

(all figures in natural size unless otherwise stated)

Figs. 1-3. *Acer arcticum* Heer. Cape Lyell, Spitzbergen (SMNH collection). fig. 1: Heer (1876) pl. 22, f. 1; fig. 2 (Lectotype): Heer (1876) pl. 22, f. 7; fig. 3: Heer (1876) pl. 22, f. 4.

Fig. 4. *Acer arcticum* Heer. Takinosawa, Bibai, Hokkaido (Ikushunbetsu Formation). HUMP no. 26202.

Figs. 5, 6. *Acer subginnala* Guo. Zekog, Qinghai, China. Holotype NIGP PB-6114. Fig. 6. ×2 (photo. by Dr. Guo)



samaras in this paper.

Acer florinii Hu et Chaney. 1938. Palaeont. Sin. [A]. (1): 56. pl. 31. f. 5, 8. [Shan-wang, China]

These two trilobed leaves with entire margin are probably related to the extant *A. buergerianum* Miq., but they are unable to confirm their modern relationship, due to the ill-preservation. These leaves are also similar to the trilobed leaves of *A. mono* Maxim. in the general appearance.

Acer grahamense auct. non Knowlton et Cockerell. Kryshtofovich. 1934. Trans. Far East Geol. Prosp. Trust. 62: 19. PL. 5. f. 28. = *Acer* sp. [Korf, Kamchatka]

This large samara is lacking in seed part for definite specific determination.

Acer hilgendorfi Nathorst. 1883. Kgl. Sv. Vet. Akad. Handl. 20 (20): 85. pl. 15. f. 11. [Unknown locality, Japan]

This species was established on the basis of a single leaf which was stored in the University Museum of Berlin, though its exact locality was unknown. Judging from the original illustration, this specimen is closely similar to a remotely minute-toothed leaf of the extant *A. mono* Maxim., and it may be the earlier synonym of *A. chiharae*. If the original specimen has been still stored in the Museum, it should be reinvestigated in detail.

Acer hilgendorfi auct. non Nathorst. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 91. pl. 9. f. 6; text-f. 1-4, -10 [Uglovoe, Primorye]

These two leaves from Primorye are different from *A. hilgendorfi* in lanceolate lobes and somewhat larger teeth. As suggested by Akhmetjev and Schmidt (1976), these two leaves resemble those of some type of the extant *A. buergerianum* Miq. The juvenile tree of this extant species bears sometimes such five-lobed leaves with toothed margin, although their leaves are mostly trilobed. If the fimbrial veins along the margin are confirmed in these fossil leaves, these Primorye specimens are included in *A. proto-trifidum*.

Acer megasamarum auct. non Tanai et N. Suzuki. Huzioka. 1964 (part). J. Min. Coll.

Explanation of Plate 2

(all figures in natural size unless otherwise stated)

Fig. 1. *Acer arcticum* Heer. Takinosawa, Bibai, Hokkaido (Ikushunbetsu Formation). HUMP no. 26203.

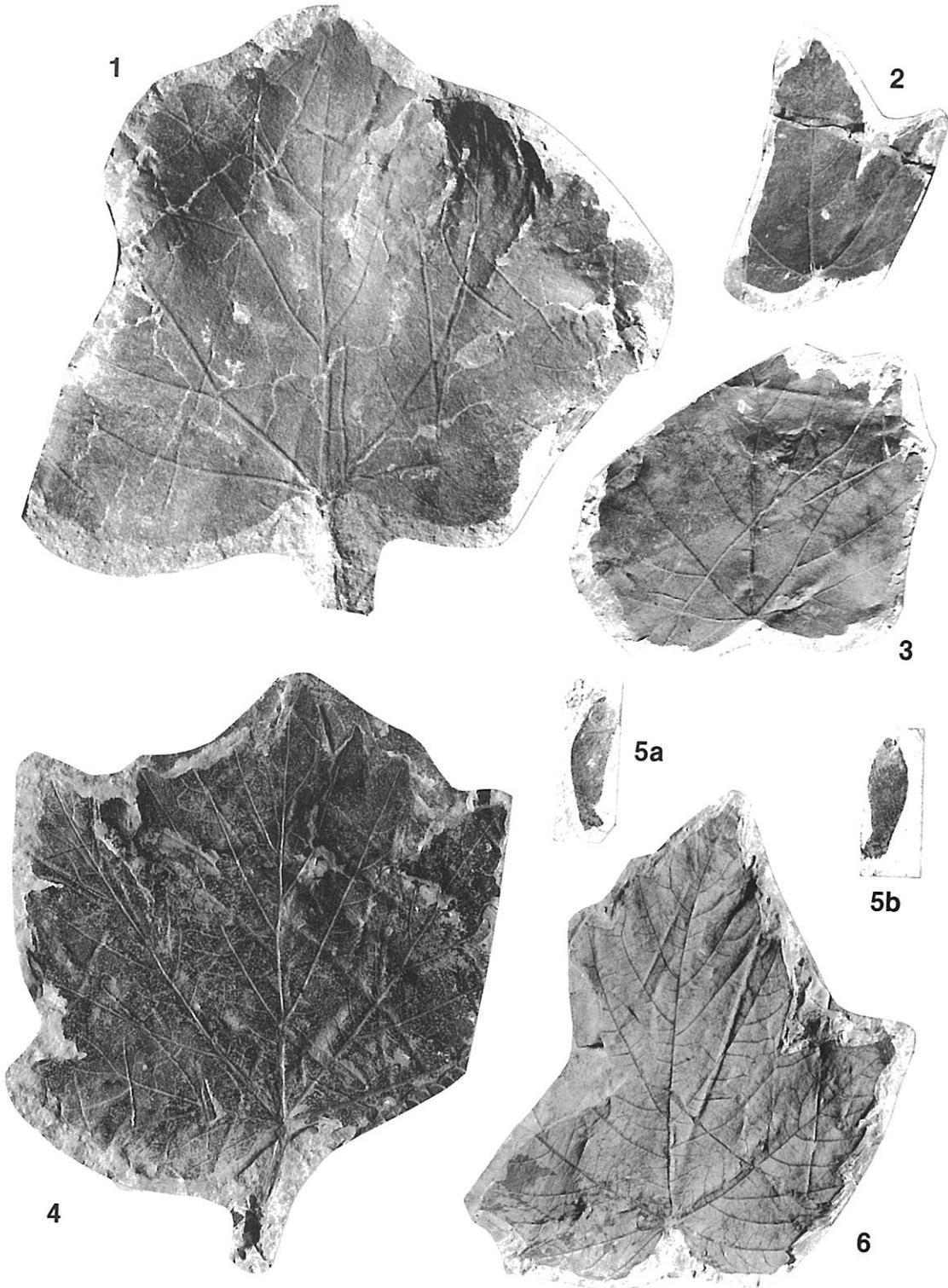
Fig. 2. *Acer oishii* Tanai. Shimizusawa, Yubari, Hokkaido (Yubari Formation). AKMG no. 6309.

Fig. 3. *Acer arcticum* Heer. Reisui-san, Yubari, Hokkaido (Ikushunbetsu Formation). HUMP no. 26205.

Fig. 4. *Acer arcticum* Heer. Cape Lyell, Spitzbergen. (SMNH collection). Heer (1876) pl. 22, f. 3.

Fig. 5a, b. *Acer oishii* Tanai. ditto. Paratype, HUMP no. 25987.

Fig. 6. *Acer oishii* Tanai. Harutori, Kushiro, Hokkaido (Harutori Formation). Holotype, HUMP no. 25986.



Akita Univ. [A]. 3 (4): 90. pl. 15. f. 1. = *Acer* sp. [Hiramaki, Gifu Pref.]

This specimen is also represented only by wing, lacking the definite base for specific identification.

Acer megasamarum auct. non Tanai et N. Suzuki. Baikovskaya. Late Miocene floras of S. Primorye. p. 83. pl. 18. f. 10. = *Acer* sp. [Udugou, South Primorye]

This incomplete samara lacks its seed part for specific determination.

Acer miodavidii Hu et Chaney. 1938. (part). Palaeont. Sinica. n. ser. A. (1): 58. pl. 32. f. 5. [Shanwang, China]

Excluding two leaves which were transferred to *Alnus*, a single samara named as *Acer miodavidii* is not clear in the contact scar, because its illustration was retouched. Although this samara seems similar to that of the extant *A. mandshuricum* Maxim. and *A. triflorum* Komarov, it is difficult to ascertain the modern relationship this time.

Acer miodavidii auct. non Hu et Chaney. Acad. Sinica. 1978. Cenozoic Plants of China. p. 126. pl. 104. f. 1; pl. 112. f. 1 [Shanwang, China]

Of the two illustrated specimens a single samara was reproduced from the original figure of Hu and Chaney (1938). The remaining leaf specimen is closely similar to the extant *Acer davidii* Franch in the foliar shape, secondary venation and margin, although it was poorly illustrated. If this modern relationships shall be confirmed, a new name should be given for this leaf specimen.

Acer miofranchetii auct. non Hu et Chaney. Acad. Sin. 1978 (part). Cenozoic Plants of China. p. 126. pl. 101. f. 5; pl. 102. f. 4; pl. 104. f. 6. = *Acer* sp. [Shanwang, China]

These three samaras from Shanwang are incomplete in seed part, and they are now difficult to determine their modern relationships from only their illustrations.

Explanation of Plate 3

(all figures in natural size)

Fig. 1. *Acer nordenskiöldi* Nathorst. Mogi, Nagasaki, Nagasaki Pref. (Mogi plant-bearing Formation). SMNH collection lectotype (Heer, 1883: pl. 11, f. 14).

Fig. 2. *Acer nordenskiöldi* Nathorst. Chojabaru, Iki Isl., Nagasaki Pref. ("Wakamatsu" Formation). HUMP no. 26207.

Fig. 3. *Acer protomatsumurae* Tanai. Keumkwandong, South Korea (Changgi Group). HUMP no. 9326.

Fig. 4. *Acer protodistylum* Endo. Fushun, Liaoning, China (Fushun Formation). Holotype IGPS no. 60988.

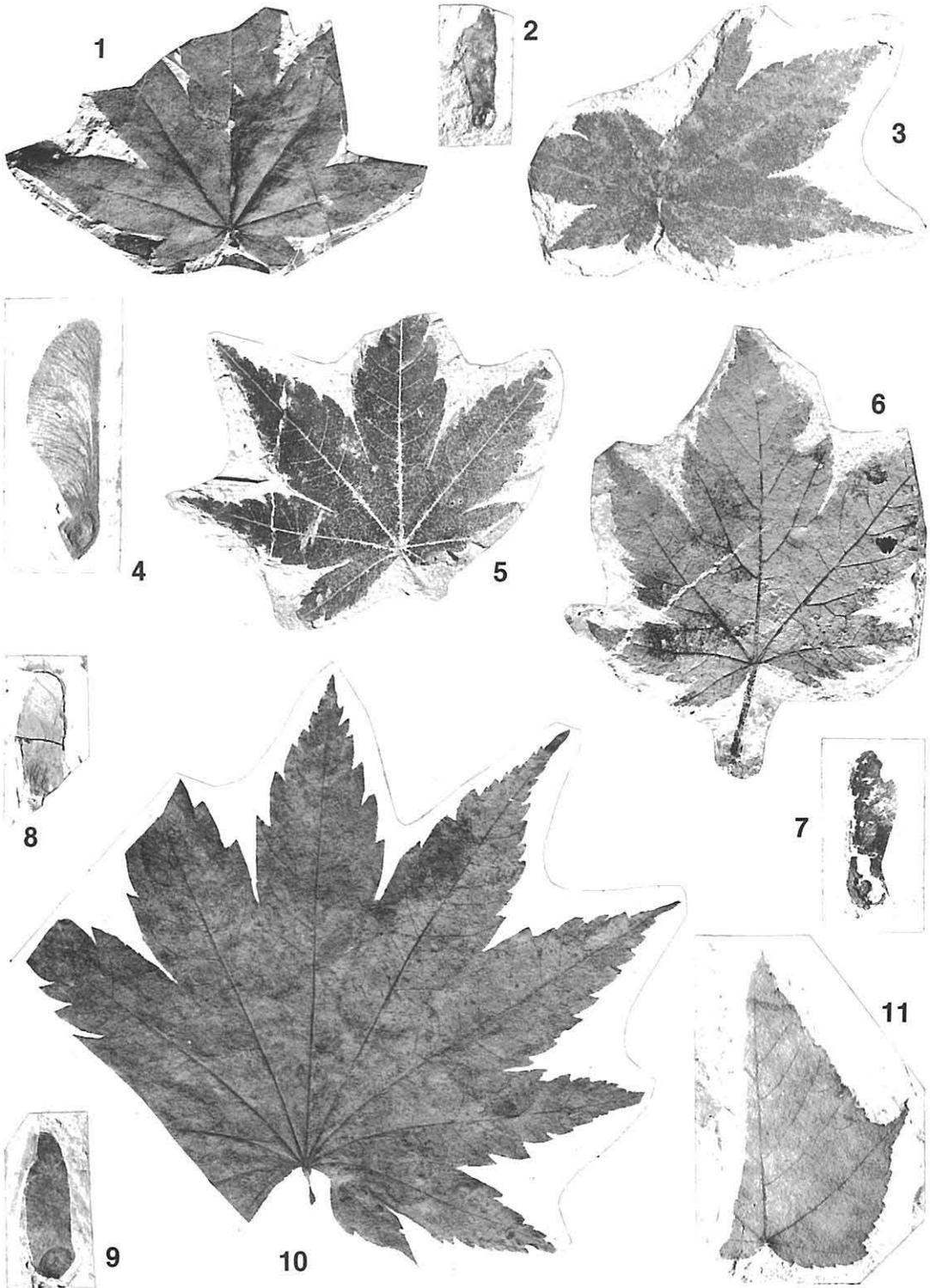
Fig. 5. *Acer protomatsumurae* Tanai. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype GSJ no. 4777.

Figs. 6, 7. *Acer tottoriense* Tanai et Ozaki. Tatsumitoge, Tottori Prefecture (Tatsumitoge Formation). Holotype TPM no. 235 (Fig. 6); Paratype NSM-PP 16213 (Fig. 7).

Figs. 8, 9. *Acer protojaponicum* Tanai et Onoe. Shichiku, Iwaki, Fukushima Pref. ("Shichiku" Formation). Holotype GSJ no. 4038 (Fig. 9); Paratype GSJ no. 4039 (Fig. 8).

Fig. 10. *Acer protojaponicum* Tanai et Onoe. Rubeshibe, Hokkaido (Komatsuzawa Formation). HUMP no. 25899.

Fig. 11. *Acer palaeorufinerve* Tanai et Onoe. Mitoku, Misasa, Tottori Pref. (Mitoku Formation). Holotype GSJ no. 4182.



Acer miotegmentosum Akhmetjev. 1973. Acad. Sci. USSR. Geol. Inst. Trans. 247: 74. pl. 20. f. 2. [Botchi, Primorye]

Although this specimen is lacking in the basal part, it resembles leaves of the section *Macrantha*, especially of the extant *Acer tegmentosum* Maxim. of Northeast Asia. The duplicate-serrate margin and the large teeth in which the secondary veins end, may indicate that this specimens from Primorye is rather close to the extant *A. nipponicum* Hara of Japan belonging to the section *Parviflora*.

Acer nomurai Okutsu. 1940. Saito Ho-on Kai Mus. Rs. Bull. (19): 162. pl. 7. f. 5. [Nenoshiroishi, Miyagi Pref.]

This specimen is closely similar to certain leaves of the section *Macrantha* as described by Okutsu (1940), and it may be unseparable from *Acer palaeorufinerve* Tanai et Onoe in all characters. Although “*nomurai*” may be an earlier epithet for such leaves, the original specimens were unfortunately lost in the Museum of Saito Ho-on Kai. The problem of name of “*nomurai*” is already discussed in earlier page.

Acer palaeonipponicum Murai. 1969. Tech. Rept., Iwate Univ. 4: 65. pl. 1. f. 2; pl. 2. f. 4, 6; pl. 5. f. 4.

Acer sp. cf. *A. nipponicum* auct. non Hara. Murai. 1963. Rept. Tech., Iwate Univ. 16 (1): 103. pl. 16. f. 7. [Shizukuishi and Hishinai, Iwate Pref.]

This species was established on the basis of five leaves including a nearly complete one, and it was compared with the extant *A. nipponicum* Hara of Japan, which belongs to *Parviflora*. These fossil leaves from northern Honshu are also superficially similar to *A. palaeorufinerve* of *Macrantha*, although they are somewhat larger. The fine veinlet is different between leaves of *Macrantha* and *Parviflora*: it is ramified more than once in the former, while mostly lacking or rarely single in the latter. Accordingly we need to investigate the fine venation of *A. palaeonipponicum*.

Acer paxii auct. non Franch. Acad. Sin. 1978. Cenozoic Plants of China. p. 128. pl. 105. f. 2; pl. 102. f. 2, 3. [Eryuan, Yunnan, China]

All these three leaves are too incomplete to determine their modern relationships,

Explanation of Plate 4

(all figures in natural size)

Fig. 1a, b. *Acer ezoanum* Oishi et Huzioka. Bifuka, Hokkaido (Ote Formation). HUMP no. 26218.

Fig. 2. *Acer subukurunduense* N. Suzuki. Rubeshibe, Hokkaido (Komatsuzawa Formation). Holotype HUMP no. 25918.

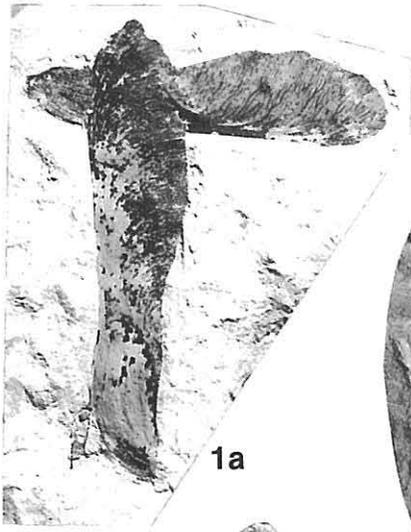
Fig. 3. *Acer palaeorufinerve* Tanai et Onoe. Penkenai, Utanobori, Hokkaido (Penkenai Formation). HUMP no. 26200.

Fig. 4. *Acer endoanum* Huzioka. Tsuyukuma, Ani, Akita Pref. (Ani Formation). AKMG no. 3928.

Fig. 5. *Acer endoanum* Huzioka. Hamjindong, North Korea (Hamjindong Formation). Holotype HUMP no. 9350.

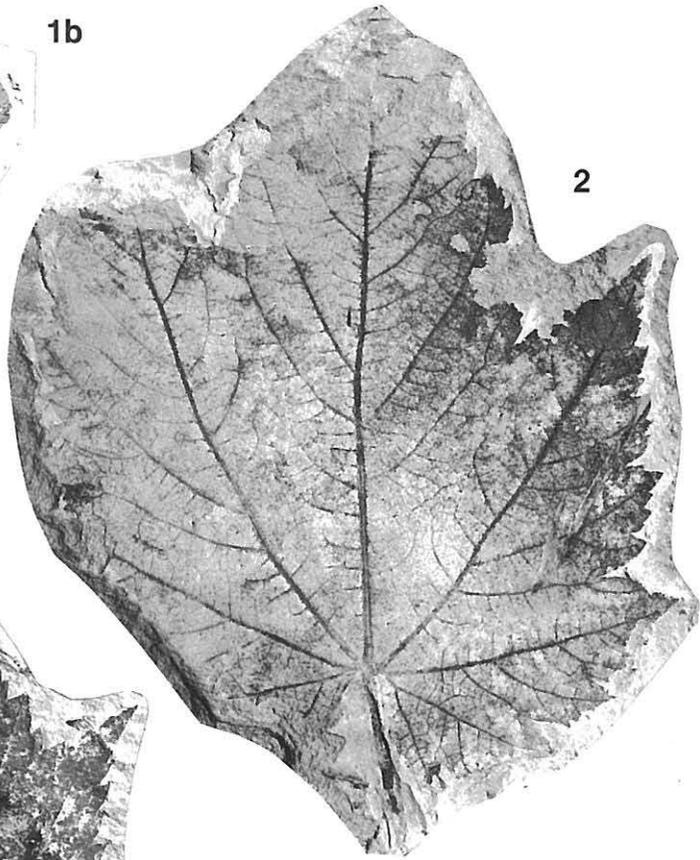
Fig. 6. *Acer endoanum* Huzioka. Shichiku, Iwaki, Fukushima Pref. (Shichiku Formation). GSJ no. 4056.

Fig. 7. *Acer oishii* Tanai. Reisuian, Yubari, Hokkaido (Ikushunbetsu Formation). HUMP no. 26206.



1a

1b



2



3



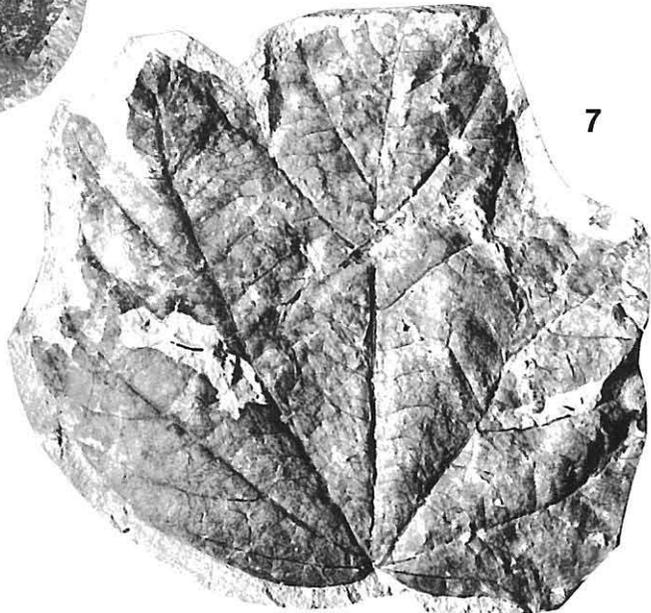
4



5



6



7

although they are trilobed leaves of some maple. If they are close to the extant *Acer paxii* Franch. belonging to Oblonga, the distinct fimbrial vein along the margin should be confirmed.

Acer ryozenense K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 80. pl. 19. f. 7
[Ryozen, Fukushima Pref.]

This species was based on a single five-lobed leaf, which is characterized by double serrate margin and a long petiole, and it was originally compared with the extant *A. capillipes* Maxim. of southern Japan. This specimen is, however, unfortunately ill-preserved in margin and the venation higher than the secondary order. So far as reinvestigated, *A. ryozenense* is different from *A. capillipes* in margin and secondary venation feature, excepting for a long petiole: there are one or two teeth between the principal teeth in which the secondaries end; the emerging position of the lowest secondary pair in central lobe is further higher than that of *A. capillipes*. Considering such characters together with a long petiole, *A. ryozenense* may be related with the extant *A. caudatum* Wall. of Himalaya region, which belongs to the section Spicata.

Acer sachalinense Heer. 1878. Mem. Acad. Imp. Sci. St. Petersburg. [7]. 25 (7): 49.
pl. 13. f. 8 [Dui, Sakhalin]

A single incomplete samara from Sakhalin is characteristic in seed feature, although it lacks the upper half of wing. The large, globular seed which is bulged outwardly, and the divergent angle of wings (100°) may indicate that this species is close to *Acer grahamense* Knowlton et Cockerell.

Acer sibiricum Heer. 1878 (part). Mem. Acad. Sci. St. Petersburg. [7]. 25 (6): 46. pl. 10.

Explanation of Plate 5

(all figures in natural size)

Figs. 1, 8. *Acer ishikariense* Tanai. Reisuian, Yubari, Hokkaido (Ikushunbetsu Formation). Holotype HUMP no. 26209 (Fig. 6); paratype HUMP no. 26210 (Fig. 1).

Fig. 2. *Acer protonegundo* Tanai. Abura, Setana, Hokkaido (Babagawa Formation). HUMP no. 25006.

Fig. 3. *Acer protonegundo* Tanai. Yongdong, North Korea (Yongdong Group). HUMP no. 9323.

Fig. 4. *Acer protonegundo* Tanai. Yoshioka, Fukushima-cho, Hokkaido (Yoshioka Formation). Holotype HUMP no. 25004.

Fig. 5. *Acer pseudoginnala* Tanai et Onoe. Shichiku, Iwaki, Fukushima Pref. ("Shichiku" Formation). Holotype GSJ no. 4040.

Fig. 6. *Acer pseudoginnala* Tanai et Onoe. Wakamatsu, Kitahiyama, Hokkaido (Sekinai Formation). HUMP no. 25043.

Fig. 7. *Acer pseudoginnala* Tanai et Onoe. Yoshioka, Hokkaido (Yoshioka Formation). HUMP no. 25056.

Fig. 9. *Acer ishikariense* Tanai. Shikanotani, Yubari, Hokkaido (Wakanabe Formation). HUMP no. 26214.

Fig. 10. *Acer palaeorufinerve* Tanai et Onoe. Penkenai, Utanobori, Hokkaido (Penkenai Formation). HUMP no. 26201

Fig. 11. *Acer uemurae* Tanai et Ozaki. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype TPM-293.



f. 4b, 5a-b; pl. 11. f. 2; f. 1c. [Simonova, West Siberia]

This species was based on five-lobed leaves from western Siberia, which are dentate at the margin. These specimens were compared with leaves of the extant *A. nigrum* Michx. by Heer (1878), but they are also similar to *A. miyabei*. It is difficult to determine their modern relationship by only the illustrations.

Acer taikuense Chaney. 1933. Bull. Geol. Soc. China. 12 (2): 136. pl. 1. f. 8, 9. [Taigu, Shansi]

Two small trilobed leaves from the Pliocene or Lower Pleistocene of central China are probably referable to *Acer* in general appearance. These leaves were recently referred to *A. pilosum* Maxim. (Acad. Sin., 1978: p. 128), and they may belong to the section Oblonga in having a few minute teeth on the lobes. Actually, the extant *A. buergerianum* Miq. of Japan and *A. paxii* Franch. of China sometimes have such leaves with lanceolate toothed leaves. However, their modern relationships have to be ascertained by the presence of the fimbrial vein.

Acer tokiensis Ozaki. 1974. Sci. Rept. Yokohama Natl. Univ. [II]. (21): 16. pl. 3. f. 8, 9. [Mizunami, Gifu Pref.]

A single leaf specimen and its counterpart with seven lobes resemble certain large leaves of the extant *Acer palmatum* Thunb. at general appearance, especially in lobation and deeply cordate base, but are different in marginal large teeth accompanied sometimes with a few minute teeth. These specimens seem somewhat similar to the extant *A. ukurunduense* Trautv. et Meyr. in marginal character, although the fine veinlets are not preserved.

Acer trifloriformis Akhmetjev. 1973. Acad. Sci. USSR Geol. Inst. Trans. 247: 74. pl. 21. f. 3. [Botchi, Primorye]

Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 95. text-f. 1-5. [Uglovoe, Primorye]

Two leaf specimens from Primorye are superficially similar to leaflets of *Trifoliata* or *Negundo*, and especially close to the former as described by Akhmetjev (1973). However, these fossil leaves are too incomplete to determine their modern relationships

Explanation of Plate 6

(all figures in natural size)

Fig. 1. *Acer ezoanum* Oishi et Huzioka. Sarutsu, Nayoshi, South Saghalin (Estoru coal-bearing Formation). HUMP no. 9425.

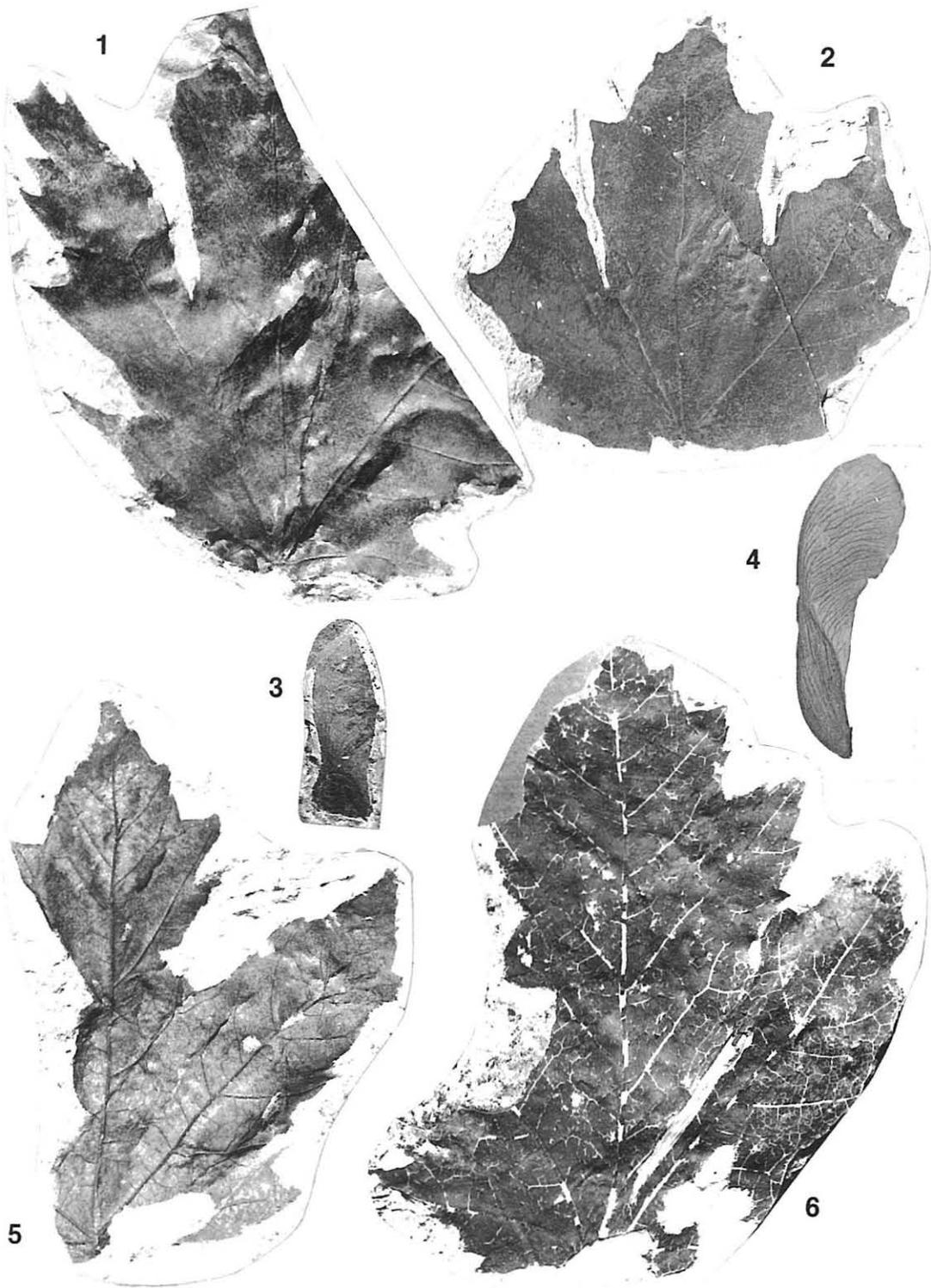
Fig. 2. *Acer protomiyabei* Endo. Yoshioka, Fukushima, Hokkaido (Yoshioka Formation). HUMP no. 25013.

Fig. 3. *Acer protomiyabei* Endo. Kudo, Taisei-mura, Hokkaido (Sekinai Formation). HUMP no. 27131.

Fig. 4. *Acer ezoanum* Oishi et Huzioka. Rubeshibe, Hokkaido (Komatsuzawa Formation). HUMP no. 25917.

Fig. 5. *Acer ezoanum* Oishi et Huzioka. Shiritori coal mine, Shiritori, South Saghaline (Shiritori coal-bearing Formation). Lectotype HUMP no. 9360.

Fig. 6. *Acer ezoanum* Oishi et Huzioka. Bifuka, Hokkaido (Ote Formation). HUMP no. 26217.



by only their illustrations.

Acer trifoliatum Geng. Acad. Sinica 1978 (part): Cenozoic Plants of China. p. 129. pl. 102. f. 5. = *Acer* sp. [Shanwang, China]

This species was established on the basis of many trifoliate or detached leaflets and a single samara (Geng in Acad. Sinica, 1978). Excluding the leaflets this samara lacks larger part of seed, and it is difficult to compare its modern relationship.

Acer trilobatum auct. non (Sternb.) Al. Br. Heer. 1978 (part). Mem. Acad. Imp. Sci. St. Petersburg. [7]. 25 (7): 48. pl. 13. f. 10. = *Acer* sp. [Mgratsch, Sakhalin]

Although this leaf from Sakhalin is lacking in basal part, it may look like a trilobed leaf of maple with large dentate teeth. This specimen is not fallen within the variation of *Acer trilobatum* which is highly variable in foliar shape and lobation; it is rather similar to *A. protomiyabei* Endo and *A. fatsiaefolium* Huzioka.

Acer sp. cf. *A. diabolicum* Bl. K. Takahashi. 1954. Mem. Fac. Sci. Kyushu Univ. [D]. 5 (1): 61. pl. 7. f. 2. [Oya, Nagasaki Pref.]

This small samara is similar not to that of the extant *Acer diabolicum* Bl. but to *A. distylum* S. et Z. in its seed shape and slender wing. It needs, however, to reinvestigation in detail.

Acer sp. cf. *A. grahamensis* Knowlton et Cockerell. Chelebaeva. 1968. Bot. Zhur. 53 (6): 744. pl. 4. f. 1; text-f. 4-e, zh. = *Acer* sp. [Pirozhnikovaya, Kamchatka]

This incomplete large samara may be similar to *Acer ezoanum* Oishi et Huzioka, but it is difficult to ascertain the specific reference, due to lacking of seed part.

Acer sp. cf. *A. hersii* Rehd. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 94. pl. 10. f. 8; text-f. 1-28. = *Acer* sp. [Rettikhovska, Primorye]

Although this trilobed leaf is missing in the upper half, it seems to be similar to certain leaves of the section *Macrantha*. However, it resembles also some leaves of the extant *Acer rubrum* L. in marginal serration, if the original illustration was valid. It

Explanation of Plate 7

(all figures in natural size)

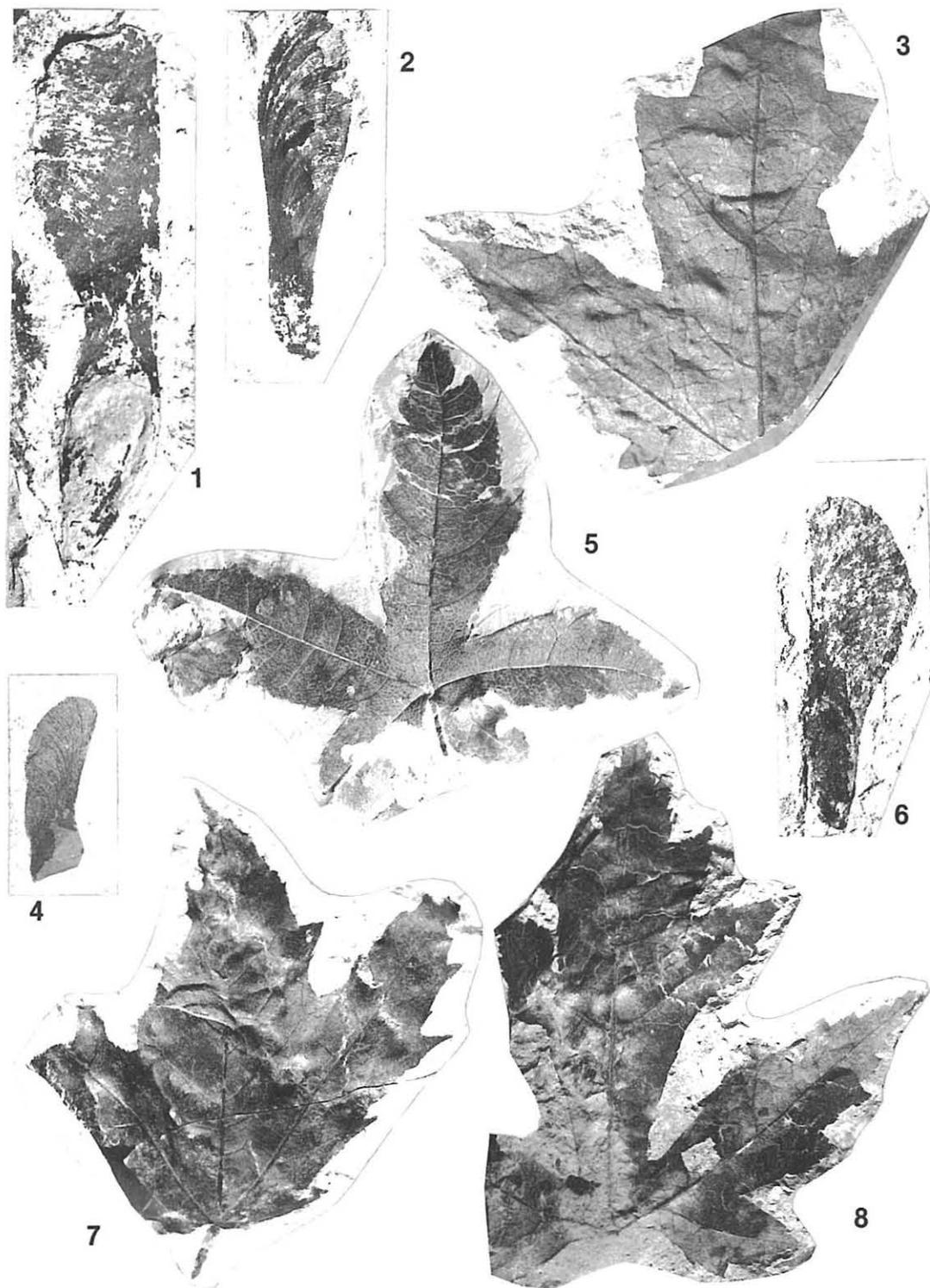
Figs. 1, 2, 6. *Acer ezoanum* Oishi et Huzioka. Onnenai, Bifuka, Hokkaido (Hotoku Formation). HUMP nos. 26219, 26220, 26346.

Fig. 3. *Acer ezoanum* Oishi et Huzioka. Taihei coal mine, Estoru, South Saghalin (Estoru coal-bearing Formation). HUMP no. 9403b.

Fig. 4. *Acer protomiyabei* Endo. Yoshioka, Fukushima, Hokkaido (Yoshioka Formation). HUMP no. 25018.

Figs. 5, 8. *Acer ezoanum* Oishi et Huzioka. Kani-cho, Gifu Pref. (Hiramaki Formation). Dr. Ina's collection.

Fig. 7. *Acer ezoanum* Oishi et Huzioka. Nayoshi, South Saghalin (Esutoru coal-bearing Formation). HUMP no. 9426.



needs to investigate the fine venation for the determination of the modern relationship.

Acer sp. cf. *A. nordenskiöldi* Nathorst. Ozaki. 1974. Sci. Rept. Yokohama Natl. Univ. [III]. (21): 17. pl. 3. f. 6 = *A. tokiense* Ozaki [Mizunami, Gifu Pref.]

This specimen seems to represent a small leaf of *Acer tokiense* which is unknown in the modern relationship.

Acer sp. cf. *A. sinense* Pax. Akhmetjev & Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 99. pl. 9. f. 9; text-f. 1-6. -30. [Kamyshev, Primorye]

This small, slender samara is easily separable from that of the extant *Acer sinense* Pax of the section *Palmata* in a rather oblong seed. Judging from the seed character and divergent angles of wings, this specimen seems to be related with the section *Macrantha* such as *A. crataegifolium* S. et Z. and *A. rufinerve* S. et Z.

Acer sp. Heer. 1934. Trans. Far East Geol. Prosp. Trust. 62: 19. pl. 5. f. 29-31 [Korf Bay, Kamchatka]

All these leaves are too fragmentary to determine their modern relationship, although they may be referable to *Acer* in superficial features.

Acer sp. Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1): 136. pl. 22. f. 7; pl. 23. f. 4 [Kilyu, North Korea]

These two fragmentary samaras from the Miocene of Korea are lacking in the lower half of seeds, and are unable to be compared with the extant species.

Acer sp. Baikovskaya. 1950. Prob. Palaeont. 1: 374. [Zeya-Bureya, Ussuri]

Although this was mentioned to be similar to *A. campestre* L., the specimen was not illustrated.

Acer sp. Akhmetjev & Schmidt. 1966. Geol. Palaeont. ept. Far East. p. 97. pl. 9. f. 4; text-f. 1-29. [Soborevka River, Primorye]

This incomplete samara from the Danian of Primorye is unfortunately lacking in most part of wing. Although Akhmetjev and Schmidt (1966) compared it with samaras

Explanation of Plate 8

(all figures in natural size)

Figs. 1-3, 6. *Acer protomiyabei* Endo. Yoshioka, Fukushima, Hokkaido (Yoshioka Formation). HUMP nos. 25007, 25019, 25008, 25016.

Fig. 4. *Acer shanwangense* Tanai. Shanwang, China (Shanwang Group). Paleobotany Collection of Academia Sinica. reproduced from the illustration of "Cenozoic Plants of China" (Acad. Sinica, 1978).

Fig. 5. *Acer tricuspdatum* Bronn. Shichiku, Iwaki, Fukushima Pref. ("Shichiku" Formation). AKMG no. 5084.

Fig. 7. *Acer tricuspdatum* Bronn. Sendai, Miyagi Pref. (Akiu Formation). IGPS no. 44246.

Fig. 8. *Acer tricuspdatum* Bronn. Rubeshibe, Hokkaido (Komatsuzawa Formation). HUMP no. 25906.



of the section *Platanoidea*, this fossil samara is different in thicker, globular seed. It may be suggested to be related with *Acer grahamense* Knowlton et Cockerell.

Acer sp. Dorofeev. 1960. Miocene flora of Mammoth-mountain. p. 100. pl. 21. f. 9; text-f. 33-1. [Mammoth-Mountain, Aldan]

A single seed with no wing was mentioned to be similar to that of the extant *Acer saccharinum* L. by Dorofeev (1969); but it is difficult to ascertain its modern relationship only by his illustration.

Acer sp. Dorofeev. 1969. ditto. p. 100. pl. 21. f. 11, 12; text-f. 33-3, 4 [Mammoth-mountain, Aldan]

Two small seeds with no wing may be related to that of the section *Palmata*, as suggested by Dorofeev (1969), in the wide divergent angles of samara.

Acer sp. Dorofeev. 1969. ditto. p. 100. pl. 21. f. 10; text-f. 33-2. [Mammoth-mountain, Aldan]

A single oblong seeds with no wing is not similar to that of the section *Platanoidea* but to that of the extant *Acer carpiniifolium* S. et Z. and *A. stachyophyllum* Hiern in the sutured surface and divergent angles of wings.

Acer sp. Baikovskaya. 1974. Late Miocene floras from South Primorye. p. 86. pl. 19. f. 4. [Pachikhezy River, Primorye]

These samaras are lacking in the seed part which needs to determine their modern relationship.

Acer sp. Huzioka. 1974. J. Min. Coll. Akita Univ. [A]. 5 (2): 104. [Daibo, Yamaguchi Pref.]

A single fragmentary samara was reported, but it was not illustrated.

Acer sp. Chelebaeva. 1978. Miocene floras of eastern Kamchatka. p. 84. pl. 21. f. 1.

Explanation of Plate 9

(all figures in natural size)

Fig. 1. *Acer palaeoplatanooides* Endo. Chojabaru, Iki Isl., Nagasaki Pref. ("Wakamatsu" Formation). HUMP no. 26225.

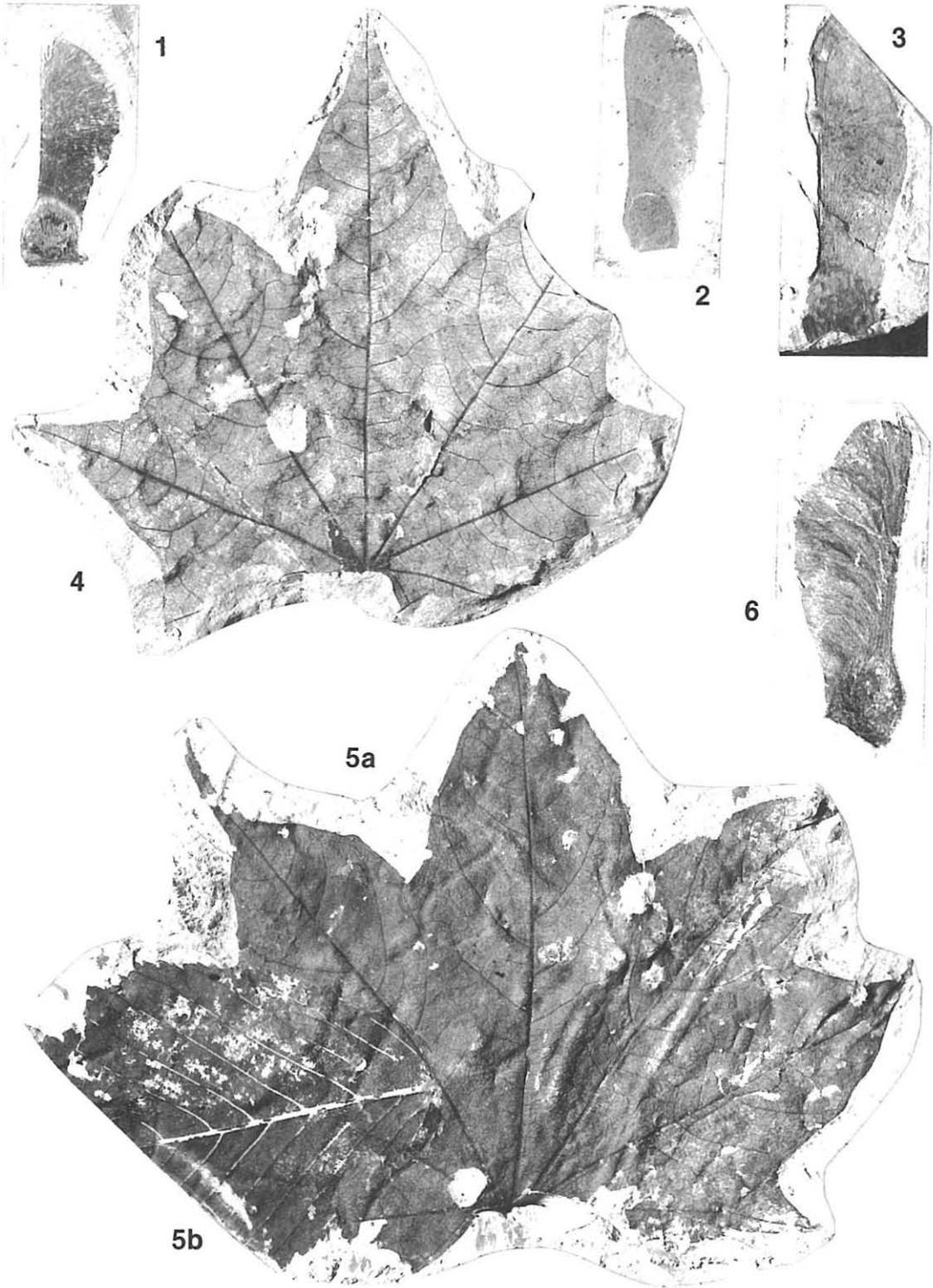
Fig. 2. *Acer palaeoplatanooides* Endo. Wakamatsu, Kitahiyama, Hokkaido (Sekinai Formation). HUMP no. 25055.

Fig. 3. *Acer palaeoplatanooides* Endo. Hamjindong, North Korea (Hamjindong Formation). Holotype IGPS no. 60987.

Figs. 4, 5a. *Acer chiharae* Huzioka et Nishida. Bifuka, Hokkaido (Ote Formation). HUMP nos. 26221, 26222a.

Fig. 5b. *Acer subcarpiniifolium* Tanai. ditto. HUMP no. 26222b.

Fig. 6. *Acer palaeoplatanooides* Endo. Garo, Kitahiyama, Hokkaido (Futuro Formation). HUMP no. 27077



[Korf Bay, Kamchatka.]

This fragmentary leaf seems to be trilobed, although missing in all the marginal area. Judging from abundant occurrence of *Acer tigilense* Chelebaeva (= *A. tricuspidatum* Bronn), this incomplete leaf may be referable to this species.

Rejected Citations of *Acer*

Acer akagawaensis K. Suzuki. 1959. Monogr. Assoc. Geol. Collab. Japan. (9): 41. pl. 5. f. 2. = *Liquidambar miosinica* Hu et Chaney. [Tenoji, Fukushima Pref.]

My reinvestigation of the original specimen and its counterpart reveals that they are doubtlessly referable to the genus *Liquidambar*, because the marginal teeth are clearly glandular and the secondary veins form distinct loops near the margin, from whose loop a slender vein emerges into the tooth.

Acer akagawaensis acut. non K. Suzuki. Murai. 1963. Rept. Tech. Iwate Univ. 16 (1): 105. pl. 17. f. 3, 4. = *Liquidambar* sp. [Gosho, Iwate Pref.]

These two leaves were compared with the extant *A. rufinerve* Sieb. et Zucc. and *A. franchetii* Pax by Murai (1963), following to K. Suzuki (1959). Murai (1959) stated that the secondary veins of these specimens form loops near the margin. However, the secondary veins of the above species of the section *Macrantha* usually enter directly the marginal teeth. Although these two Gosho specimens are too poorly illustrated to determine, they probably belong to *Liquidambar*.

Acer arcticum auct. non Heer. Kryshtofovich. 1958. Palaeobotanika. 3: 104. pl. 8. f. 3 = genus and species indetermined [Lake Tastakh, East Siberia]

This incomplete leaf lacks most marginal area, and is unconfirmed to be referable to *Acer*.

Acer cuneatum Huzioka. 1972. J. Min. Coll. Akita Univ. [A]. 5 (1): 62. pl. 8. f. 1. = *Liquidambar* ? sp. [Kogeonweon, North Korea]

This trilobed leaf is very questionable to referable to *Acer*, and has no comparable leaves of the extant maples. The acute teeth with gland-like thickening, the secondary venation forming irregularly marginal loops, and distinctly thickened margin suggest that this Korean leaf may be referable to *Liquidambar*, although the trilobed leaf with a

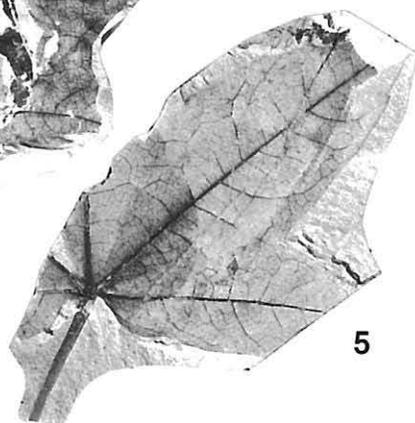
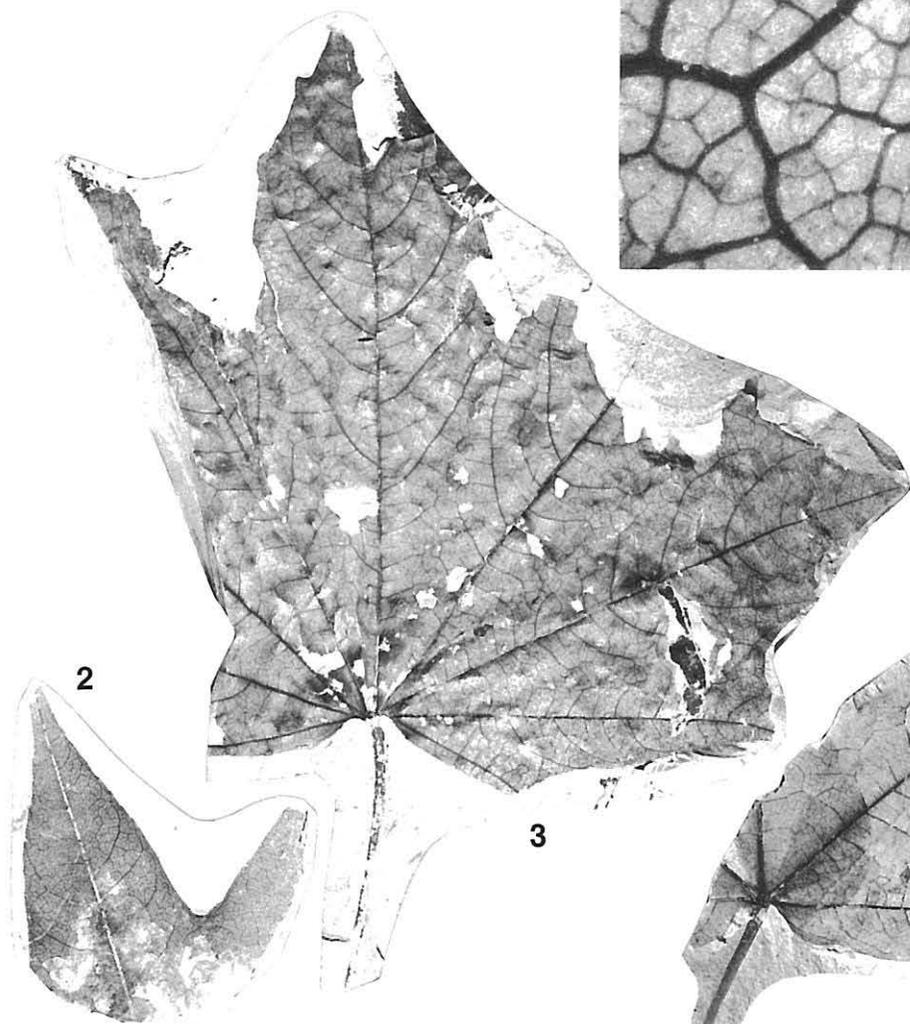
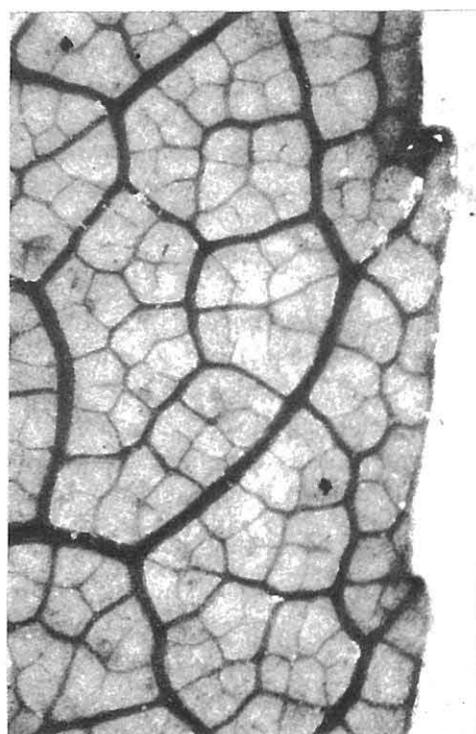
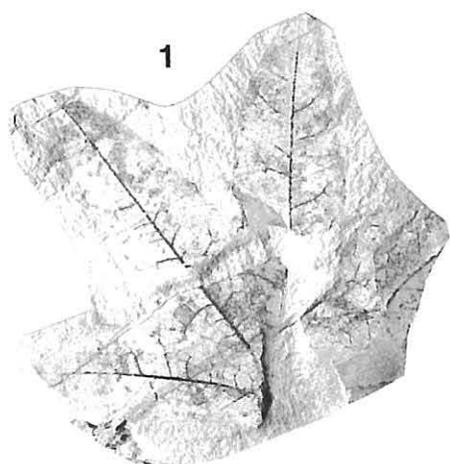
Explanation of Plate 10

(all figures in natural size unless otherwise stated)

Figs. 1, 2, 5. *Acer chiharae* Huzioka et Nishida. Seki, Sado Isl., Niigata Pref. (Suginoura Formation). Holotype AKMG no. 3312 (Fig. 1); Paratype AKMG no. 3313 (Fig. 2); AKMG no. 3311. (Fig. 5).

Fig. 3. *Acer chiharae* Huzioka et Nishida. Bifuka, Hokkaido (Ote Formation). HUMP no. 26223. ×0.5.

Fig. 4. Showing the marginal teeth and venation in *Acer chiharae* (paratype) ×10



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cuneate base is uncommon in the extant *L. formosana* Hance of China. Unfortunately this fossil leaf is too ill-preserved in the fine venation to determine its generic status.

Acer fujitogensis K. Suzuki. 1961. Sci. Rept., Fukushima Univ. (10): 83. pl. 18. f. 5 = *Liquidambar miosinica* Hu et Chaney [Fujitoge, Fukushima Pref.]

The reinvestigation of the original specimen reveals that this single trilobed leaf is excluded from *Acer* by the glandular teeth, and that it is doubtlessly referable to *Liquidambar miosinica*.

Acer megasamarum auct. non Tanai et N. Suzuki. Huzioka. 1964. (part). J. Min. Coll. Akita Univ. [A]. 3 (4): 90. pl. 15. f. 2 = *Banisteriaecarpum giganteum* (Goeppert) Kräusel. [Hiramaki, Gifu Pref.]

Lack of a distinct contact scar of seed part and no concentration of principal veins along the outer margin of wing, exclude this large winged fruit from the genus *Acer*. This specimen is probably referred to *Banisteriaecarpum giganteum* which was described from the Miocene of Europe (Kräusel, 1951).

Acer miodavidii Hu et Chaney. 1948 (part). Palaeont. Sinica. n. ser. A. (1): 58. pl. 32. f. 1, 3. [Shanwang, China]

Tanai & N. Suzuki. 1963. Tert. floras Japan. p. 139. pl. 21. f. 8 [Yoshioka, Hokkaido]

Huzioka. 1963. ditto. p. 208. pl. 36. f. 8 [Utto, Akita Pref.]

Tanai & N. Suzuki. 1972. J. Fac. Sci. Hokkaido Univ. [4]. 15: 335. pl. 8. f. 1. [Garo, Hokkaido]

Two original leaves from Shanwang is not similar to *Acer davidii* Franch., but to some leaves of the Betulaceae in their secondary venation. In leaves of *A. davidii* the secondary veins arise up to form loops or to enter the principal teeth. Furthermore a lowest pair of the secondaries emerges at acute angles as reaching near the middle margin of blade. All the leaves from Japan listed above, shows no character of *Acer*, and are included in *Alnus protomaximowiczii* Tanai, which is one of common alders in

Explanation of Plate 11

(all figures in natural size)

Fig. 1. *Acer rotundatum* Huzioka. Keumkwandong, South Korea (Changgi Group). Lectotype HUMP no. 9339b.

Fig. 2. *Acer huziokae* Tanai. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype TPM no. 400.

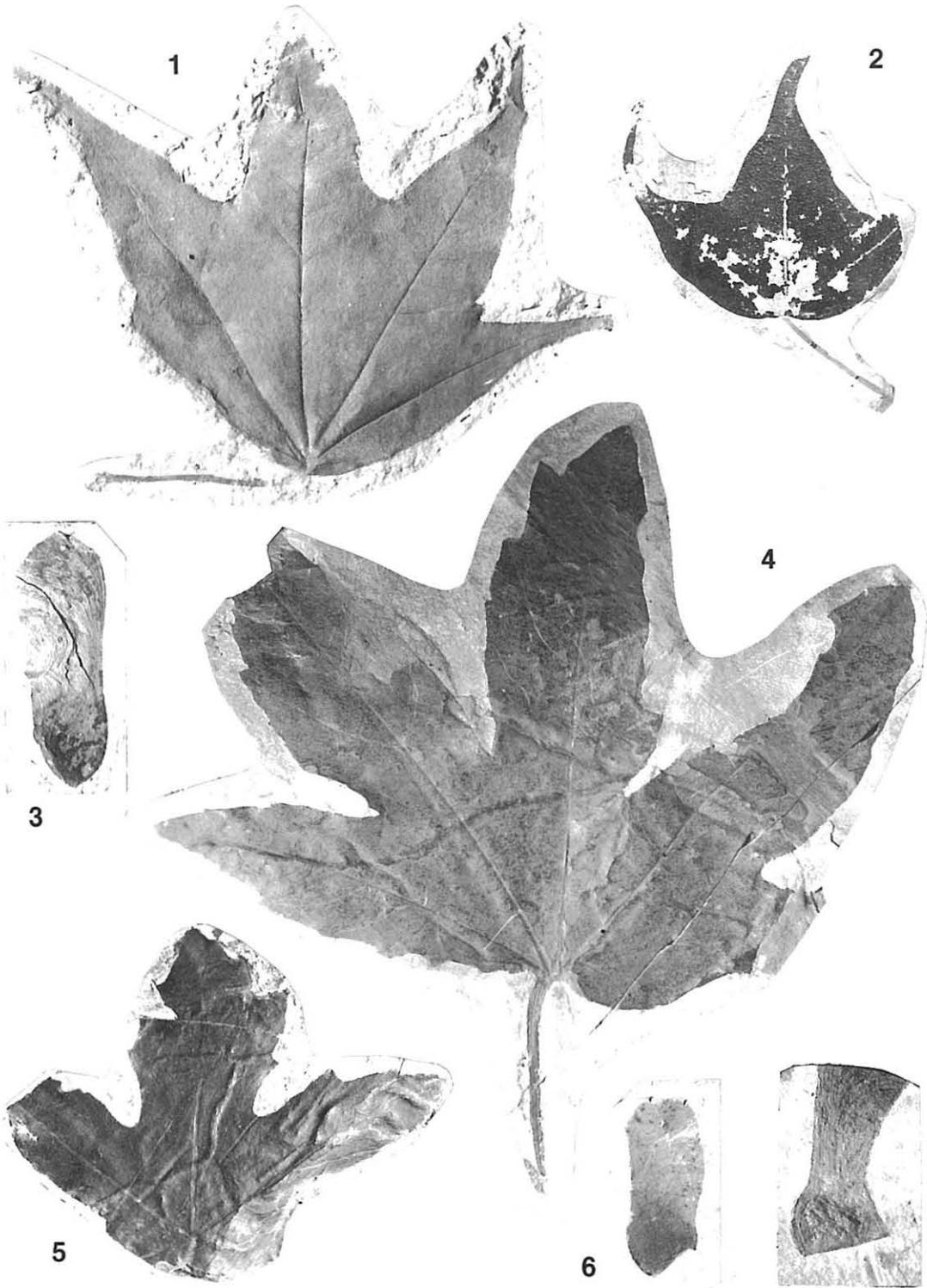
Fig. 3. *Acer rotundatum* Huzioka. Kudo, Taisei-mura, Hokkaido (Sekinai Formation). HUMP no. 27139.

Fig. 4. *Acer kushiroanum* Tanai. Yubetsu, Akan, Hokkaido (Yubetsu Formation). Holotype HUMP no. 25990.

Fig. 5. *Acer kushiroanum* Tanai. Shimizusawa, Yubari, Hokkaido (Yubari Formation). AKMG no. 6254.

Fig. 6. *Acer rotundatum* Huzioka. Yongil, South Korea (Yeonil Group). HUMP no. 26227.

Fig. 7. *Acer kushiroanum* Tanai. Shimizusawa, Yubari, Hokkaido (Wakanabe Formation). HUMP no. 26228.



the Miocene of Japan.

Acer miofranchetii Hu et Chaney. 1938. (part). Palaeont. Sinica. n. ser. A. (1): 58. pl. 32. f. 2; pl. 33. f. 2. [Shangwang, China]

Acad. Sinica. 1978 (part). Cenozoic plants of China. p. 126. pl. 106. f. 5; pl. 107. f. 7; pl. 110. f. 3. [Shanwang, China]

Guo. 1978. Acta Palaenot. Sin. 17 (3): 348. pl. 1. f. 7 [Dechang, China]

These trilobed leaves from Shangwang are probably included in *Liquidambar miosinica* Hu et Chaney by their marginal teeth and looping of secondary veins. The foliar shape such as these leaves are rather common in leaves of the extant *L. formosana* Hance of China, although the holotype of *L. miosinica* is obtuse at the base and elongate in each lobe.

Acer miohenryi Hu et Chaney 1938 (part). Palaeont. Sinica. n. ser. A. (1): 59. pl. 33. f. 3c; pl. 34. f. 2; pl. 35. f. 2. = *Zelkova ungeri* (Ettings.) Kavats [Shanwang, China]

As already pointed out by Brown (1946), the regularly single serrate margin with equal-sized teeth and secondary venation character show that these leaves are identical with *Zelkova ungeri*, which is also common in the Shanwang flora.

Acer miohenryi Hu et Chaney. 1938 (part). Palaeont. Sinica. n. ser. A. (10): 59. pl. 35. f. 4. = *Sorbus* ? sp. [Shangwang, China]

This single leaf is distinctly different from that of *Acer henryi* Pax in the duplicate serrate margin with a sharply acuminate tip. It was suggested to belong to the Rosaceae (Acad. Sinica, 1978), probably to *Sorbus*.

Acer protopalmatum K. Suzuki. 1961. Sci. Rept. Fukushima Univ. (10): 83. pl. 18. f. 6-9 = *Liquidambar* sp. [Fujitoge, Fukushima Pref.]

This species based on four leaves from the Upper Miocene of northern Honshu, was compared with the extant *A. palmatum* Thunb. by the lanceolate lobes and finely serrate margin. Although the original specimens are ill-preserved, they are distinctly glandular at the margin with incurved teeth and are irregularly branching more than twice within the medium-sized areoles. These characters indicate that these leaves are

Explanation of Plate 12

(all figures in natural size)

Figs. 1, 2. *Acer yamanae* Tanai et Ozaki. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). NSM-PP 16216 (Fig. 1); GSJ no. 4827 (Fig. 2).

Fig. 3. *Acer yamanae* Tanai et Ozaki. Kani, Gifu Pref. (Hiramaki Formation). Dr. Ina's collection.

Fig. 4. *Acer subcarpinifolium* Tanai. Shanabuchi, Engaru, Hokkaido (Shanabuchi Formation). Paratype HUMP no. 25909.

Fig. 5. *Acer subcarpinifolium* Tanai. Bifuka, Hokkaido (Ote Formation). HUMP no. 26336.

Fig. 6. *Acer yamanae* Tanai et Ozaki. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype NSM-PP 16022.



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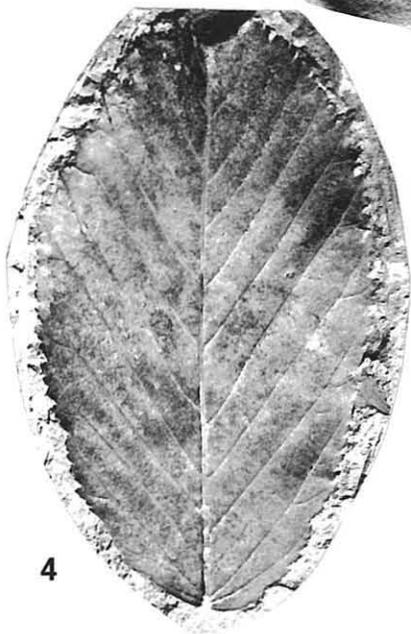
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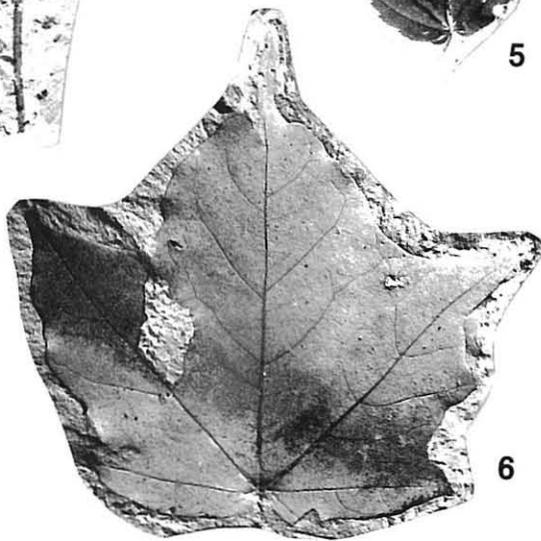
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not referable to *Acer* but to *Liquidambar*. These leaves of Fujitoge are somewhat different in slender five-lobation from *Liquidambar miosinica* which is common in the Neogene of East Asia. On the one hand, these five-lobed leaves are distinguishable from those of the extant *L. styraciflua* L. by somewhat smaller areoles.

Acer prototrifidum auct. non Tanai. Hojo. 1973. Mem. Fac. Sci., Kyushu Univ. [D]. 22 (1): 31. pl. 9. f. 12. = *Liquidambar miosinica* Hu et Chaney [Suki, Oki Isl., Shimane Pref.]

The glandular teeth of margin and more than twice branching veinlets show clearly that this leaf is referable to *Liquidambar*.

Acer rettichovicum Ablaeu et Schmidt ex Schmidt. 1975. Materials on Palaeont. Stratigr. Cont. deposits Far East. p. 51. pl. 11. = *Platanus bendirei* (Lesq.) Wolfe [Rettikhovskaya, Primorye]

The large dentation of margin in this leaf is quite unlike to that of any extant maple leaves, and is similar to that of *Platanus*. Although the original specimen lacks its basal portion, a cautious reinvestigation may confirm to be referable to *P. bendirei* which is one of the common members in the Miocene of the western United States including Alaskan region.

Acer sibiricum Heer. 1978 (part). Mem. Acad. Sci. St. Petersburg. [7]. (2596): 46. pl. 12 f. 1b. = *Menispermites* sp. [Simonova, Western Siberia]

Of six specimens illustrated as *A. sibiricum*, a single specimen is excluded from *Acer* by its apparently peltate character, and it probably belongs to the Menispermaceae.

Acer ternicum Akhmetjev et Schmidt. 1976. Geol. Palaeont. Rept. Far East. p. 85. pl. 10. f. 5; text-f. 1-25. = genus and species indetermined [Sobolevka River, Primorye]

This fragmentary leaf is too incomplete to be assignable to *Acer*, because its lower half of the blade is missing. Although this fossil leaf resembles *A. tricuspdatum* Bronn

Explanation of Plate 13

(all figures in natural size)

Fig. 1. *Acer palaeodiabolicum* Endo. Mitoku, Misasa, Tottori Pref. (Mitoku Formation). GSJ no. 4177.

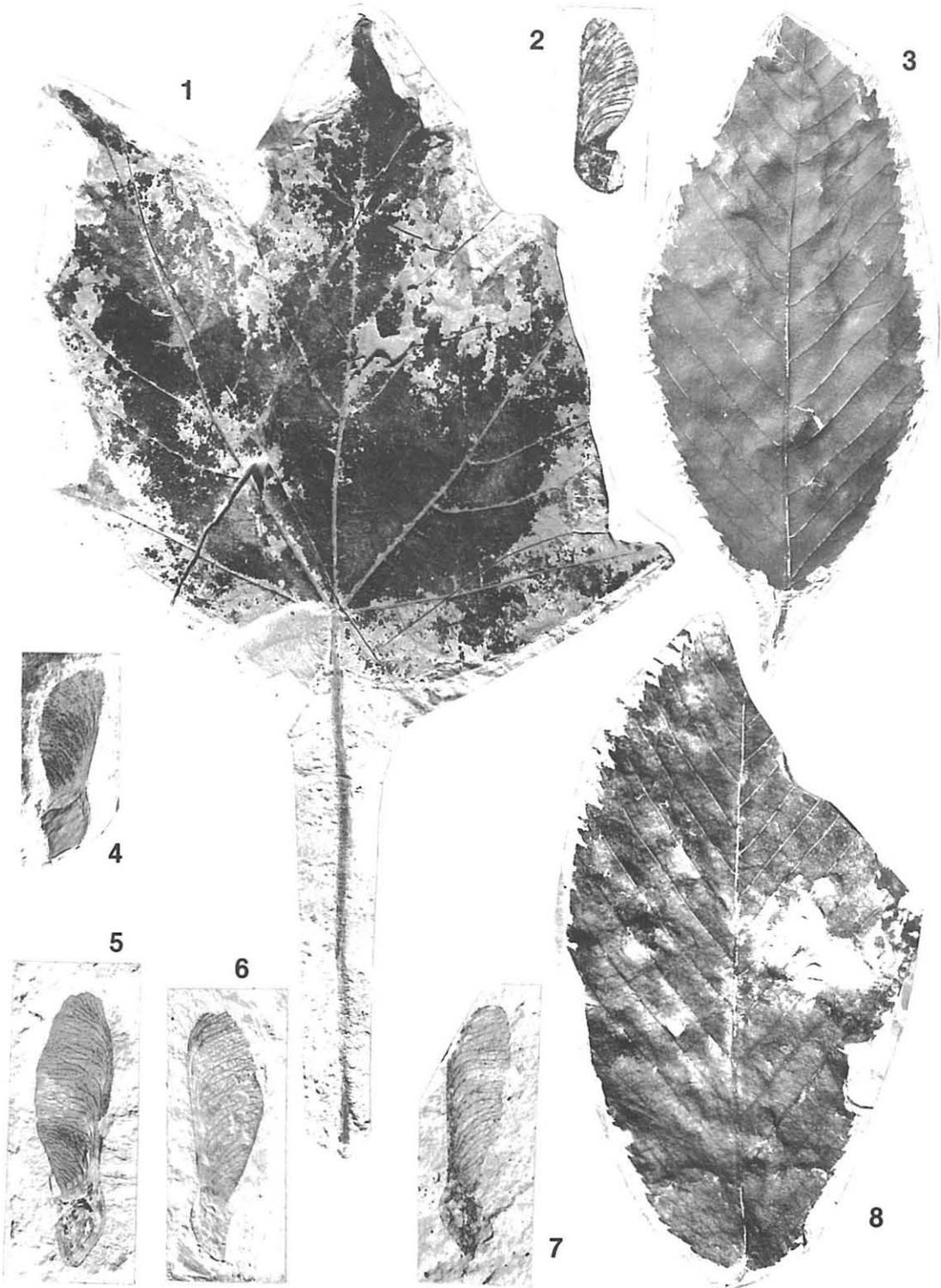
Fig. 2. *Acer miofranchetii* Hu et Chaney. Shanwang, China. Holotype Nat. Geol. Survey China no. 183b. [reproduced from the illustration of Hu and Chaney (1938)]

Figs. 3, 8. *Acer subcarpinifolium* Tanai. Bifuka, Hokkaido (Ote Formation). HUMP nos. 26337, 26338.

Fig. 4. *Acer palaeodiabolicum* Endo. Kilju, North Korea (Hamjindong Formation). Holotype IPGS no. 60989.

Fig. 5. *Acer palaeodiabolicum* Endo. Rubeshibe, Hokkaido (Kamatsuzawa Formation). HUMP no. 25895.

Figs. 6, 7. *Acer palaeodiabolicum* Endo. Chojabaru, Iki Isl., Nagasaki Pref. ("Wakamatsu" Formation). HUMP nos. 26334, 26335.



at a glance, it resembles also leaves of *Platanus* or *Viburnum* at the marginal feature.

Acer ukurunduense auct. non Trautv. et Meyr. Iwao. 1975. Rept. Fac. Sci. Eng., Saga Univ. (3): 93. pl. 5. f. 2, 5. = *Kalopanax* sp. cfr. *K. pictus* (Thunb.) Nakai. [Togo, Kagoshima Pref.]

These two leaves with five to seven lobes are excluded from *Acer ukurunduense* by the distinct looping of the secondary veins, and they are probably included in *Kalopanax pictus* by their foliar shape and marginal character.

Acer sp. Heer. 1878. Mem. Acad. Imp. Sci. St. Petersburg. [7]. 25 (7). pl. 15. f. 11a. = genus et species indeterminated. [Khanka Lake, Primorye]

This incomplete leaf with finely serrate margin shows no character to be referable to the genus *Acer*.

Acer sp. Matsuo. 1971. Ann. Sci., Kanazawa Univ. 8: 31. pl. 1. f. 13a. = genus and species indeterminated. [Kishima coal mine, Saga Pref.]

This fragmentary specimen has no features referable to *Acer*. Although it was described as a trilobed leaf, it looks to be composed of two overlapped simple leaves.

Acer sp. Konstantow. 1914. Mem. Comité Geol. n. ser. 113: 9. pl. 5. f. 1. = genus and species indeterminated. [Breja, Ussuri]

This incomplete specimen shows no features to be referable to *Acer*, and it may be probably to be referred to *Platanus*.

Acer sp. Kryshstofovich. 1939. Publ. 50th Anniv. Sci. Educ. Activity, M-L. p. 283. pl. 2, fig. 1. = genus and species indeterminated. [Siniy Utios, Ussuri]

This specimens is too fragmentary to make its generic assignments.

Acer sp. Oishi et Huzioka. 1943. J. Fac. Sci., Hokkaido Univ. [4]. 7 (1). pl. 14. f. 2. = *Liquidambar* sp. [Kamiashibetsu, Hokkaido]

Although ill-preserved, the incurved acute teeth with glands indicate that this small trilobed leaf is referable to *Liquidambar*.

Explanation of Plate 14

(all figures in natural size)

Fig. 1. *Acer subcarpinifolium* Tanai. Honhorobetsu, Utanobori, Hokkaido (Honhorobetsugawa Formation). Paratype HUMP no. 23342.

Figs. 2, 5. *Acer subcarpinifolium* Tanai. Bifuka, Hokkaido (Ote Formation). HUMP nos. 23343, 23344.

Figs. 3, 4. *Acer subcarpinifolium* Tanai. ditto. Holotype HUMP no. 26339 (Fig. 4): HUMP no. 26340 (Fig. 3).

Fig. 6. *Acer grahamense* Knowlton et Cockerell. Abura, Setana, Hokkaido (Babagawa Formation). HUMP no. 25029.



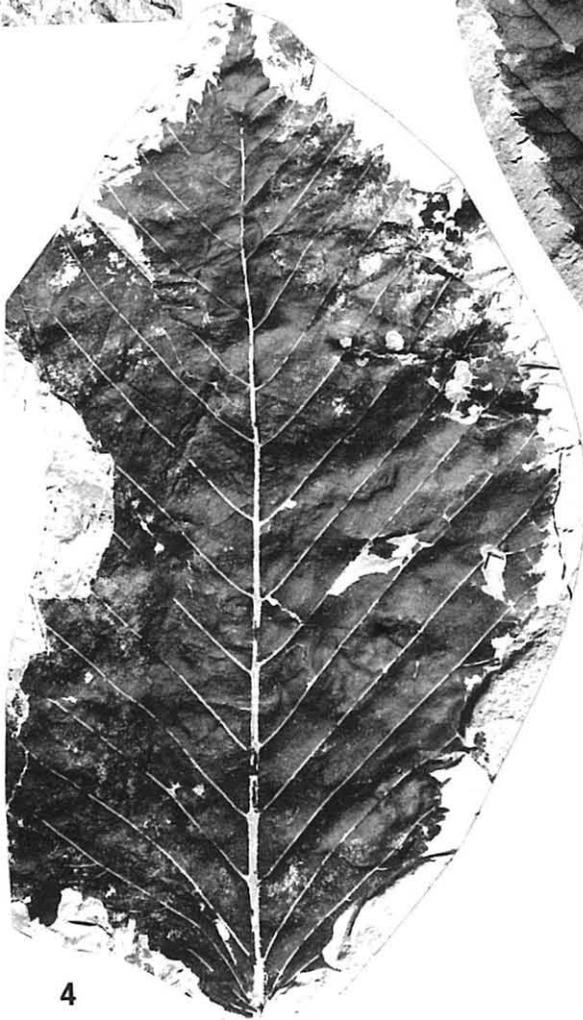
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Acer sp. Huzioka. 1943. J. Fc. Sci., Hokkaido Univ. [4]. 7 (1): 135. pl. 25. f. 1. = *Kalopanux* sp. cf. *K. n-suzukii* Wolfe et Tanai [Yongdong, North Korea]

A single ill-preserved leaf from Korea is excluded from *Acer* by the looping of the secondary veins, and is referable to *Kalopanux* by its shallowly lobed shape, the secondary looping and serrate marginal character.

Acer sp. Akhmetjev. 1973. Acad. Sci. USSR Geol. Inst. Trans. 247: 76. pl. 21. f. 9 = genus and species indetermined [Botchi River, Primorye]

This incomplete leaf is difficult to refer to *Acer* because of ill-preservation, although it was compared with the extant *A. campestre* L. by Akhmetjev (1973).

Acer sp. Chelebaeva. 1976. Acad. Sci. USSR Geol. Inst. Trans. 294: 100. pl. 18. f. 2, 4. = genus and species indetermined [Kheysli River, Kamchatka]

This fragmentary specimen has no definite character to be referable to *Acer*.

Acer sp. Hori. 1976. Fossil plant from Kobe p. 132. pl. 14. f. 1; text-f. 133. = genus and species indetermined. [Kobe, Hyogo Pref.]

These two oblong leaves with finely serrate margin have no characters of venation and margin to be referable to *Acer*. The oblong leaves of the extant *A. fabri* Hance of southern China and *A. laevigatum* Wall. of Himalaya are sometimes serrate at the margin, but they are quite different from these fossils in the tertiary venation and coarse serration of margin.

Acer sp. Ina. 1977. Geol. & Paleont. Kani Town. p. 85. pl. V-24. f. 4. = *Liquidambar* sp. [Hiramaki, Gifu Pref.]

A single five-lobed leaf from Hiramaki is probably referred to *Liquidambar* by its marginal character. This specimen was also illustrated again as *Acer* sp. by Ina (1981).

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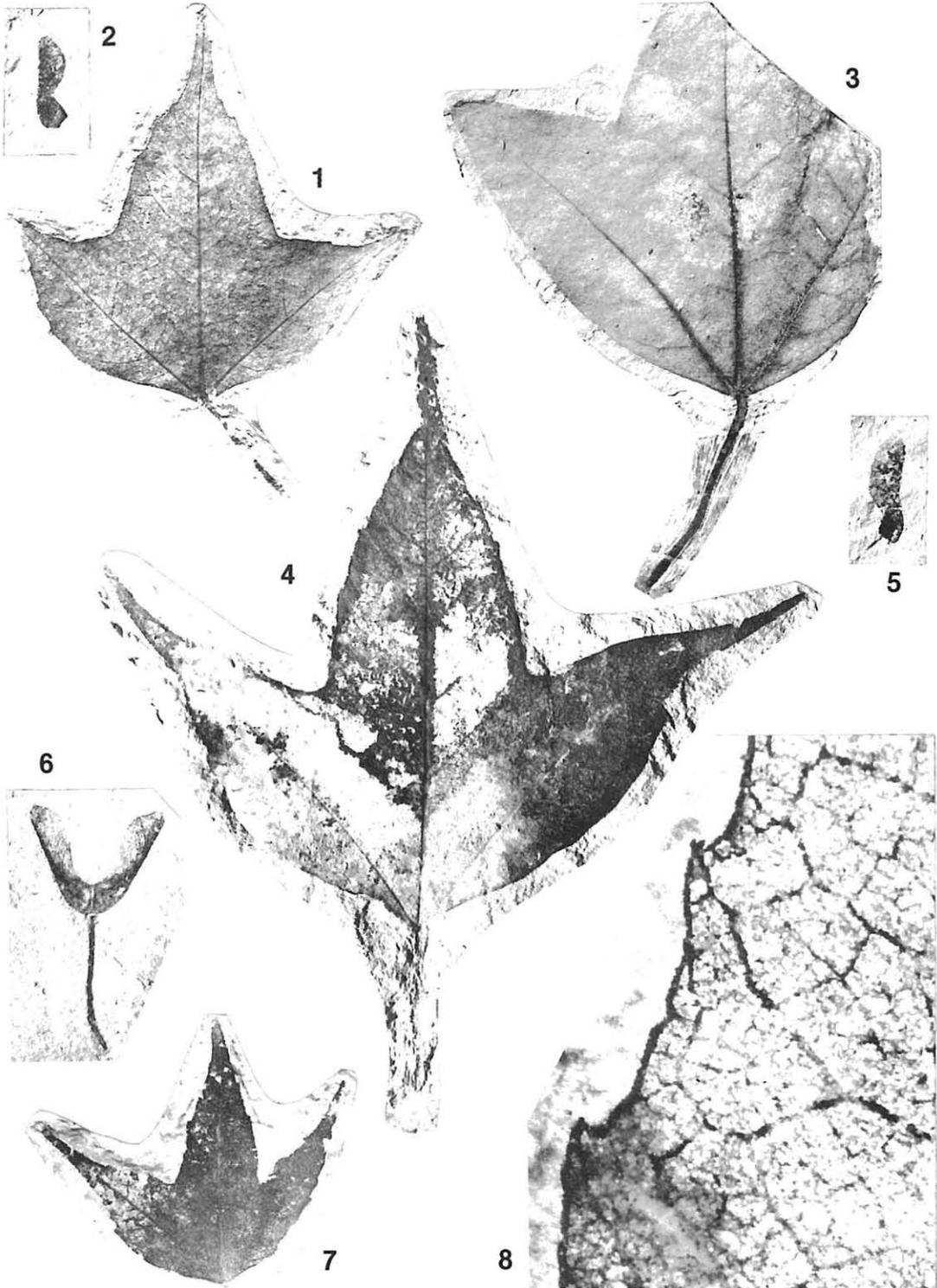
Explanation of Plate 15

(all figures in natural size unless otherwise stated)

Fig. 1. *Acer prototrifidum* Tanai. Chojabaru, Iki Isl., Nagasaki Pref. ("Wakamatsu" Formation). Neotype HUMP no. 26229.

Figs. 2-7. *Acer prototrifidum* Tanai. ditto. HUMP nos. 26230-26233, 26250, 26351.

Fig. 8. Showing serrate teeth and fimbrial vein at the margin in the neotype specimen of *Acer prototrifidum* (Fig. 1). $\times 10$.



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Explanation of Plate 16

(all figures in natural size)

Figs. 1, 2. *Acer fatsiaefolium* Huzioka. Kyeongweon, North Korea ("Engelhardia Beds"). IGPS no. 60993a, b.

Figs. 3, 4. *Acer honshuense* Tanai et Ozaki. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype TPM-382 (Fig. 3); paratype NSM-PP-16215 (Fig. 4).

Fig. 5. *Acer fatsiaefolium* Huzioka. Keumkwandong, Yeongil, South Korea (Changgi Group). IGPS no. 30990.

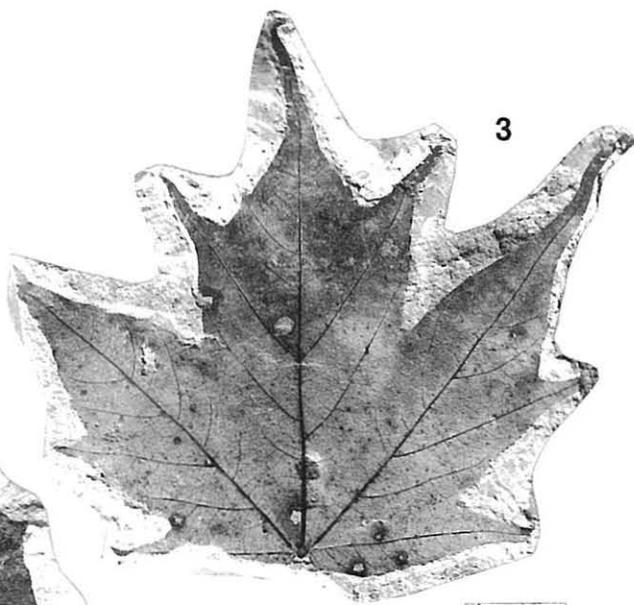
Fig. 6. *Acer fatsiaefolium* Huzioka. ditto. Holotype HUMP no. 9342.



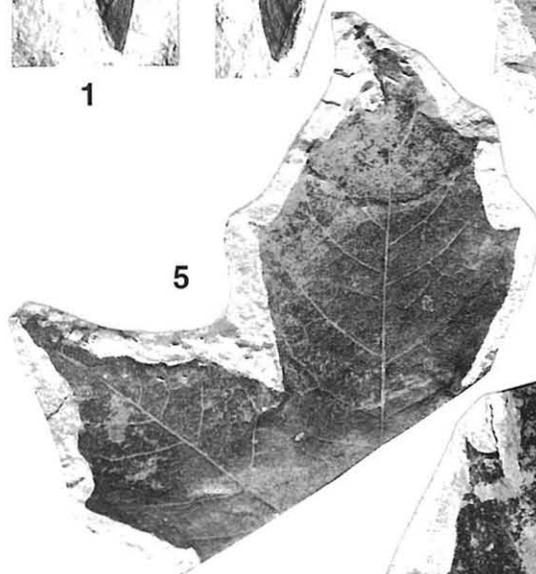
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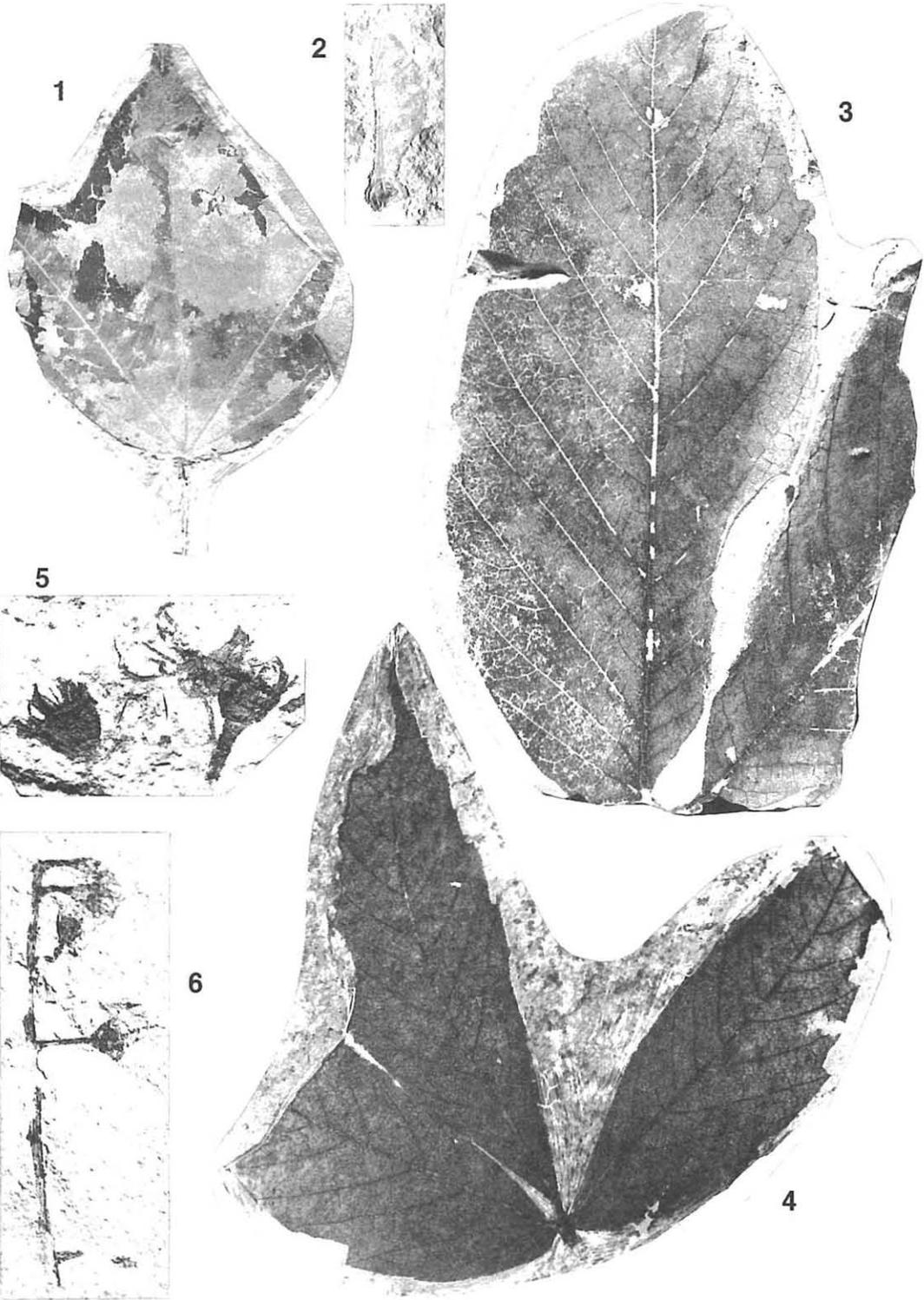
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Explanation of Plate 17

(all figures in natural size unless otherwise stated)

- Fig. 1.** *Acer prototrifidum* Tanai. Mogi, Nagasaki, Nagasaki Pref. (Mogi plant-bearing Formation). IGPS no. 7725.
- Fig. 2.** *Acer koreanicum* Endo. Kogeaonwon, North Korea ("Engelhardia Beds"). Holotype IGPS no. 60996.
- Fig. 3.** *Acer subnikoense* Tanai et Ozaki. Tatsumitoge, Tottori Pref. (Tatsumitoge Formation). Holotype NSM-PP 16017.
- Fig. 4.** *Acer trifoliatum* Geng. Shanwang, China (Shanwang Group). Paleobotany Collection of Academia Sinica (Inst. of Botany). reproduced from the illustration of "Cenozoic Plants of China" (Acad. Sinica, 1978).
- Fig. 5.** *Acer* sp. detached male flowers. Chojabaru, Iki Isl., Nagasaki Pref. ("Wakamatsu" Formation). HUMP no. 26347. × 2.5.
- Fig. 6.** *Acer* sp. An incomplete racemose inflorescence. *ditto*. HUMP no. 26348. × 1.5.



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Explanation of Plate 18

(Showing the areolation and ultimate veinlets)

Fig. 1. *Acer palaeorufinerve* Tanai et Onoe. HUMP no. 26201 (pl. 5, f. 10). ×40

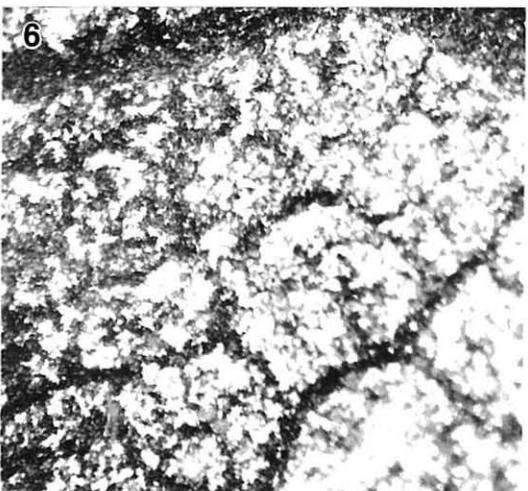
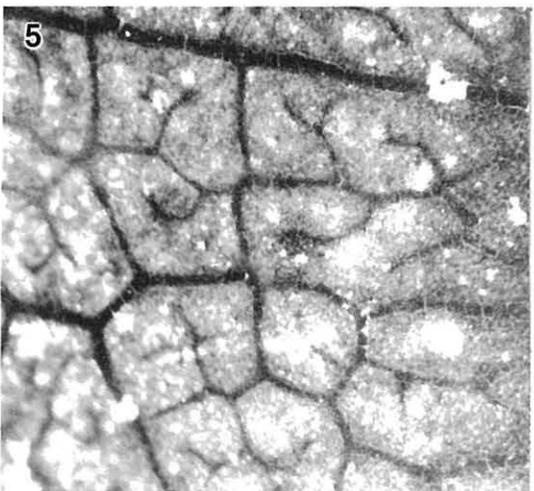
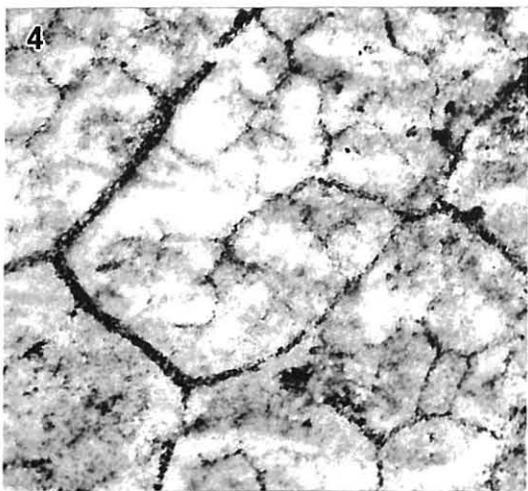
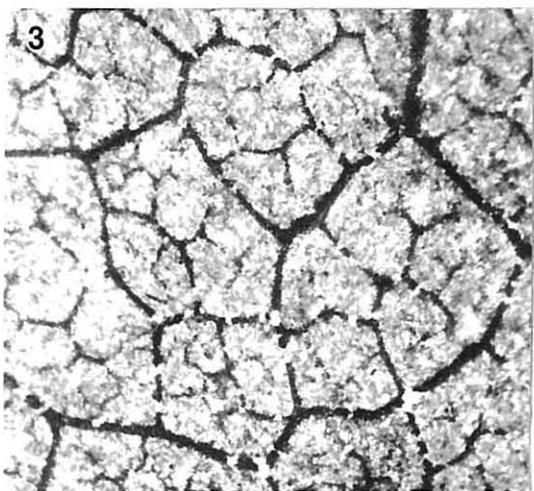
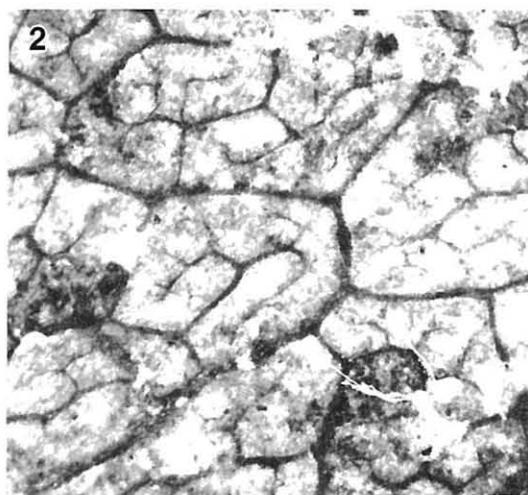
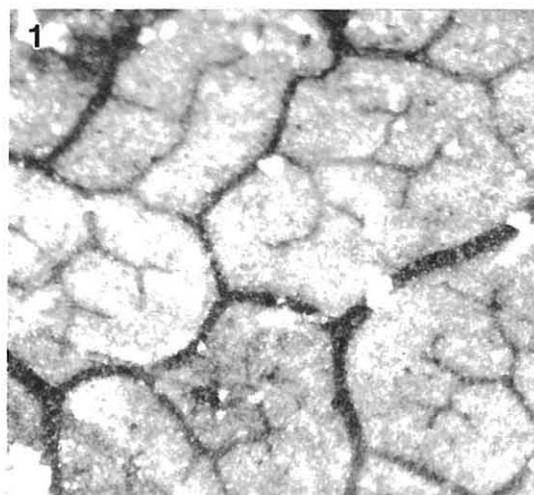
Fig. 2. *Acer protomatsumurae* Tanai. Holotype GSJ no. 4777 (pl. 3, f. 5). ×40

Fig. 3. *Acer protojaponicum* Tanai et Onoe. HUMP no. 25037 (Tanai & N. Suzuki, 1960: pl. 5, f. 6). ×25

Fig. 4. *Acer oishii* Tanai. HUMP no. 26206 (pl. 4, f. 7). ×25

Fig. 5. *Acer subcarpinifolium* Tanai. HUMP no. 26338 (pl. 13, f. 8). ×40

Fig. 6. *Acer arcticum* Heer. HUMP no. 26205 (pl. 2, f. 3). ×40



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Explanation of Plate 19

(Showing the areolation and ultimate veinlets)

Fig. 1. *Acer fatsiaefolium* Huzioka. Holotype HUMP no. 9342 (pl. 16, f. 6). ×25

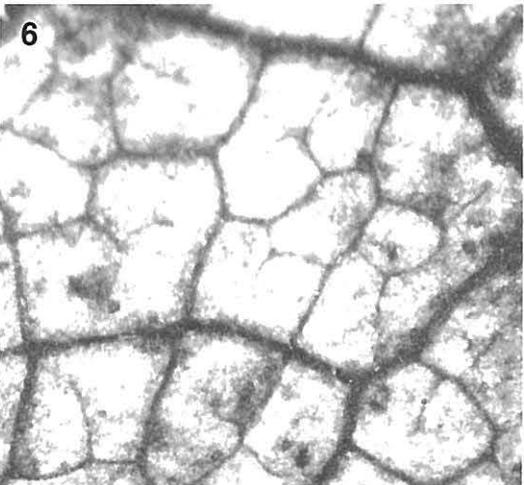
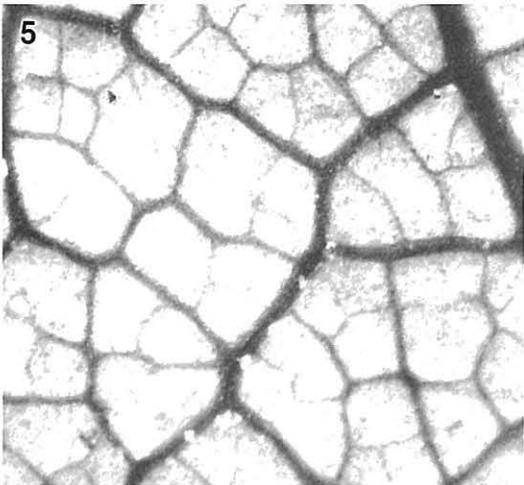
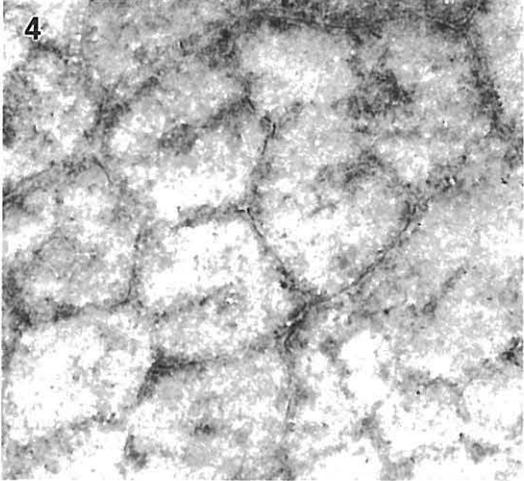
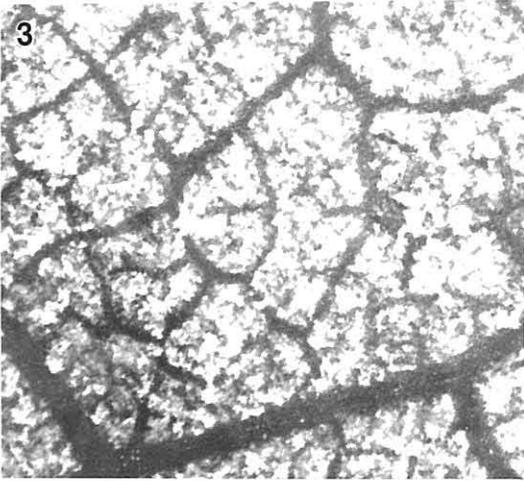
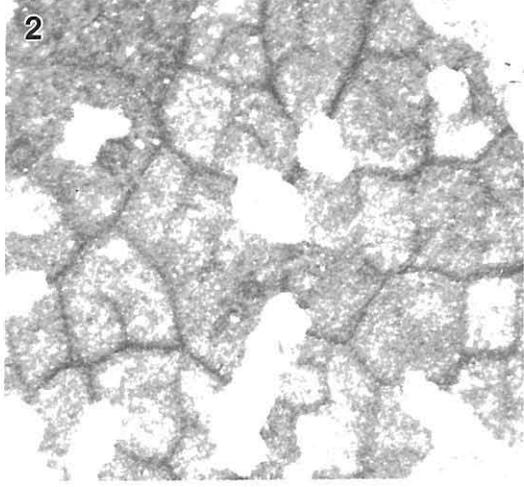
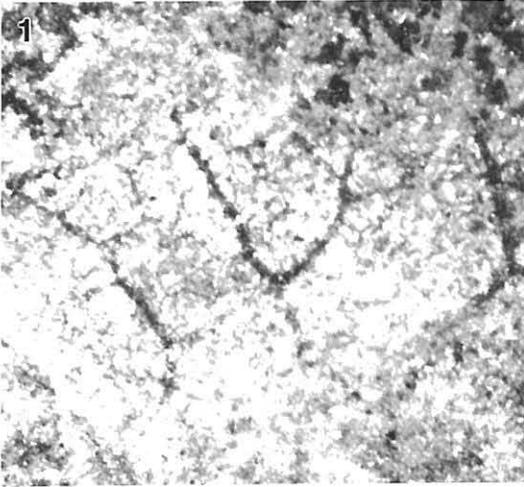
Fig. 2. *Acer kushiroanum* Tanai. Holotype HUMP no. 25990 (pl. 11, f. 4). ×40

Fig. 3. *Acer protomiyabei* Endo. HUMP no. 25010 (Tanai & N. Suzuki, 1960: pl. 2, f. 2). ×40

Fig. 4. *Acer rotundatum* Huzioka. HUMP no. 25913 (N. Suzuki, 1963: pl. 5, f. 3). ×40

Fig. 5. *Acer chiharae* Huzioka. Paratype AKMG no. 3313 (pl. 10, f. 2). ×40

Fig. 6. *Acer chiharae* Huzioka. HUMP no. 26223 (pl. 10, f. 3). ×40

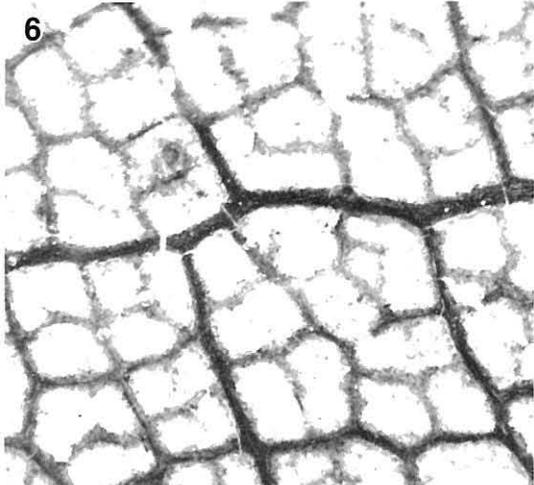
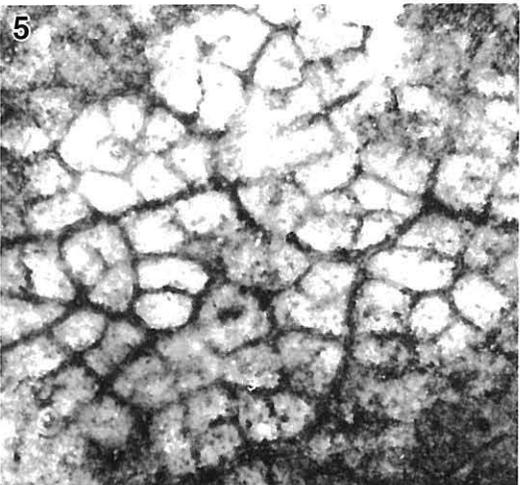
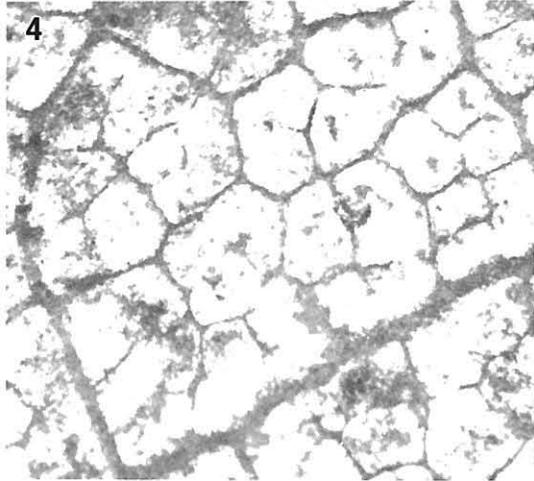
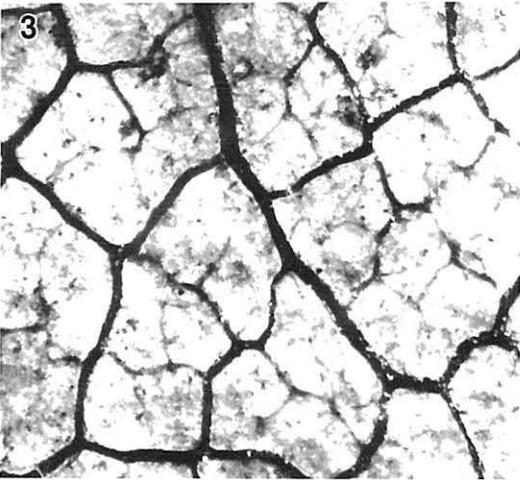
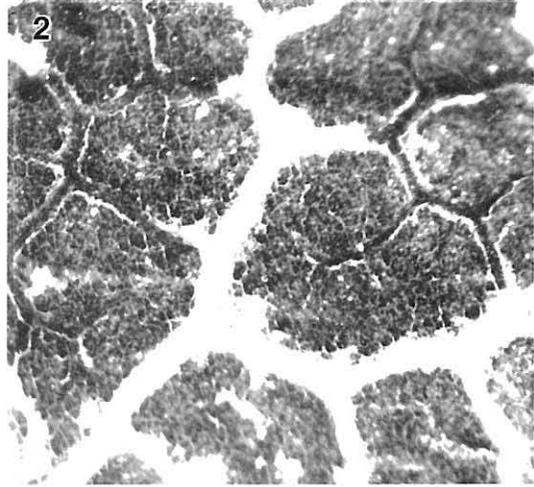
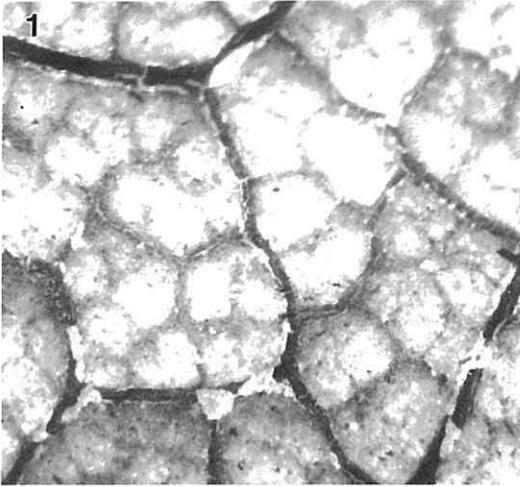


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Explanation of Plate 20

(Showing the areolation and ultimate veinlets; all figures $\times 40$)

- Fig. 1.** *Acer ezoanum* Oishi et Huzioka. Dr. Ina's collection (pl. 7, f. 5).
Fig. 2. *Acer ezoanum* Oishi et Huzioka. HUMP no. 26217 (pl. 6, f. 6).
Fig. 3. *Acer subnikoense* Tanai et Ozaki. Holotype USM-PP 16017 (pl. 17, f. 3).
Fig. 4. *Acer yamanae* Tanai et Ozaki. Holotype NSM-PP 16022 (pl. 12, f. 6).
Fig. 5. *Acer palaeodiabolicum* Endo. GSJ no. 4177 (pl. 13, f. 1).
Fig. 6. *Acer prototrifidum* Tanai. IGPS no. 7725 (pl. 17, f. 1).



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(Manuscript received on Sept. 3, 1983)