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# ENGELHARDIA FRUITS FROM THE TERTIARY OF JAPAN*

*by*

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(With 2 text-figures and 3 plates)

*Abstract*

The winged fruits of *Engelhardia* (Juglandaceae) are described on the basis of the new materials from Kitami in Hokkaido and Heki in Yamaguchi Prefecture, in addition to the re-investigation of the type specimens of *E. koreanica* Oishi and *E. poronaica* Endo. All the winged fruits known from East Asia are identical with *E. koreanica* in all characters. *E. koreanica* is characterized by trilobed fruits which have marked stalk, pinnate venation, straight primaries reaching the apices and branched fine veinlets. *E. koreanica* shows a close relationship to the extant *E. roxburghiana* Wall. of the section Psilocarpeae in the above-noted characters.

Reviewing *Engelhardia* bearing floras in Japan, North Korea, southern Primorye and Sikhote-Alin, they are concluded to be of Late Oligocene age by floristic composition, as well as by K-Ar datings and other biostratigraphic evidences.

## Introduction

Fossil winged fruits of *Engelhardia* (Jugalndaceae) and its closely allied *Oremunnea* are easily distinguishable by their marked trilobed bracts, compared with the difficulty of identifying their fossil leaflets. The wide distribution of *Engelhardia* in the Northern Hemisphere during the Tertiary is proved by winged fruits, along with pollen and leaflets. These fossil evidences were reviewed lately by Leopold and MacGinitie (1972) and Dilcher et al. (1976). Especially, it is noteworthy for the evolutionary history of the Juglandaceae that two extinct genera, *Paraoreomunnea* and *Paleooreomunnea* closely related to *Oreomunnea* of the New World, were established from the Middle Eocene of the southeastern United States. Jänichen et al. (1977) also summarized European fossil records of *Engelhardia*, based on the detailed revision of a number of leaves, winged fruits and nutlets, although they treated the genus *Oreomunnea* as one section of the genus *Engelhardia.*

As early as 1936, Oishi described first the fossil *Engelhardia* fruits from the North Korean Tertiary in East Asia. Additional materials from the Korean Tertiary have been examined later by Endo (1939) and Huzioka (1972). Common occurrences of *Englelhardia* from southern Primorye and Sikhote-Alin, USSR have been recently reported by such Russian authors as Akhmetyev and Bratzeva (1973), Ablaev and Solonovskaja (1975), and Ablaev (1978). All the winged fruits described from the Tertiary of East Asia were referred to a single species, *Engelhardia koreanica* Oishi. In contrast with common occurrence in Asian Mainland, the fossil records of *Engelhardia* have been scarcely known in Japan except for an Oligocene winged fruit from Hokkaido and some Miocene and Oligocene pollen from Hokkaido and Kyushu (Sato, 1963; Takahashi, 1961).

A single winged fruit of *Engelhardia* was recently reported from the "Miocene

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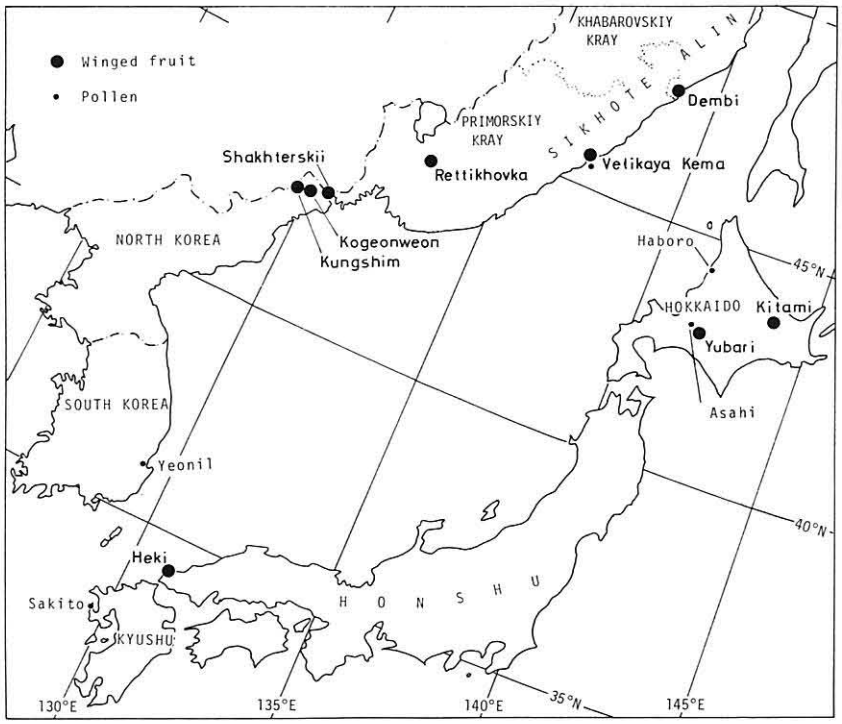
Wakamatsuzawa Formation" in Kitami province of northeastern Hokkaido by N. Suzuki et al. (1976), although it was only illustrated without the description. Through our stratigraphical reinvestigation during these years, we also collected some *Engelhardia* fruits from the same formation at two localities, along with a number of the well-preserved leafy twigs of conifers and deciduous broad leaves. These new materials with well preservation of venation provide an important information not only for the morphological characters but for the past phytogeographical distribution in East Asia.

In this paper the floristic characteristics and geological age of the *Engelhardia*-bearing floras of East Asia are briefly discussed, in addition to the taxonomic survey of *Engelhardia* fruits. This study is based on an examination of the fossil specimens stored at the Paleontology Museum of Hokkaido University (Oishi, 1936), the Institute of Geology and Paleontology, Tohoku University (Endo, 1939), and the National Science Museum of Tokyo (Endo, 1968), and unlabelled specimens available at the Museum of Geological Survey of Japan and National Sicence Museum, and new materials collected by us.




**Text-fig. 1.** Tertiary distribution of *Engelhardia* in East Asia.

## Materials from the Tertiary of East Asia

All the fossil specimens from Japan are represented by the detached winged fruits. Their localities and geological informations are as follows:

Kitami: Loc. Minamigaoka (NSM-PP 16334) and loc. Wakamatsuzawa (NSM-PP 16333, 16351); Wakamatsuzawa Formation, probably Middle or late Oligocene.

Yubari: Loc. Futamata, Yubari City, Hokkaido; Upper part (G-zone) of the Poronai Formation, Middle or late Oligocene; NSM-10461 (holotype of *E. poronaica* Endo, 1968); collected by A. Teshima.

Heki: Kiwado, Heki-mura, Yamaguchi Prefecture; the basal part of the Jyuraku Formation, Late Oligocene or Early Miocene; GSJ-F-5069; collected by T. Onoe.

In East Asia outside of Japan the fossil winged fruits of *Englehardia* have been described as follows:

North Korea

Kogeonweon: Yongpukdong, Kogeonweon coal field, Hamg'yeong-bukdo; "*Engelhardia* Beds", probably Late Oligocene; HUMP no. 6478a, b, c (Oishi, 1936; Huzioka, 1972); IGPS-51795 (Endo, 1939); NSM-PP 16332.

Kungshim: Kungshim coal mine, Hoeryeong, Hamg'yeong-bukdo; Hoeng-yeong Formation, probably Late Oligocene; IGPS-92376, 92325a (Endo, 1943; Huzioka, 1972).

Asian region of USSR

Velikaya Kema: Velikaya Kema village, Sikhote-Alin; Kizin member, probably Late Oligocene (Akhmetyev & Bratzeva, 1973).

Dembi: Dembi Bay, south of Nelma village, Sikhote-Alin; Kchutsin member, probably Late Oligocene (Akhmetyev & Bratzeva, 1973).

Rettikhovka: Rettikhovka depression, southern Primorye; Nadezhdinskaya member, probably Late Oligocene (Akhmetyev & Bratzeva, 1973; Ablaev, 1978).

Shakhterskii: Shakhterskii, southern Primorye; Khasanskaya Formation, probably Late Oligocene (Ablaev, 1978).

The localities of fossil winged fruits of *Engelhardia* in East Asia are shown in Figure 1. The fossil records of *Engelhardia* pollen are also added in the figure from our bibliographic survey. However, eight Tertiary species of *Engelhardia* pollen described from Primorye by Bolotnikova (1975b) are not included in Figure 1, because she did not show any accurate localities.

## Description of the Species

Family Juglandaceae

Genus *Engelhardia* Lechen. ex Bl.

*Englehardia koreanica* Oishi

(Pl. 1, figs. 1-7; pl. 2, figs. 1, 7; pl. 3, figs. 1, 2; text-fig. 2)

*Englehardia koreanica* Oishi. 1936. J. Geol. Soc. Japan, vol. 43, p. 58, text-fig. 1-3.
Endo. 1939. Jubil. Publ. Commem. Prof. H. Yabe's 60th Birthday, vol. 1, p. 337, pl. 23, figs. 1, 2.
Huzioka. 1955. Trans. Proc. Palaeont. Soc. Japan, N.S., no. 19, p. 59.
Huzioka. 1972. J. Mining Coll. Akita Univ., ser. A, vol. 5, p. 43, pl. 2, figs. 9, 10, 10a.
Akhmetyev and Bratzeva. 1973. Rev. Palaeobot. Palynol., vol. 16, p. 130 pl. 1, figs. 2-6, 8-11 [new emendation was given]
Ablaev. 1978. Geol. Foss. Fl. Japan Sea Coast, p. 129, pl. 14, fig. 3; pl. 23, fig. 4.
*Englelhardia poronaica* Endo. 1968. Bull. Natn. Sci. Mus. Tokyo vol. 11, p. 421, pl. 6, fig. 2.

*Lectotype:* HUMP-6478c (Oishi, 1936, text-fig. 3). Oishi's original types (syntypes) include three figured specimens among which the lectotype is chosen. Though Oishi's fig. 3

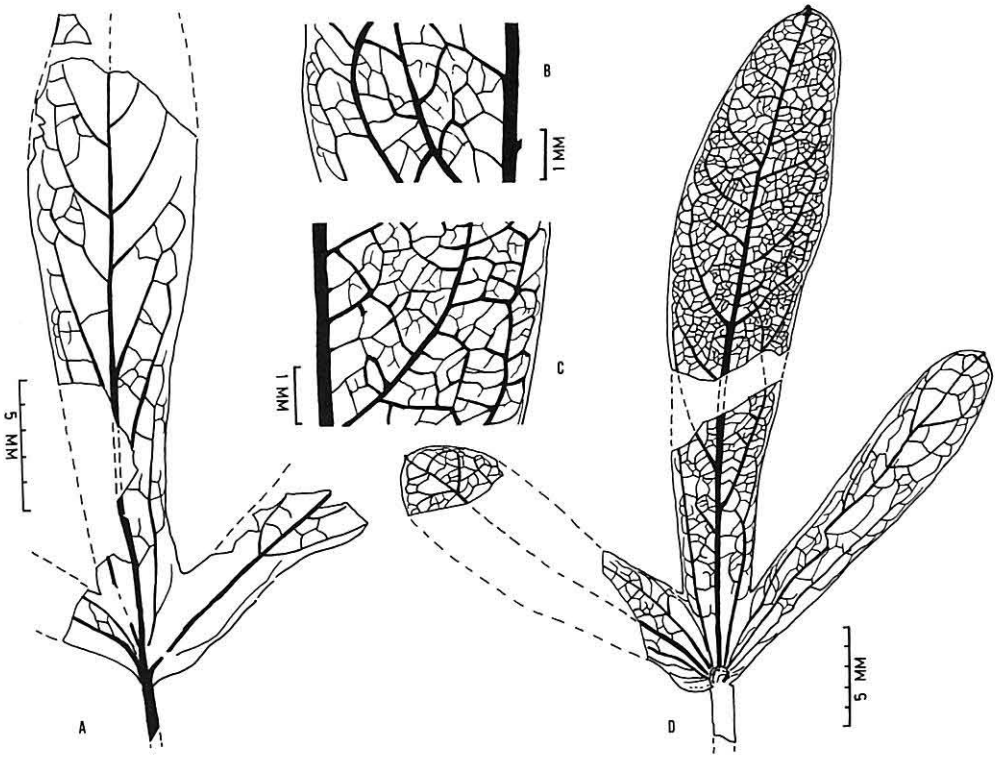
illustrates only the basal part, the remaining upper part is found in the HUMP collection as figured in the present paper. This specimen (lecto-type) preserves the fine details of the venation.

*Type locality and stratigraphic occurrence:* Yongpukdong, Kogeonweon coal field, Hamg'yeong-bukdo, North Korea; "*Engelhardia* Beds" (Oishi, 1936), probably of Late Oligocene.

*Supplementary description:* Winged fruits stalked, comprising a nutlet with a deeply incised, 3-lobed bract; stalk medium in thickness, 2.5–4mm long or much longer. Central lobe longer than laterals, oblanceolate, 3.4–5cm long and 6–8mm wide; lateral lobes oblanceolate to narrow oblong, usually inequilaterally diverging at angles of 35–80° from central lobe, 1.3–2.2cm long and 3.5–8mm wide; apex of each lobe obtuse to rounded, or sometimes mucronate; base in equilaterally obtuse to rounded. Venation within each lobe pinnate; primary vein strong, nearly straight or somewhat arcuate in course, occassionally slightly flexuous in upper half of the lobes, terminating at the apex where the remains of a mucro may be present; secondary veins prominent, 6-9 in number, diverging from the primary at angles of 40–60° in upper part of lobes; a pair of the lowest secondary veins (or subprimary veins) diverging from or near top of stalk, running parallel along margin, ascending one third to half the lobe-length in central lobe, sometimes ascending two thirds in lateral lobes; each secondary vein joining superadjacent secondary to form serial loops which give off tertiary veins forming another outer serial loops within margin: tertiary veins random reticulate, irregular in thickness; fourth order veins thin, forming polygonal areols with medium size (less than 1mm across), veinlets simple to once branched, or occasionally closed. The surface of the lobes of a Kitami specimen (NSM-PP 16334) is dotted with numerous discoid glands. Nutlets subglobose, 2.5mm in diameter, showing extended tip (probably perianth), but further details not preserved.

*Discussion:* The fruits from Japan are identical with *E. koreanica* in their general outline of lobe, pinnate venation, characters of the lowest secondary veins, and presence of marked stalk, although the size and diverging angles of lobes are variable to some extent. *E. poronaica* was described by Endo (1968), based on a poorly-preserved winged fruit from the Oligocene marine deposits of Hokkaido. Our re-examination of the holotype (pl. 2, fig. 1) reveals that the specimen was invalidly illustrated and inadequatly described by Endo, and that *E. poronaica* is unseparable from *E. koreanica* by the venation features of lobes, as already noted by Akhmetyev et al. (1972).

Regarding the primary venation of lobes, Oishi (1936) described that "each wing bears three distinct primary nerves, of which the median one is stronger than the rest . . . . ." So far as we examined all the specimens including the original specimens, a pair of lateral "primary veins" is farther slender than the medial, and is in same rank as the upper secondary veins in their thickness, as shown in Text-fig. 2, D. These lateral veins emerging from or near the base of each lobe are understood to represent one of the secondaries. Such venation characters of each lobe shows that all the specimens from East Asia are distinguishable from *Oreomunnea* of the New World, whose winged fruits have three prominent primary veins in each lobe as pointed out by some workers (Stone, 1972; Dilcher et al. 1976; Manning, 1978). Akhmetyev and Bratzeva (1973) suggested that *E. koreanica*




**Text-fig. 2.** Sketches showing the details of *Engelhardia koreanica* Oishi.

A. NSM-10461 (holotype of *E. poronaica* Endo); Loc. Futamata, Yubari City, Hokkaido.

B. Enlargement of central lobe. NSM-PP 16334 (pl. 1. fig. 2); Loc. Minamigaoka, Kitami City, Hokkaido.

C. HUMP no. 6478c (lectotype); Loc. Yongpukdong, Kogeonweon coal field, Hamg'yeong-bukdo, North Korea.

D. Ditto, enlargement of central lobe.

represents probably a extinct member in the sectional level, because they considered this East Asian fossils are similar to *Engelhardia* in their fruit size and also to *Oreomunnea* in the highly raised lateral veins. However, such extint section suggested for *E. koreanica* is not supported by the above-noted discussion.

Among the fossil winged fruits described under the name of *Engelhardia* in the Northern Hemisphere, *E. koreanica* is similar in general appearance to such species as *E. mississippiensis* Berry (Berry, 1916), *E. uintaensis* MacGinitie (MacGinitie, 1969) and some specimens of *E. macroptera* (Brongniart) Unger (Jähnichen et al., 1977). *E. koreanica,* however, is distinctly different from these European and North American species in the lack of fourth lobe (adaxial bract), essentially pinnate venation and the presence of stalk.

Five extant species are now distributed in tropical Asia, extending north into Central China and Taiwan. These extant species are divided into two sections, Engelhardia and Psilocarpeae, by the flowering and fruiting characters (Jacob, 1960; Manning 1966, 1978). Among these extant species, *E. koreanica* is closely related to *E. roxburghiana* Wall. of the

section Psilocarpeae in the lack of fourth lobe, the secondary venation feature and the stalk of medium-length. However, *E. koreanica* is different from *E. roxburghiana* in the termination of the medial vein toward the lobe apex: the medial vein of each lobe in the fossil species terminates at the lobe apex with a mucro-like thickening, while that of the extant species does not reach the lobe apex but dividing to form marginal looping series of two orders. As far as we investigated the extant species of the section Engelhardia which are stored in the herbaria of the University of Tokyo and Kyoto University, medial vein of each lobe is extending more straightly just near the lobe apex than of *E. roxburghiana*; a slender vein from one looping series ends within the apex. These characters are especially conspicuous in *E. spicata* Lesch. ex Blume among the extant species. Most bracts of other two species*, *E. rigida* Blume and *E. serrata* Blume, show similar character in the medial vein, but they include many exceptions. Four species of the section Engelhardia, however, are distinguishable from *E. koreanica* in the presence of small adaxial lobe and bristly hairs on the basal part of fruit.

The above-described discussion can reach a conclusion that *E. koreanica* is closely akin to the extant *E. roxburghiana* in all morphological characters except for a minor difference, and that this fossil species widely distributed in East Asia during the older Tertiary is included in the section Psilocarpeae. The related species is now living in the mesic broad-leafed forests of southern China, Taiwan, Malaysia, western Himalaya, Sumatra and Borneo.

## Engelhardia-bearing Floras in East Asia

Tertiary *Engelhardia*-bearing floras of East Asia are, as shown in Text-fig. 1, largely distributed in northeastern regions such as North Korea, Primorye, Sikhoto-Alin and Hokkaido, excepting for Heki of western Honshu. No fossil remains of *Engelhardia* have been recorded in Honshu up to the present with an exception, though Neogene floras of Honshu have been well investigated by many workers.

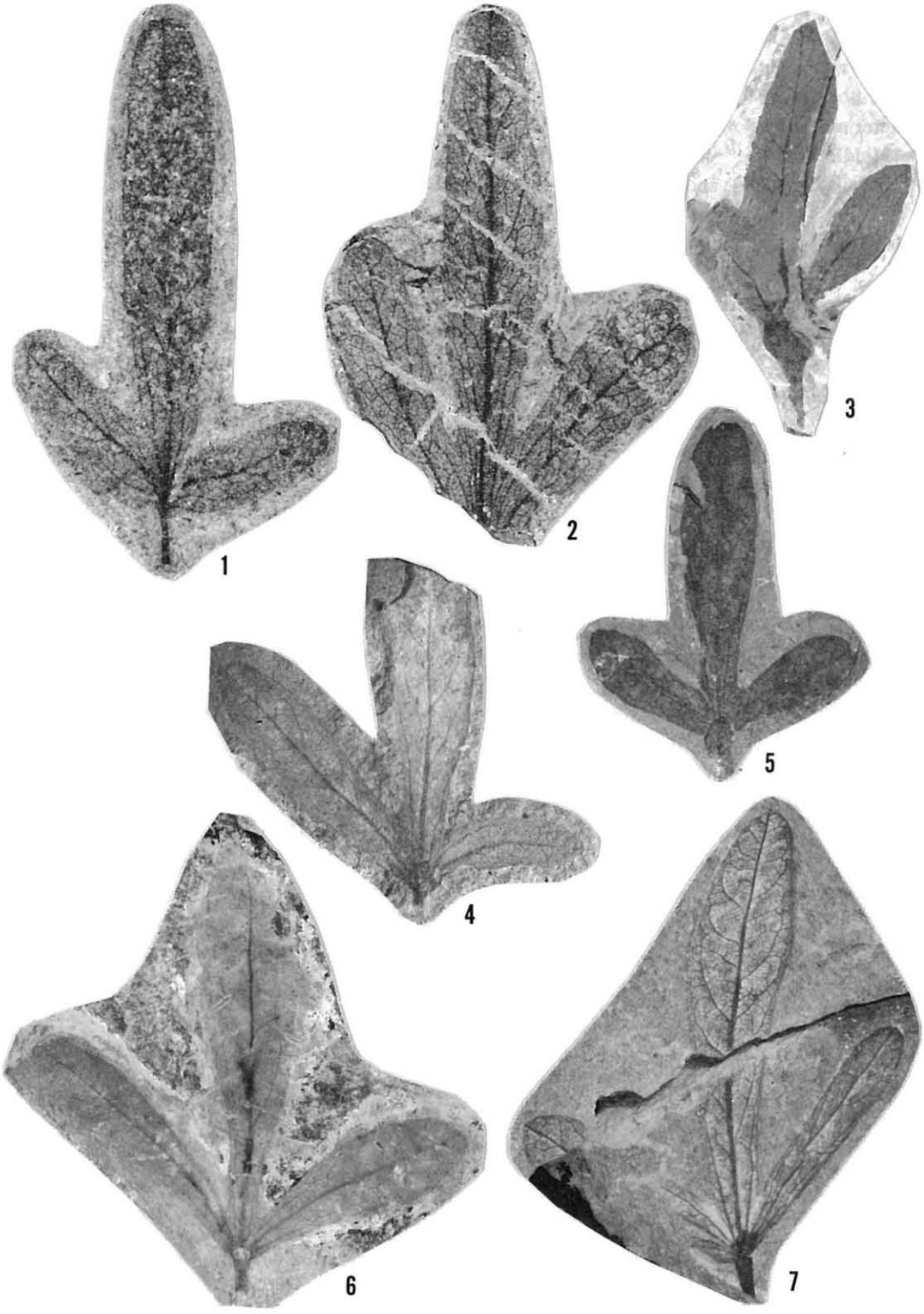
North Korean and Primorye floras containing *Engelhardia* have been regarded as late-Early Miocene in age (Endo, 1938; Tanai, 1961; Huzioka, 1972; Bolotnikova, 1975a; Ablaev, 1978), because they are similar in composition and components to the Daijima-type floras which are characteristic to the late-Early Miocene** terrestrial deposits of Japan. On

**Explanation of Plate 1**
(all the figures × 2)
**Figs. 1-8.** *Engelhardia koreanica* Oishi
1. Loc. Wakamatsuzawa, Kitami City, Hokkaido; Wakamatsuzawa Formation; NSP-PP 16333.
2. Loc. Minamigaoka, Kitami City, Hokkaido; Wakamatsuzawa Formation; NSM-PP 16334.
3. Loc. Kiwado, Heki-mura, Yamaguchi Prefecture; Jyuraku Formation; GSJ-F 5069 (coll. by T. Onoe).
4. Loc. Yongpukdong, Kogeonweon coal field, Hamg'yeong-bukdo, North Korea; "*Engelhardia* Beds"; NSM-PP 16332.

5-7. Ditto, specimens figured originally by Oishi (1936); H.U.M.P. no. 6478a, 6478b, 6478c (lectotype).

* *E. apoensis* Elmer ex Nagel could be not yet investigated, because no materials are stored in the herbaria of both the Universities.

** The Diajima-type flora indicating a Miocene warmer climatic episode, was formerly dated as Middle Miocene in age (Tanai, 1961). It is, however, currently considered to be of late-Early Miocene (correlative to Blow's N7-8), based on the recent biochronological studies of the Japanese Neogene.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the other hand, Akhmetyev and Bratzeva (1973) asserted that the *Engelhardia*-bearing floras of Sikhote-Alin are of Oligocene age, based on the facts that an *Engelhardia* fruit was described from the Oligocene of Central Hokkaido (Engo, 1968), and that the Dembi plant-bearing beds underlie dacite lava, which was dated as 34 m.y. by the K-Ar age determination. Pollen grains of *Engelhardia* are often described from the Paleogene to the "Middle Miocene" in Primorye (Bolotnikova, 1975b), from the Oligocene of Kyushu (Takahashi, 1961), and from the "Middle Miocene" of Hokkaido (Sato, 1963), South Korea (Takahashi and Kim, 1979) and North Korea (Bolotnikova, 1975b); but no fruits and leaflets have been known from these beds.

Although it is now under study by us on the basis of a large collection, the Wakamatsuzawa flora of Kitami is composed mainly of temperate species represented by conifers and deciduous broad-leafed trees; the dominant members are *Abies, Picea, Pseudolarix, Tsuga, Glyptostrobus, Metasequoia, Sciadopitys, Thuja, Alnus, Betula, Corylus, Fagus, Quercus* (deciduous), *Hamamelis,, Acer, Vitis* and *Viburnum.* Most of these species appear to be referable to Miocene species of Japan, excepting some leaves of the Betulaceae. A few species indicating warm climate contain such as *Quercus* (evergreen), *Alangium* and an evergreen species of *Ilex.* Predominant occurrence of conifers, *Fagus antipofi, Quercus ussuriensis* and *Alnus* spp., and common presence of *Platanus* spp. are characteristic to the Wakamatsuzawa flora. Such floristic composition of the Wakamatsuzawa is distinctly common with those of the *Engelhardia*-bearing floras of North Korea, southern Primorye and Sikhote-Alin. Furthermore, along with *Engelhardia,* worthy to note is *Quercus ussuriensis* or its allied species, which are represented by incisedly-lobed oak leaves with aristate teeth. These peculiar deciduous oak leaves are predominant in Kitami and Dembi, and are also common in Kogeonweon, Kungshim, Shakterskii and Rettikhovka.

The Wakamatsuzawa Formation from which new materials were collected, is terrestrial in origin, and is covered unconformably by the marine thick deposits containing some planktonic foraminiferas of Oligocene-Early Miocene age (lower than Blow's N6). K-Ar age of 31.44 ±1.0 M.A. for andesite of the "Futamata andesite lava", a southern equivalent of the Wakamatsuzawa Formation, was very lately determined (Shibata and Tanai, 1982). Accordingly, the Wakamatsuzawa flora is assignable to be of Middle to Late Oligocene age, although it contains many Miocene relatives.

An *Engelhardia* fruit of Yubari was described from the Poronai Formation which is composed of marine argillaceous rocks. Plant fossils rarely found, are *Glyptostrobus,*

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**Explanation of Plate 2.**
(all the figures x 2 except fig. 7)

**Fig. 1.** *Engelhardia koreanica* Oishi. Loc. Futamata, Yubari City, Hokkaido; Poronai Formation; NSM-10461 (holotype of *E. poronaica* Endo)

**Figs. 2-6.** Winged fruits of the extant *Engelhardia* species for comparison, showing the general outline and venation.

2a, b. *Engelhardia roxburghiana* Wall. Taiwan, NSM Paleobot. Ref. Coll.

3. *Engelhardia rigida* Blume. New Guinea. Kyoto Univ. Coll. (coll. by S. Miki)

4. *Engelhardia spicata* Blume. Java, TNS-318684.

5, 6. *Engelhardia serrata* Blume. A.D.E. Elmer no. 21972, isotype of *E. zambalensis* Elmer, Luzon. Kyoto Univ. Coll.; A.F.G. Kerr no. 18187, Thailand. Kyoto Univ. Coll.

**Fig. 7.** *Engelhardia koreanica* Oishi. Upper part of lateral lobe, showing the mucronate apex and venation details, x 9.2. NSM-PP 16334 (Pl 1, fig. 2)

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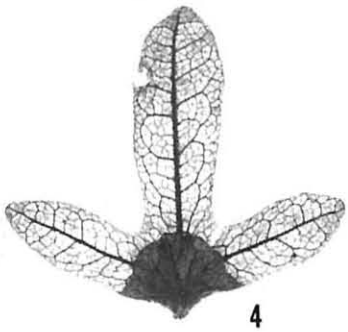

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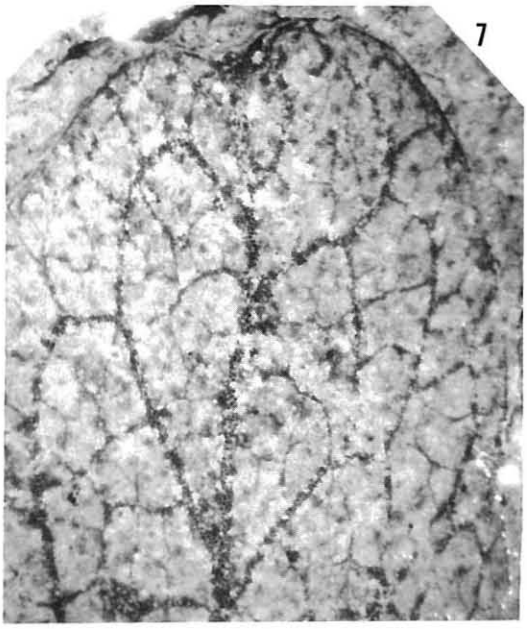

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*Metasequoia, Taiwania*?, *Pinus, Fagus, Quercus* (evergreen), *Laurophyllum, Acer, MacClintockia* and others. The Poronai Formation abundantly yields marine molluscs and foraminiferas ranging from Late Eocene to Late Oligocene in age (Takeda, 1953; Asano, 1962). At another locality of western end of Honshu the plant-bearing Jyuraku Formation conformably underlies the marine Kiwado Formation containing the Ashiya molluscan fauna of Latest Oligocene-Early Miocene age (Okamoto and Imamura, 1964, Okamoto, 1965). Plant fossils from the Jyuraku have not been yet studied; they involve commonly evergreen *Osmunda, Pinus* (3-needled), *Psudotsuga, Taiwania, Thuja, Comptonia, Quercus* (evergreen), *Zelkova, Laurophyllum* and *Leguminosites.* Both the Poronai and Jyuraku plant assemblages are too poor to compare in composition with the above-described floras, but it is evident that *Engelhardia* fruits occurred in the Oligocene of Yubari and Heki areas.

From the foregoing discussion we can conclude that the floras of East Asia accompanied by *Engelhardia koreanica* should be, if not all, of Late Oligocene age. Especially, the *Engelhardia*-bearing floras of North Korea, southern Primorye, Sikhote-Alin and northeastern Hokkaido may represent the Late Oligocene forests which have not been fully known in East Asia. A detailed taxonomical investigation shall be expected for these floras.

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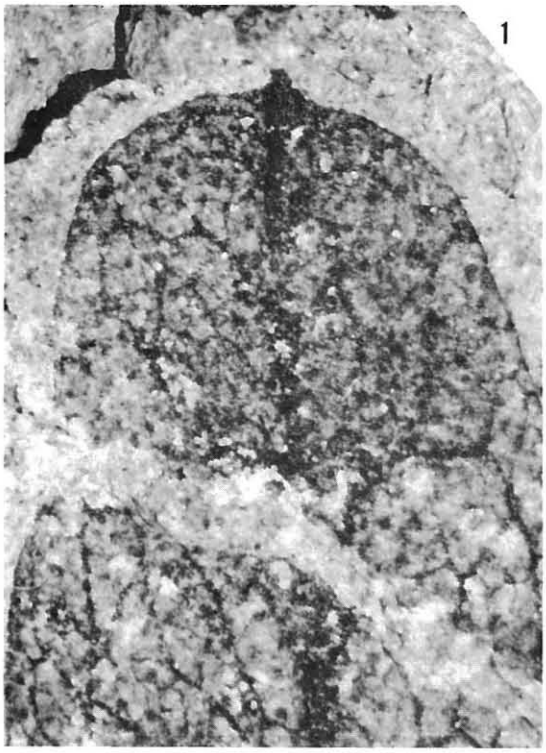
**Explanation of Plate 3**

**Fig. 1.** *Engelhardia koreanica* Oishi. Central lobe apex showing mucro-like thickeing at the termination of the primary vein, and note small dots scattered on the wing. x 14. NSM-PP 16334 (Pl. 1, fig. 2).

**Fig. 2.** *Engelhardia koreanica* Oishi. Middle portion of central lobe showing the fine venation. x 11. H.U.M.P. 6478c (lectotype; Pl. 1, fig. 7).

**Figs. 3, 4.** Enlargement of the central lobe of the extant *Engelhardia* species. x 9.2. Peltate scales are observed as small dots.

3. *Engelhardia serrate* Blume. Enlargement of pl. 2, fig. 6.
4. *Engelhardia roxburghiana* Wall. Enlargement of pl. 2, fig. 2.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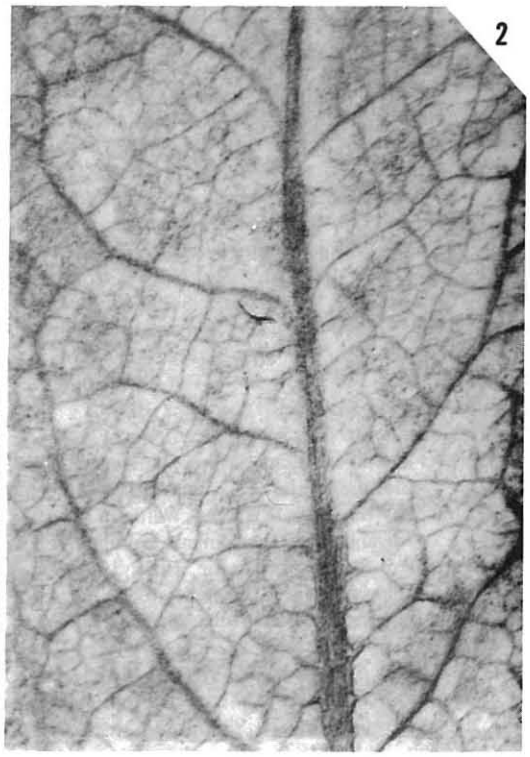
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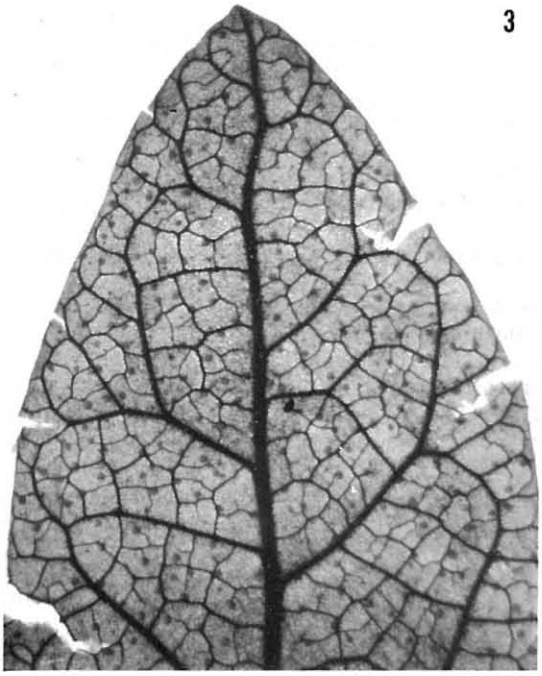
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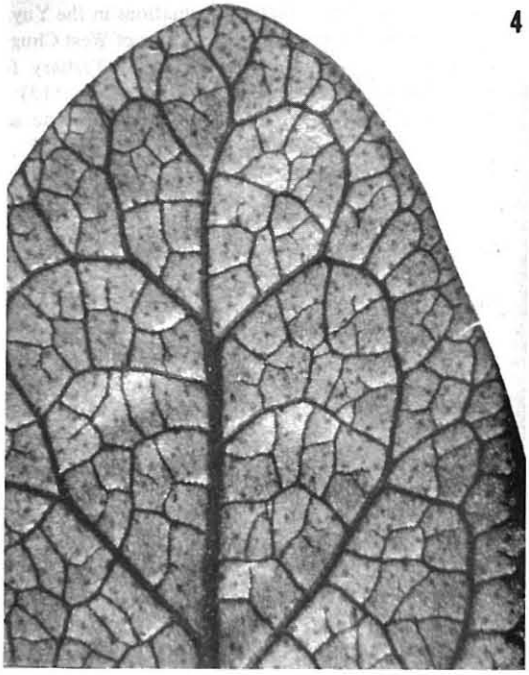
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