

Euphorbiaceae and Icacinaceae from the Paleogene of Hokkaido, Japan

By

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Abstract Fossil leaves doubtlessly referable to the Euphorbiaceae and Icacinaceae are uncommon in the Paleogene of the northern hemisphere, compared with wide occurrence of fossil woods and reproductive organs of these two families. My recent investigation of Paleogene leaf floras of Hokkaido revealed that many tropical plants belonging to the Euphorbiaceae and Icacinaceae are included. The Euphorbiaceae consists 4 genera of *Acalypha*, *Alchornea*, *Hura* and *Mallotus*. The Icacinaceae contains three extant genera of *Merrilliodendron*, *Phytocrene* and *Pyrenacantha*, and two extinct genera of *Goweria* and *Huziokaea*. New taxa and combination proposed are: *Alchornea harutoriensis*, n. comb.; *Mallotus orbiculatus*, n. sp.; *Mallotus yubariensis*, n. sp.; *Goweria bibaiensis*, n. sp.; *Huziokaea eoutilus*, n. gen. and n. comb.

Introduction

The Paleogene sediments, both of terrestrial and marine origin, are well distributed in Hokkaido, and they provide a standard stratigraphic sequence of Eocene and Oligocene age in East Asia. The terrestrial deposits interbedding many coal seams, contain a number of well-preserved plant fossils, most of which are represented by leaf impressions. It has not been easy to determine reliable taxonomy of these Paleogene leaves only by their gross features, because of lacking reproductive organs accompanied. In actual, the Eocene Ikushunbetsu plants described by ENDO (1968) are too inaccurate to envisage the floristic composition, because of many invalid identification. The recent study of leaf architecture for these Paleogene plants reveals that Eocene floras of Hokkaido contain commonly many tropical taxa, though most of the floras have been once considered to show generally temperate aspect except the palm-bearing horizon (TANAI, 1970, 1972).

Eocene floras of Hokkaido are composed of a mixture of taxa, whose modern counterparts are found in habit ranging from temperate deciduous hardwood forests to tropical or paratropical rain forests, as WOLFE (1975) referred to such assemblages as the "boreotropical flora." The temperate dicot taxa are represented principally by Aceraceae, Betulaceae (*Alnus*, *Carpinus*, and *Corylus*), Cercidiphyllaceae, Juglandaceae (*Carya*, *Cyclocarya*, *Juglans*, *Pterocarya* and other extinct genera), Rosaceae (*Prunus*, *Rosa*, *Sorbaria*, *Sorbus* and others), Salicaceae (*Populus* and *Salix*) and Ulmaceae (*Ulmus* and *Zelkova*). The exclusively tropical to paratropical taxa are dom-

inated by Euphorbiaceae, Icacinaceae, Menispermaceae and Sterculiaceae. Tropical monocots such as palms and Musaceae are common in some horizons. Minor tropical taxa are Apocynaceae, Lauraceae, Mastoxiaceae, Melastomaceae and Rubiaceae. On the one hands, there are many families whose genera are mostly paratropical but some extend in distribution to temperate regions: they are Alangiaceae, Fagaceae, Hamamelidaceae, Platanaceae, Sabiaceae, Theaceae and Tiliaceae.

Of predominant tropical families from the Paleogene of Hokkaido, the Sterculiaceae and some Menispermaceae are already discussed taxonomically (TANAI, 1981, 1989). I will discuss here the taxonomy and stratigraphic ranges of the Euphorbiaceae and Icacinaceae, based mainly on my collection from Hokkaido and partly on ENDO's collection.

Acknowledgments

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Stratigraphic Relationships of the Paleogene Plant-bearing Formations in Hokkaido

The Paleogene plant-bearing formations are widely distributed in the Ishikari, Rumoi (including the Owada coal-bearing field) and Kabato coal fields of central Hokkaido, and in the Kushiro and Rikubetsu (including Kitami area) coal fields of eastern Hokkaido. The stratigraphy of these field has been well established through geologic investigations for prospecting coal seams by many workers, because these fields include important coal resources in Japan.

Paleogene sequence of Hokkaido, ranging from the Middle Eocene to the Middle Oligocene, is most well developed in the Ishikari field, represented by the coal-bearing Ishikari and overlying marine Poronai Groups that cover the Upper Cretaceous by unconformity. To the north of this field lies the Rumoi coal field, where the equivalent sediments of the middle Ishikari to the Poronai Group overlie the Upper Cretaceous, lacking the lower Ishikari. To the west of the Ishikari field lies the Kabato coal field, where the Paleogene equivalent only to the upper Ishikari Group directly covers the Mesozoic sediments by unconformity. The Owada coal-bearing field is a small area of the northern extension of the Kabato coal field. The similar stratigraphic sequence of the Paleogene has been confirmed in eastern Hokkaido. In the Kushiro

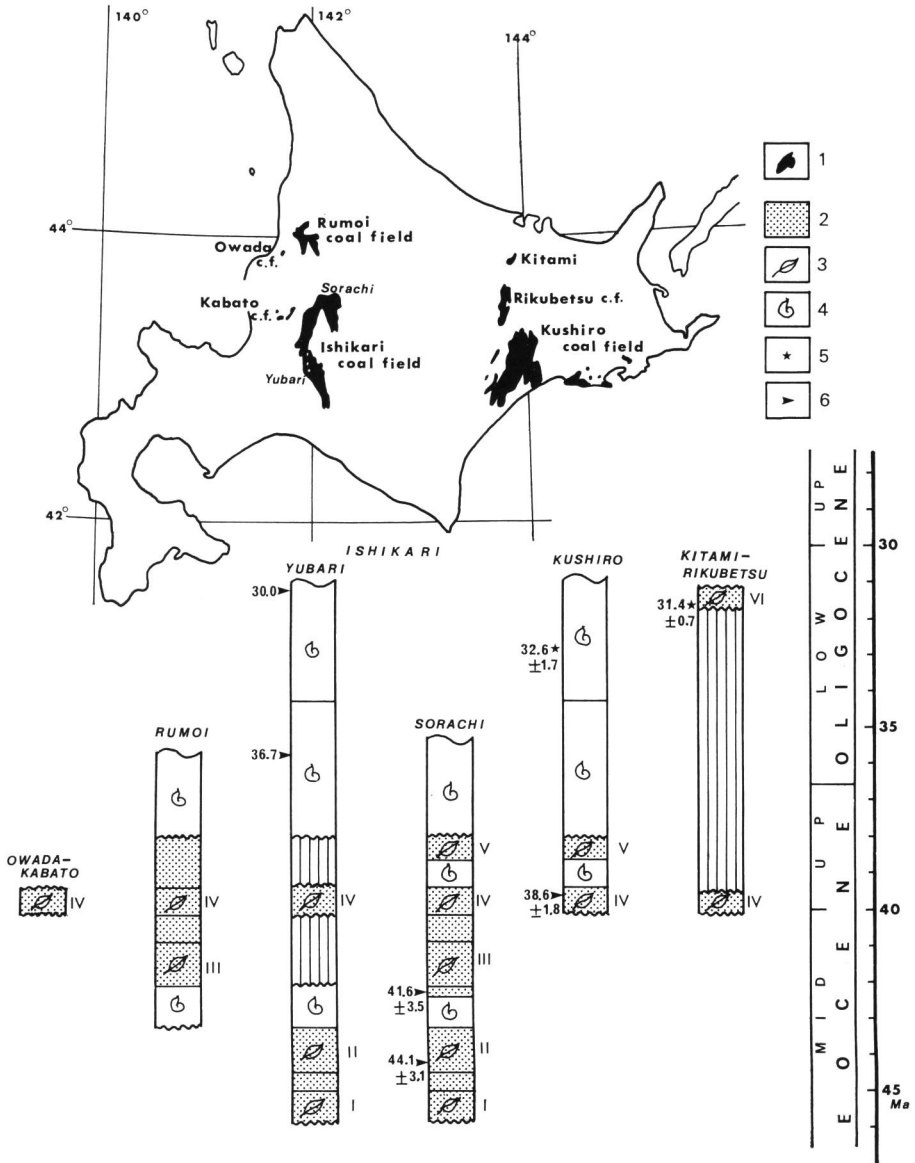


Fig. 1. The areal distribution and stratigraphic relationships of the Paleogene plant-bearing deposits in Hokkaido.

Geologic time scale is followed by BERGGREN *et al.* (1985).

1. Areal distribution of the Paleogene. 2. Terrestrial deposits. 3. Plant-bearing sediments. 4. Marine sediments. 5. Radiometric age (K-Ar dating). 6. Radiometric age (Fission track dating).

coal field occupying the land and offshore areas, the Paleogene, lacking the equivalents of the lower and middle Ishikari Group, lies on the Upper Cretaceous with unconformity. The uppermost part of the Upper Cretaceous here was recently confirmed to include partly the marine Paleocene to lower-Middle Eocene (KAIHO & SAITO, 1986; OKADA *et al.*, 1987). The Rikubetsu coal field is a northern extension of the Kushiro coal field, and includes only the basal part of the coal-bearing Urahoro Group of the Kushiro field. The Oligocene plant-bearing deposits called the Wakamatsuzawa Formation (TANAI & UEMURA, 1983) are distributed on the Jurassic sediments or on the Eocene sediments equivalent to the lower Urahoro Group.

Considering the floristic composition and stratigraphic relationships together with the available radiometric ages, the Paleogene plant-bearing formations of Hokkaido are grouped in 6 horizons (TANAI, 1989). Of these 6 horizons, the horizon 4 is most widely distributed in all the above-noted coal fields of Hokkaido, and its floras comprise most abundant plant fossils. The horizon 3 is known from the Ishikari and Rumoi fields, and the horizons 1 and 2 are known only from the Ishikari field. The horizon 5 is from the Ishikari and Kushiro fields, and the youngest horizon 6 is from Kitami area, where the plant fossils are included in the lacustrine deposits accompanied by no coal seams. Recent accumulation of radiometric age data for Paleogene plant-bearing sediments of Hokkaido (SHIBATA & TANAI, 1982; TANAI, 1984; KIMURA & TSUJI, 1989) has made partly possible to calibrate the floristic sequence in time scale, although these age data are not always sufficient. As discussed previously (TANAI, 1989), Paleogene plant-bearing formations of Hokkaido are dated as Middle Eocene to Early Oligocene: the horizons 1–3 are Middle Eocene, the horizons 4 and 5 are early-Late Eocene, and the horizon 6 is late-Early Oligocene in age respectively. Compared with abundant tropical plants at the horizon 3, a considerable increase of temperate plants at the horizon 4 indicates climatic deterioration during Late Eocene time; this corresponds with "Terminal Eocene Events." The stratigraphic relationships in the Paleogene coal fields of Hokkaido are shown in Figure 1, indicating the marine and terrestrial phases.

The above-noted conclusion regarding age discussion is, however, not always consistent with those of marine formations which cover the plant-bearing formations by unconformity. The age discussion of the Paleogene of Hokkaido have been based mainly on marine fossils that are abundantly contained in the Poronai Group and its correlatives. For instance, these marine formations were dated as Oligocene by molluscs (TAKAEDA, 1953; OYAMA *et al.*, 1960; HONDA, 1987), while they are of Eocene age by benthic foraminifers (ASANO, 1962). Based on the recent discovery of a few planktonic foraminifers (KAIHO, 1984) and calcareous nannofossils (OKADA & KAIHO, in press), it was concluded that the Poronai Group in the Ishikari coal field is ranged from late-Middle Eocene to Late Eocene age, and that the Onbestu Group of the Kushiro coal field is of Late Eocene to Early Oligocene age. If we accept the age assignment of Okada and Kaiho, the plant-bearing Ishikari Group is older than the Middle Eocene. Such discrepancy on the age of the Ishikari Group and its correlatives

must be solved, collecting more much reliable radiometric determination on the Paleogene of Hokkaido.

Late Cretaceous and Early Tertiary records of the Euphorbiaceae and Icacinaceae

Fossil records of the Euphorbiaceae and Icacinaceae are traceable back to Late Cretaceous time, and are well represented in the Early Tertiary. Since these fossil remains were found in the Eocene of London Clay by REID and CHANDLER (1933), the similar fruits or seeds have been described in the Upper Cretaceous and Lower Tertiary of Africa, Central Europe and North America. The tropical taxa showing the Indomalaysian affinity were once widely distributed along the Thethys Sea, and also across North America from eastern to western parts of the Continent.

The Euphorbiaceae is a large family of angiosperms, including some 300 genera and over 5,000 extant species (WILLIS, revised by AIRY SHAW, 1973). The family is predominantly tropical in its present-day distribution, but has some temperate representatives. The extant species comprises trees, shrubs and herbs, and includes xerophytic vegetative forms (*Euphorbia*) like cactus.

Fossils of the Euphorbiaceae have been known from the Upper Cretaceous through the Tertiary, based on fruits, woods and pollen in the world. These fossil records, except woods, were critically evaluated by WEBSTER (1967), CREPET and DAGHALIAN (1982) and recently by DILCHER and MANCHESTERS (1988). These authors afforded no special attention to fossil leaves, refering their unreliable records to gross morphological comparison with the extant leaves, though leaves of this family have been also reported through the Tertiary. Cretaceous fossils of Euphorbioid affinity are represented by woods (MADEL, 1962; BAILEY, 1924) and fruits (CHANDLER, 1954); they are mostly Africa, and rarely from North America. Paleocene and Eocene reproductive organs were described from southern England (REID & CHANDLER, 1933; CHANDLER, 1961), Germany (MAI & WALTHER, 1985), and the southeastern United States (MAZER & TIFFNEY, 1982; CREPET & DAGHALIAN, 1982; DILCHER & MANCHESTERS, 1988). All these Cretaceous and Paleogene fossils, both of wood and reproductive organs, are referred to the form-genera with Euphorbioid affinity, except *Acalypha* seeds from Germany. Fossil woods with Euphorbioid affinity have been also widely reported as the form-genera from the Tertiary of the world by many workers; Paleogene woods are known from North America (KRUSE, 1954), Japan (OGURA, 1932; WATARI, 1943) and India (PRAKASH, 1957, 1958; others).

Extant leaves of Euphorbiaceae are diverse from non-lobed to lobed in leaf form, pinnate to palmate in venation, and entire to serrate on margin. It is frequently difficult to determine Euphorbioid affinity of leaf fossils, especially of leaf impression, only by gross features. Many glands on the principal veins or margin, and numerous punctate small glands (oil drops) on the surface of blade are characteristic to many genera of this family such as *Alchornea*, *Aleurites*, *Antidesma*, *Aporosa*, *Glochidion*,

Mallotus, *Sapium* and others. Prominent basilaminar or acropetiolar glands are characteristic to some genera such as *Alchornea*, *Aleurites*, *Mallotus* and others. When leaf margin is toothed (for instance, *Acalypha*, *Alchornea*, *Coelodepas*, *Excoecaria*, *Mercurialis*, and others), the tooth tip expands with glandular termination (violoid tooth type: HICKEY & WOLFE, 1975). The secondary veins ascend up markedly in most case, and are usually craspedodromous to camptodromous. The Tertiary veins are percurrent, and the ultimate veinlets are profusely branching.

Many genera of Euphorbiaceae, based on fossil leaves, have been described through the Tertiary in the northern hemisphere, though no leaf has been known from the Cretaceous. Except the form-genus such as *Euphorbiophyllum*, Paleogene leaves are frequently referred to the extant genera by many workers: they are *Acalypha*, *Alchornea*, *Aleurites*, *Aporosa*, *Euphorbia*, *Macaranga*, *Mallotus*, and *Sapium*. Of these genera, *Alchornea*, *Macaranga* and *Mallotus* are confirmed their existence during the Eocene by extensive investigation of MULLER (1981, 1984), based on dispersed pollen. Most of Paleogene leaves referred to Euphorbiaceae need to reinvestigate cautiously in leaf architecture compared with the extant taxa, although some of genera are valid in identification.

A single leaf described as *Macaranga pugetensis* from the Eocene of Washington (WOLFE, 1968), has deeply-cordate base appearing peltate features, regularly spaced teeth, and prominent quaternary veins between the tertiaries; these characters are features of *Macaranga*. Several leaves described as *Aleurites glandulosa* and *A. fremontensis* from the Eocene of the western United States (MACGINITIE, 1969, 1974) indicate Euphorbioid affinity, having many minute punctation (glands) scattered on the surface of blade. The presence of *Mallotus* leaves during the Upper Eocene in Hokkaido is also confirmed by me (TANAI, 1989).

The Icacinaceae comprises 58 genera and about 400 extant species (WILLIS, revised by AIRY SHAW, 1973) of trees, shrubs and lianas, almost all of which inhabit tropical rain forests. It occurs mainly in Malaysia and tropical regions of India, Africa and Central America, decreasing rapidly toward the subtropics.

Fossils with Icacinaceae affinity have been known from the Upper Cretaceous and the Paleogene, and they were once evaluated by RUFFLE (1976). The endocarp specimens have been well known from the Upper Cretaceous in central Europe (KNOBLOCH & MAI, 1986), West and North Africa (CHESTERS, 1955; GREGOR & HAGN, 1982), and eastern North America (SCOTT & BARGHOORN, 1957). Paleocene and Eocene records are further common in Europe (REID & CHANDLER, 1933; CHANDLER, 1961, 1962; RUFFLE, 1976; MAI & WALTHER, 1978; MAI, 1987; others), but they are rather sparse in North America (BERRY, 1922; SCOTT, 1954; MACGINITIE 1969; WOLFE, 1977). On the other hand, fossil leaves referred to the Icacinaceae were only from the Eocene of western North America (MACGINITIE, 1941; WOLFE, 1977), and none has been from Europe. No fossils referred to this family have been known in the Oligocene and Neogene of the world, except wood fossils which were described as *Citronella* and *Icacinoxylon* from Hungary (GREGUSS, 1969) and *Icacinoxylon* from

	E	O	C	E	N	E	OLIG.
	I	II	III	IV	V	VI	
Euphorbiaceae							
<i>Acalypha</i> sp.							
<i>Alchornea harutoriensis</i>							
<i>Hura</i> sp.							
<i>Mallotus hokkaidoensis</i>							
<i>M. orbiculatus</i>							
<i>M. yubariensis</i>							
Icacinaceae							
<i>Goweria bibaiensis</i>							
<i>Huziokaea eoutilus</i>							
<i>Merrilliodendron ezoanum</i>		?					
<i>Phytocrene ozakii</i>							
<i>Pyrenacantha</i> sp.							

Fig. 2. Stratigraphic distribution of the Euphorbiaceae and Icacinaceae in the Paleogene of Hokkaido.

Rumania (GIVULESCU, 1975).

Of Paleogene fossils of the Icacinaceae, 6 genera (*Hosiea*, *Iodes*, *Natsiatum*, *Phytocrene*, *Pyrenacantha* and *Stemonurus*) based on leaves or endocarps, have the living representatives, while other endocarp fossils were referred to the form genera such as *Icacinicarya*, *Palaeophytocrene*, *Aitzocarya* and *Sphaerioides*.

The extant leaves of the Icacinaceae are non-lobed (rarely lobed) in form, diverse from actionodromous to pinnate in venation, and mostly entire but sometimes toothed on the margin. The secondary veins are typically brochidodromous with apically elongate arches, and the marginal tertiary veins sometimes end in minute protuberances on the margin. The ultimate veinlets are usually more than twice branching. Three modern genera of Icacinaceae (*Phytocrene*, *Pyrenacantha* and *Stemonurus*) based on leaves, were known from the Eocene of California (MACGINITIE, 1941) and Alaska (WOLFE, 1977). These leaves have sufficient characters to be referable to the Icacinaceae.

The recent investigation of Paleogene floras of Hokkaido revealed that leaves of the Euphorbiaceae and Icacinaceae are doubtlessly included. The Euphorbiaceae contains 3 genera of *Alchornea*, *Hura* and *Mallotus*; the former two are represented by a single species each, and *Mallotus* consists of 3 species. The Icacinaceae is represented by 5 genera; three (*Merrilliodendron*, *Phytocrene*, and *Pyrenacantha*) having living representatives, and the other two (*Goweria* and *Huziokaea*) being the extinct genera. These Euphorbioid and Icacinoid plants are confirmed from the Middle and Upper Eocene in Hokkaido, and their stratigraphic distribution is shown in Fig. 2.

Systematic Descriptions

Terms of leaf architecture used in the description are based mostly on those of Hickey (1979). For the occurrence of each species, the localities and stratigraphic names that are cited here, are referred to those of the previous papers (TANAI, 1981, 1989).

Order Euphorbiales

Family Euphorbiaceae

Genus *Acalypha* Linn.

Acalypha sp.

(Pl. 1, fig. 3; Fig. 3-C)

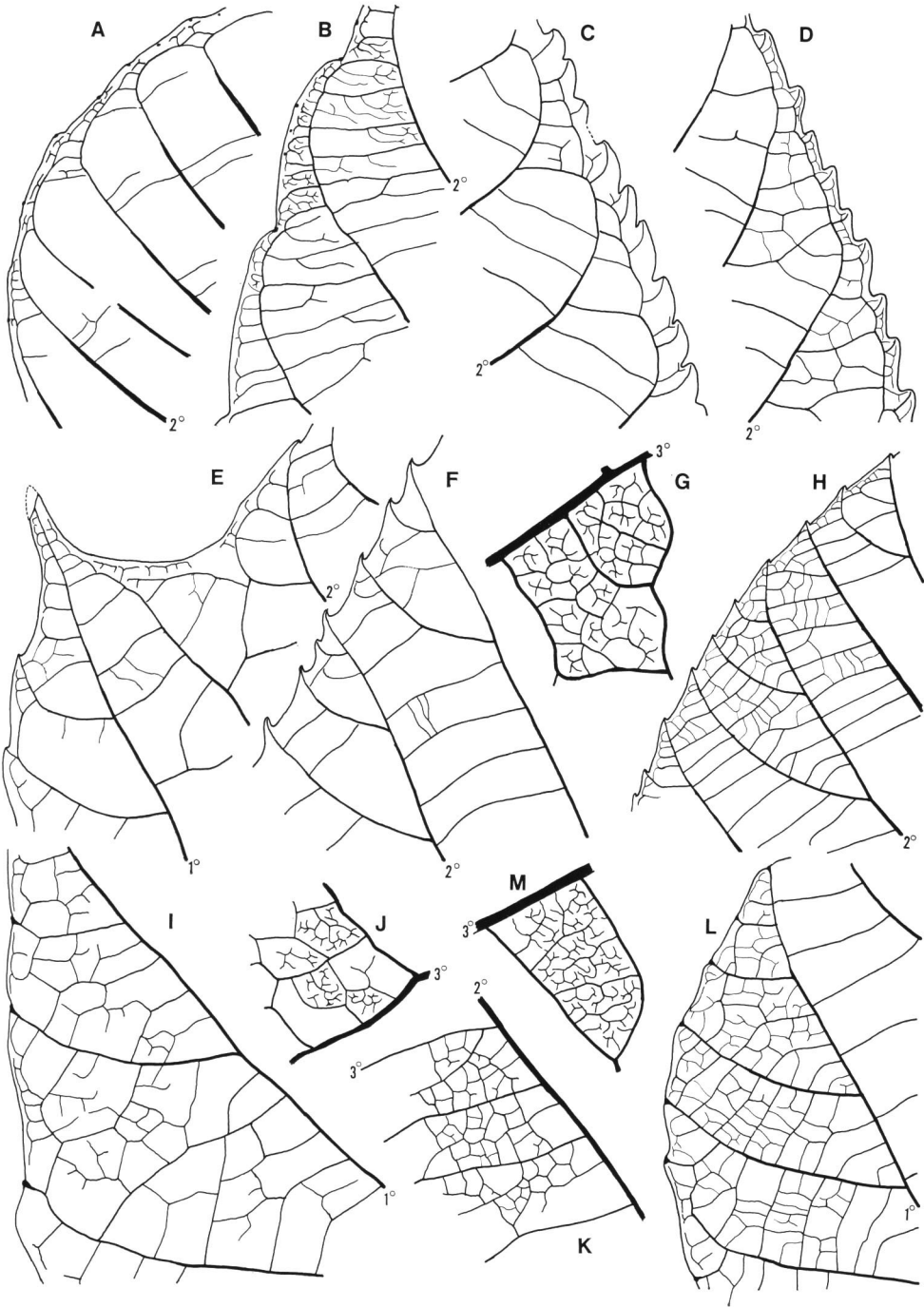
Discussion: The leaf specimen has the closely spaced, crenato-serrate margin with glandular teeth, and the medial secondary from the midvein and exmedial secondary veins from a pair of basal primary veins that are nearly straight, and then form loops just near the margin. The intercostal tertiary veins are convex-percurrent, and those of the upper half of blade are nearly perpendicular to the midvein. The marginal tertiaries from the secondary loops enter the teeth centrally. This fossil is referable to *Acalypha* in the above features, although ill-preserved in the fine venation. Some of popular leaves are similar to this fossil leaves; however, popular leaves have usually bifurcate secondary veins, and the secondary loops that are not so close to the margin.

Occurrence: Ishikari coal field Ic-3.

Collection: Hypotype NSM PP 10342.

Fig. 3. The venation features of marginal area and areoles of Paleogene Euphorbiaceae leaves and their related extant species.

- A. *Hura* sp. NSM PP 10347b (Pl. 5, fig. 4) × 3
- B. *Hura crepitans* LINN. NSM Paleobot. Reference Coll. no. T-502. × 3
- C. *Acalypha* sp. NSM PP 10342 (Pl. 1, fig. 3) × 3
- D. *Acalypha hispida* BURM. f. NSM Paleobot. Reference Coll. not. T-378. × 3
- E. *Mallotus yubariensis* TANAI. NSM PP 10353 (Pl. 6, fig. 4) × 3
- F, G. *Alchornea harutoriensis* (OISHI & HUZIOKA) TANAI. NSM PP 10344 (Pl. 4, fig. 4).
F: × 3, G: × 15
- H. *Alchornea trewioides* MUELL.-ARG. NSM Paleobot. Reference Coll. no. T-946.
× 3
- I. *Mallotus orbiculatus* TANAI. Paratype NSM PP 10350 (Pl. 2, fig. 1) × 3
- J, K. *Mallotus orbiculatus* TANAI. Holotype NSM PP 10349 (Pl. 1, fig. 2). J: × 15,
K: × 3
- L, M. *Mallotus apelta* (LOUR.) MUELL.-ARG. NSM Paleobot. Reference Coll. no. T-951. × 3



Genus *Alchornea* Sw.*Alchornea harutoriensis* (OISHI et HUZUIOKA)

TANAI comb. nov.

(Pl. 3, fig. 4; pl. 4, fig. 4; pl. 6, fig. 3; Fig. 3-F, G)

Tilia harutoriensis OISHI et HUZUIOKA. 1943. J. Fac. Sci., Hokkaido Univ. [4], 7(1): 76. pl. 8. fig. 1.*Typus*: Holotype HUMP no. 9261; Harutori coal mine, Kushiro, Hokkaido; Harutori Formation (Late Eocene).

Emended Description: Leaves cordate to depressed-cordate in general outline, 7.5 to 12 cm (estimated) long and 6.3 to 11.5 cm wide, length/width ratio 1.06 to 1.28; base cordate, broadly opened; apex acute to slightly acuminate; margin toothed with shallowly-rounded sinus; teeth small, adaxially oriented, with swollen glandular tip; 1 to 3 teeth per secondary vein, intersecondary teeth slightly smaller than principal teeth; petiole thick but incomplete, more than 1 cm long. Venation basal actinodromous with 3 primary veins; midvein stout, straight; lateral primary veins diverging at 40° to 50°, nearly straight or slightly curving up, extending to about the middle of blade, craspedodromous; medial secondary veins 7 opposite or subopposite in pairs, parallel to lateral primary veins, craspedodromous; secondaries emerging abaxially from lateral primaries at moderate angles, gently curving upward, craspedodromous; 2 or 3 abaxial branches extending from secondaries, ending in smaller teeth; intercostal tertiary veins thin but distinct, convex-percurrent, comparatively regularly spaced with distance of 2 to 3 mm, the highest order venation sixth; quaternary veins nearly perpendicular to the tertiaries, flexuous, with distance of 0.5 to 0.8 mm; fifth order veins forming 4 or 5 sided areoles which are about 0.2 mm across; freely ending veinlets thin, ill-preserved, probably more than twice branching.

Discussion: These orbiculate leaves with 3 palmate venation, although the basilaminar glands are not preserved, are assignable to the genus *Alchornea* by the following characteristics: craspedodromous primary and secondary veins whose branches are also craspedodromous; serrate margin with small, glandular-tipped swollen teeth; closely spaced intercostal tertiary veins; and quaternary veins perpendicular to the tertiaries.

Fig. 4. The venation features of marginal area and areoles of Paleogene Icacinaceae leaves and their related extant species.

A, B. *Phytocrene ozakii* TANAI. Holotype NSM PP 10359 (Pl. 5, fig. 2). ×3 A: left lateral lobe, B: central lobe.

C, D. *Phytocrene bracteata* WALL. NSM Paleobot. Reference Coll. no. T-2035. ×3 C: central lobe, D: left lateral lobe.

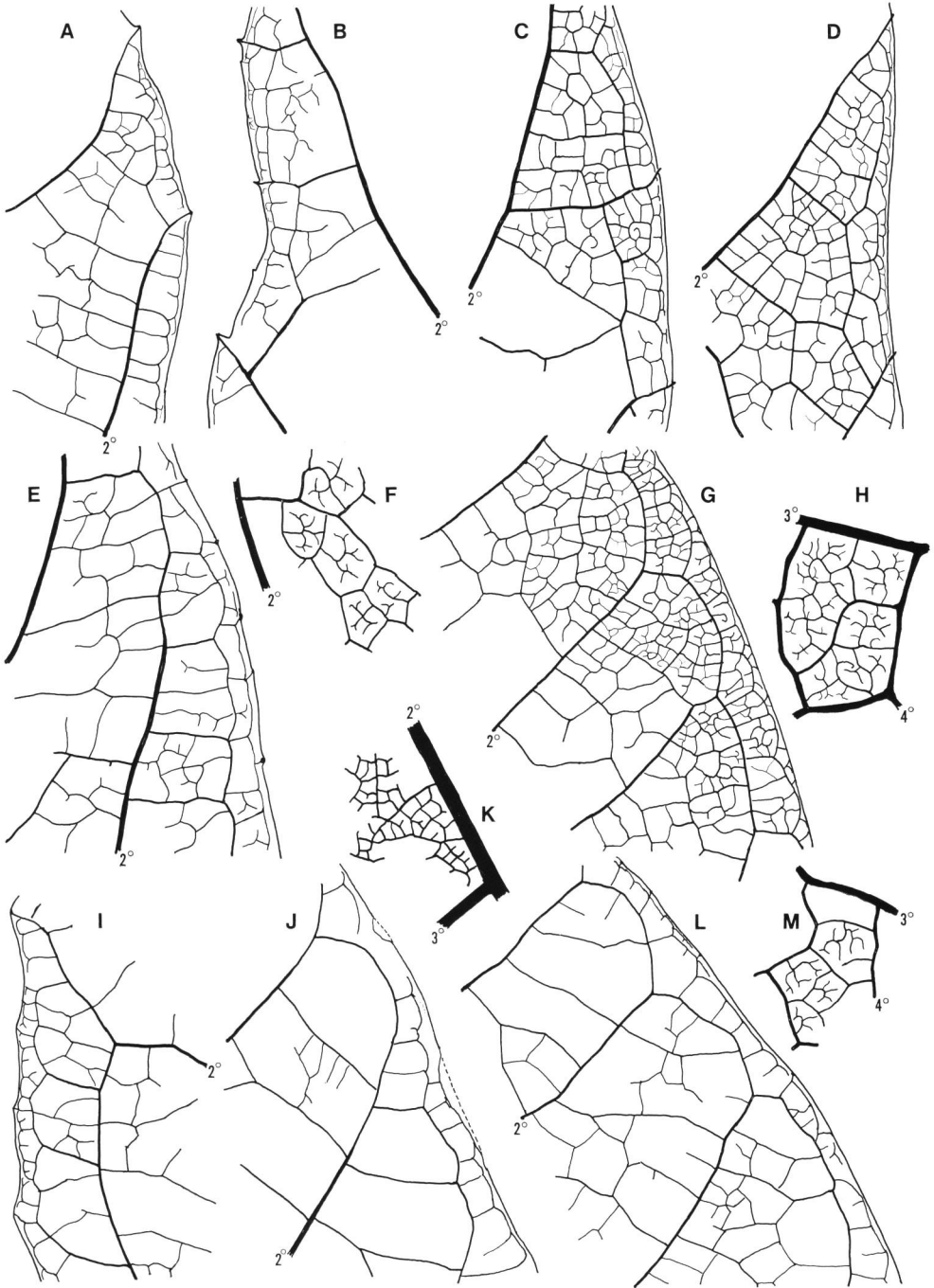
E, F. *Huziokaia eoutilus* (ENDO) TANAI. Holotype NSM PP 1831 (pl. 2, fig. 4). E: ×3, F: ×5

G, H. *Merrilliodendron megacarpum* (HEMSL.) SLEUMER. NSM Paleobot. Reference Coll. no. T-2216. G: ×3, H: ×15

I. *Pyrenacantha* sp. NSM PP 10362 (Pl. 5, fig. 1). ×3

J, K. *Goweria bibaiensis* TANAI. NSM PP 10345 (Pl. 4, fig. 3). J: ×3, K: ×15

L, M. *Merrilliodendron ezoanum* TANAI. Holotype NSM PP 1974. (Pl. 4, fig. 2). L: ×3, M: ×15



The fossils are closely related to *A. trewioides* MUELL.-ARG. living in central to southern China, and northern Viet Nam, although the extant species is less conspicuous in marginal teeth and somewhat more much basal secondary veins than in the fossils.

The holotype specimen of *Tilia harutoriensis* from the Kushiro coal field (OISHI & HUZIOKA, 1943) has small glandular teeth on the margin that are separated by arcuate sinus, and is thus clearly referable to *Alchornea*. The marginal teeth of *Tilia* leaves are typically large with mucronate, non-glandular tips, and are usually separated by angular sinus.

Occurrence: Ishihari coal field Ic-9, Ic-10; Kushiro coal field Kh-1.

Collections: Holotype HUMP no. 9261 (Kh-1); hypotypes NSM PP 10343, 10344, 10345 (Ic-9); NSM PP 10346 (Ic-9).

Genus *Hura* LINN.

Hura sp.

(Pl. 1, fig. 4; pl. 5, fig. 4; Fig. 3-A)

Discussion: The oblong to obovate shape with acuminate apex, thick secondary veins that extend straightly near the margin and abruptly arise up to form regular loops, thin percurrent tertiary veins, and small glands that are sparsely arranged on the margin, indicate that the fossil leaves are closely similar to *Hura crepitans* LINN. The marginal tertiary veins form irregular loops along the margin, or enter the glandular tips which sometimes project slightly beyond the margin as the protuberance. The fossil leaves also resemble those of *Sapium* such as *S. sebiferum* SMALL and *S. rotundifolium* HEMSL. living in southern China; however, *Sapium* has usually glands on the secondary and tertiary veins forming marginal loops.

Because *Hura* is now confined to the New Tropics such as in Mexico to tropical South America, I assigned the fossil leaves to this genus with some hesitation. However, the fossils well match with this genus in many features of major venation and gland position. The poor preservation of the higher order venation and lack of basal lamina, do not allow a satisfactory specific diagnosis or description.

Occurrence: Uryu coal field Ur-1.

Collection: NSM PP 10347a, b.

Genus *Mallotus* LOUR.

Mallotus hokkaidoensis TANAI

(Pl. 3, fig. 3)

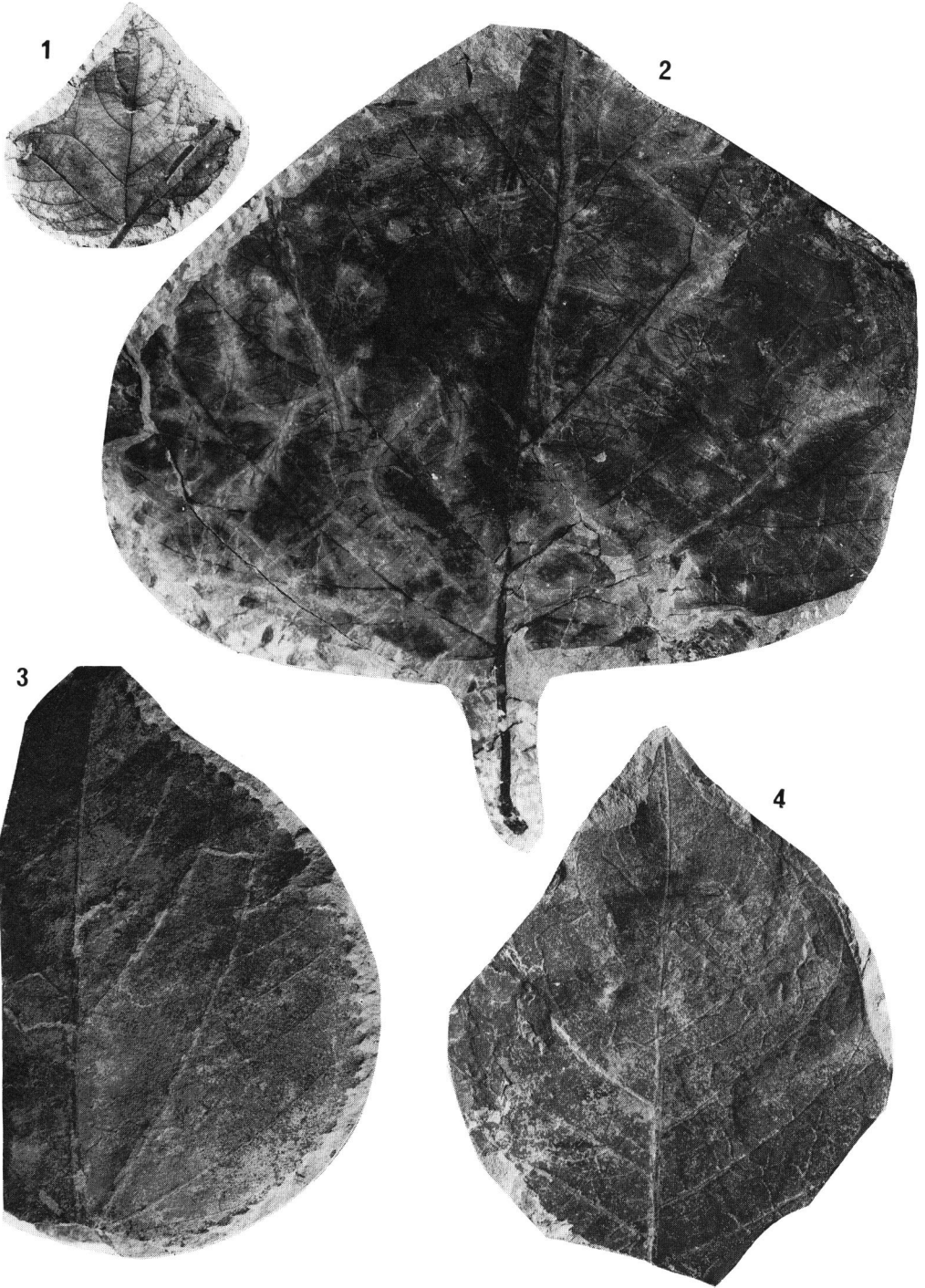
Mallotus hokkaidoensis TANAI. 1970. J. Fac. Sci., Hokkaido Univ., [4], 14(4): 487, pl. 13, fig. 8.

TANAI. 1989. Bull. Nat'n. Sci. Mus. [C], 15(4): 128. pl. 1, figs. 2, 3; Fig. 2-G, H.

Plate 1. (All figures in natural size)

Fig. 1. *Mallotus yubariensis* TANAI. the counterpart of holotype (NSM pp 10352).

Fig. 2. *Mallotus orbiculatus* TANAI. Holotype NSM PP 10349 (Ic-9). Fig. 3. *Acalypha* sp. NSM PP 10342 (Ic-3). Fig. 4. *Hura* sp. NSM PP 10347a (Ur-1).



Discussion: As already discussed in detail (TANAI, 1989), this species is closely similar to *Mallotus japonicus* MUEL.-ARG. living in Japan, and central to southern China in the venation features. *M. hokkaidoensis* is common in the Upper Eocene of Hokkaido (Horizon 4). Considering that leaves of *M. hokkaidoensis* are usually acute at the base, this fossil species is also related to the extant *M. paniculatus* (LAM.) MUEL.-ARG. of southern China (Hainan).

Occurrence: Ishikari coal field Ic-3, Ic-9, Ic-10; Kushiro coal field Kh-1.

Collections: Holotype HUMP no. 26979; hypotypes NSM PP 10289, 10319, 10348.

Mallotus orbiculatus TANAI sp. nov.

(Pl. 1, fig. 2; pl. 2, figs. 1, 3; Fig. 3-I, J, K)

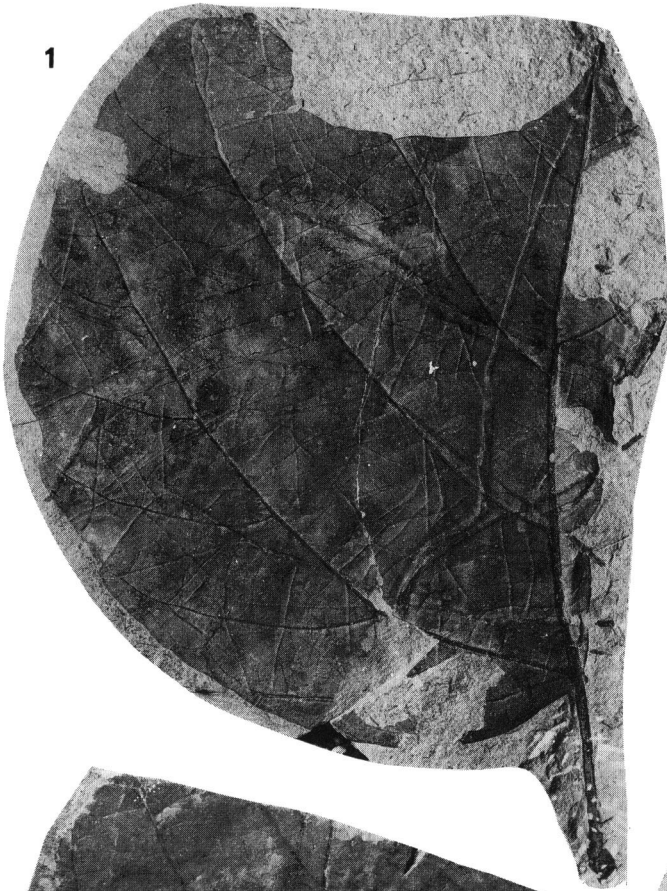
Typus: Holotype NSM PP 10349; Reisui-zan, Yubari, Hokkaido; Ikushunbetsu Formation (Late Eocene).

Description: Leaves very wide ovate or heart-shaped orbiculate in general outline, 10 to 13 cm (estimated) long and 13 to 13.5 cm (estimated) wide; apex acuminate; base broadly cordate; margin entire but slightly undulate; petiole thick, with swollen distal end, 2 to 2.3 cm long. Venation basal actiondromous with 3 primary veins; midvein thick, straight or slightly arcuate; lateral primary veins thinner than midvein, diverging at 65° to 70°, gently curving up, extending about half the distance to the apex, craspedodromous, ending in glandular protuberance; 7 or 8 secondary veins extending abaxially from lateral primary, curving up, craspedodromous to end in marginal protuberance or rarely camptodromous; medial secondary veins 6 in pairs, parallel to lateral primary, craspedodromous, ending in glandular protuberance; 1 to 3 subsecondary veins branching exmedially, ending in marginal protuberance; intercostal tertiary veins straight or slightly convex-percurrent, typically unforked but sometimes forking, nearly perpendicular to the secondaries, with distance of 3 to 5 mm; marginal tertiary and quaternary veins forming loops; intercostal quaternary veins thin, forming 4 or 5 sided meshes; highest order veins sixth; areoles formed by quinternary veins mostly 4 sided, 0.5 to 0.7 mm across; veinlets ill-preserved but profusely branching as far as observed.

Discussion: Leaves of some genera of the Euphorbiaceae are closely similar to the fossil leaves in having orbiculate shape, three prominent palmate veins that extend about the half the distance to apex, distinct straight or convex percurrent tertiary veins, thin quaternary veins forming 4 or 5 sided meshes and more than twice branching veinlets within areoles of thin quinternary veins. In *Aleurites*, the lateral primary, secondary veins and their exmedial branches arise up considerably along the margin, and frequently join with fimbrial vein. In *Alchornea*, the margin is usually serrate with

Plate 2. (All figures in natural size)

Fig. 1. *Mallotus orbiculatus* TANAI. Paratype NSM PP 10350 (Ic-9). Fig. 2. *Merrilliodendron ezoanum* TANAI. Hypotype NSM PP 10357 (Ow-1). Fig. 3. *Mallotus orbiculatus* TANAI. Hypotype NSM PP 10351 (Ur-1). Fig. 4. *Huziokaea eoutilus* (ENDO) TANAI. Holotype NSM PP 1831 (Ic-11).



minute teeth that are separated by arcuate sinus.

Leaves of the extant *Mallotus* include two types in marginal termination features of major veins: lateral primary and secondary veins are camptodromous to form loops in the one type as observed in *M. japonicus* MUELL.-ARG., *M. paniculatus* (LAM.) MUELL.-ARG. and *M. repandus* (WILLD.) MUELL.-ARG., while they are typically craspedodromous to end in marginal protuberance in other type as seen in *M. apelta* (LOUR.) MUELL.-ARG. and *M. tenuifolius* PAX. In *M. philippinensis* (LOUR.) MUELL.-ARG., the major veins are typically camptodromous but sometimes craspedodromous.

All the significant features of the fossils match with those of the extant *M. apelta*, although the extant species is variable from rounded to broadly cordate at base. The basilaminar glands that are characteristic of *Mallotus*, however, are not preserved in the fossils.

Occurrence: Ishikari coal field Ic-9; Uryu coal field Ur-1.

Collection: Holotype NSM PP 10349 (Ic-9); Paratype NSM PP 10350 (Ic-9); hypotype NMS PP 10351(Ur-1).

Mallotus yubariensis TANAI sp. nov.

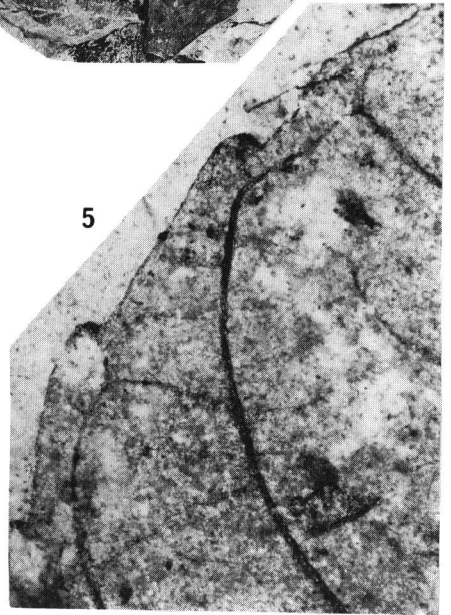
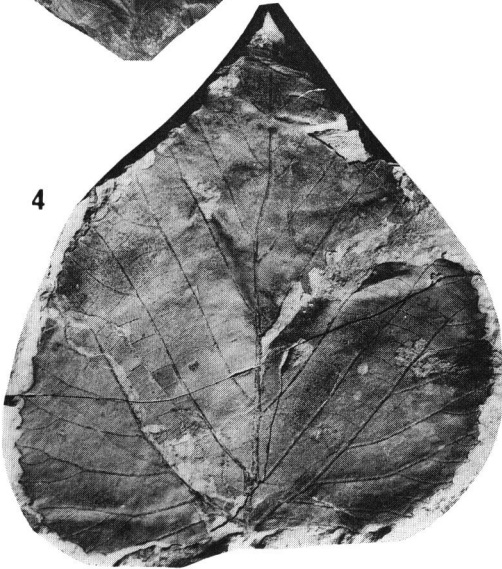
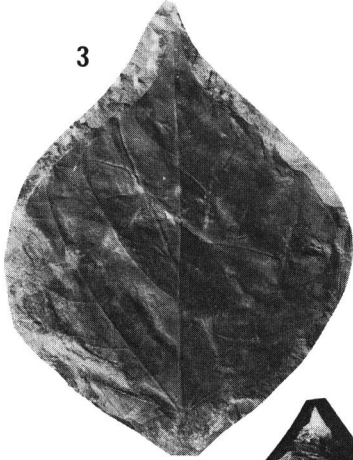
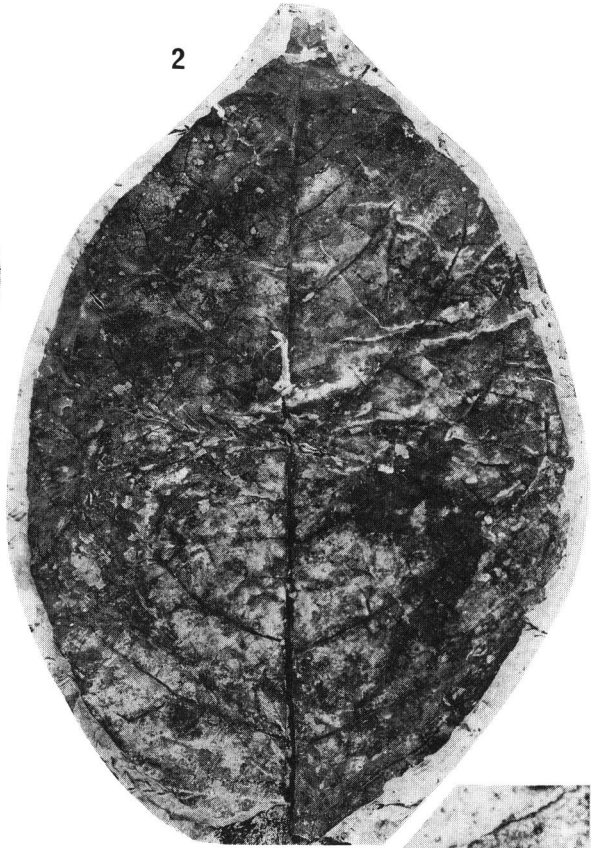
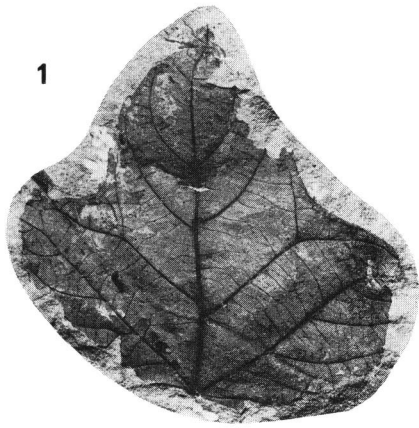
(Pl. 1, fig. 1; pl. 3, figs. 1, 5; pl. 6, fig. 4; Fig. 3-E)

Typus: Holotype NSM PP 10352; Reisui-zan, Yubari, Hokkaido; Ikushunbetsu Formation (Late Eocene).

Description: Leaves pentagonal in general outline, trilobed, 3.4 to 5.5 cm (estimated) long and 3.4 to 6 cm wide; base broadly rounded to truncate; each lobe deltoid, acute to slightly acuminate at apex; medial lobe larger than the laterals; lobe sinus broadly opened, rounded; margin revolute, thickened, remotely serrate with minute glandular tipped teeth; petiole missing. Venation basal actinodromous with 3 primary veins; midvein stout, straight; lateral primary veins stout, diverging at 45° to 50°, nearly straight or slightly curving up; 5 opposite pairs of secondary veins emerging from midvein at acute angles, parallel to the lateral primary, the upper 4 pairs curving upward, joining the superadjacent secondary vein to form large marginal loop from which a vein emerges and ends in minute obtuse tooth; the lowest pair of the secondary veins forking at about two-thirds distance from the origin, the basal branch extending to apex of lateral lobes, while the apical branch joining the superadjacent secondary vein to form a loop; 5 to 7 secondary veins emerging from lateral primaries at acute angles, entering directly the teeth or forming large loops from which a branch emerges to end in tooth; intercostal tertiary veins distinct, straight or slightly convex-percurrent with distance of 2–3 mm, sometimes forking; a subtertiary vein parallel to the tertiaries

Plate 3. (All figures in natural size unless otherwise stated)

Fig. 1. *Mallotus yubariensis* TANAI. Holotype NSM PP 10352 (Ic-9). $\times 5/3$ Fig. 2. *Merrilliodendron ezoanum* TANAI. Holotype NMS PP 1974 (Ic-11). Fig. 3. *Mallotus hokkaidoensis* TANAI. Hypotype NMS PP 10348 (Ic-10). Fig. 4. *Alchornea harutoriensis* (OISHI & HUIZIOKA) TANAI. Hypotype NSM PP 10343 (Ic-9). Fig. 5. Showing the marginal venation feature of *Mallotus yubariensis* TANAI (Fig. 1). $\times 10$



sometimes present, connecting with transversed quaternary veins; marginal tertiary and quaternary veins forming two series of looping some slender veins from marginal small loops entering glandular protuberances; quaternary veins thin, approximately perpendicular to the tertiaries; the higher order venation ill-preserved; many minute punctate glands scattered on undersurface of blade as dark spots.

Discussion: The small protuberances of margin, well-developed tertiary veins, slender transversed quaternary veins, and glands scattered on undersurface indicate that these trilobed leaves are closely related to some extant leaves of *Mallotus* such as *M. apelta* (LOUR.) MUELL.-ARG. and *M. tenuifolius* PAX, although the basilaminar glands are not preserved.

Because *M. apelta* has sometimes trilobed leaves, the fossil leaves may represent the trilobed leaves of the above described *M. orbiculata* which is closely related to *M. apelta*. Leaves of this extant species, however, are not toothed, although the marginal protuberances are characteristic. The fossil leaves well match with toothed trilobed leaves of the extant *M. tenuifolius*, and are distinguishable from *M. orbiculata*.

Occurrence: Ishikari coal field Ic-9.

Collection: Holotype NSM PP 10352, paratype 10353.

Order Celastrales

Family Icacinaceae

Genus *Goweria* WOLFE

Goweria bibaiensis TANAI sp. nov.

(Pl. 4, fig. 3; pl 6, fig. 2: Fig. 4-J, K)

Typus: Holotype NSM PP 10354; Rokuno-sawa, Bibai, Hokkaido; Noborikawa Formation (Middle Eocene).

Description: Leaves narrow ovate, slightly inequilateral, 7 to 9.7 cm long and 2 to 4.6 cm wide; base asymmetrically rounded; margin entire, thickened; petiole stout, 1.7 cm long. Venation palmate with 5 primary veins; midvein thick, straight; a pair of apical lateral primary veins diverging at 25° to 35°, extending slightly beyond half the distance to apex; basal pair of lateral primaries weaker than others, diverging at 60° to 65°; 5 pairs of medial secondary veins subparallel to apical primaries at middle part but wider angles on apical part of blade; 4 or 5 secondary veins extending ex-medially from apical lateral primaries at acute angles, forming loops along lower margin; lateral primary and medial secondary veins camptodromous, forming large loops whose apical sides are nearly perpendicular to midvein; intercostal tertiary veins rather thin but distinct, widely spaced, forking or unforking; marginal tertiary veins

Plate 4. (All figures in natural size)

Fig. 1. *Merrilliodendron ezoanum* TANAI. Paratype NSM PP 10356 (Ic-11). Fig. 2. *Huziokaia eoutilus* (ENDO) TANAI. the counterpart of holotype (NMS PP 1974). Fig. 3. *Goweria bibaiensis* TANAI. Holotype NSM PP 10354 (Nc-3). Fig. 4. *Alchornea harutoriensis* (OISHI & HUZIOKA) TANAI. Hypotype NSM PP 10344 (Ic-9).



mostly looping but rarely craspedodromous, ending in minute marginal bumps; quaternary veins typically forming elongate meshes parallel to tertiary veins; the highest order venation sixth or seventh; the higher order veins reticulate; areoles minute, mostly 4 sided, 0.12 to 0.16 mm across; freely ending veinlet mostly lacking, rarely single linear.

Discussion: The fossil leaves superficially resemble those of some extant species of the Lauraceae such as *Neolitsea* and *Cinnamomum*, but the basal actinodromous venation with five primary veins and marginal bumps in which marginal tertiary veins sometimes end, exclude the fossils from the Lauraceae. The following features of the fossils, however, indicate that they are referable to the form genus *Goweria*: five palmate venation, lateral primary and secondary veins forming angular loops; marginal tertiary veins sometimes craspedodromous and ending in marginal bumps; reticulation of quaternary veins typically forming polygons elongated parallel to tertiaries; minute areoles intruded rarely by single veinlet.

Of three described species of *Goweria* from North America, *G. hibaiensis* is closely similar to *G. alaskana* WOLFE from the Eocene of Alaska (WOLFE, 1977) in venation features, although different in having longer foliar shape. The genus *Goweria* proposed by WOLFE (1968) was later emended to belong to the Icacinaceae, having some characters similar to *Phytocrene* (WOLFE, 1977).

Occurrence: Ishikari coal field Nc-1, Nc-3.

Collection: Holotype NSM PP 10354 (Nc-3); paratype NSM PP 10355 (Nc-1).

Genus *Huziokaea* TANAI gen. nov.

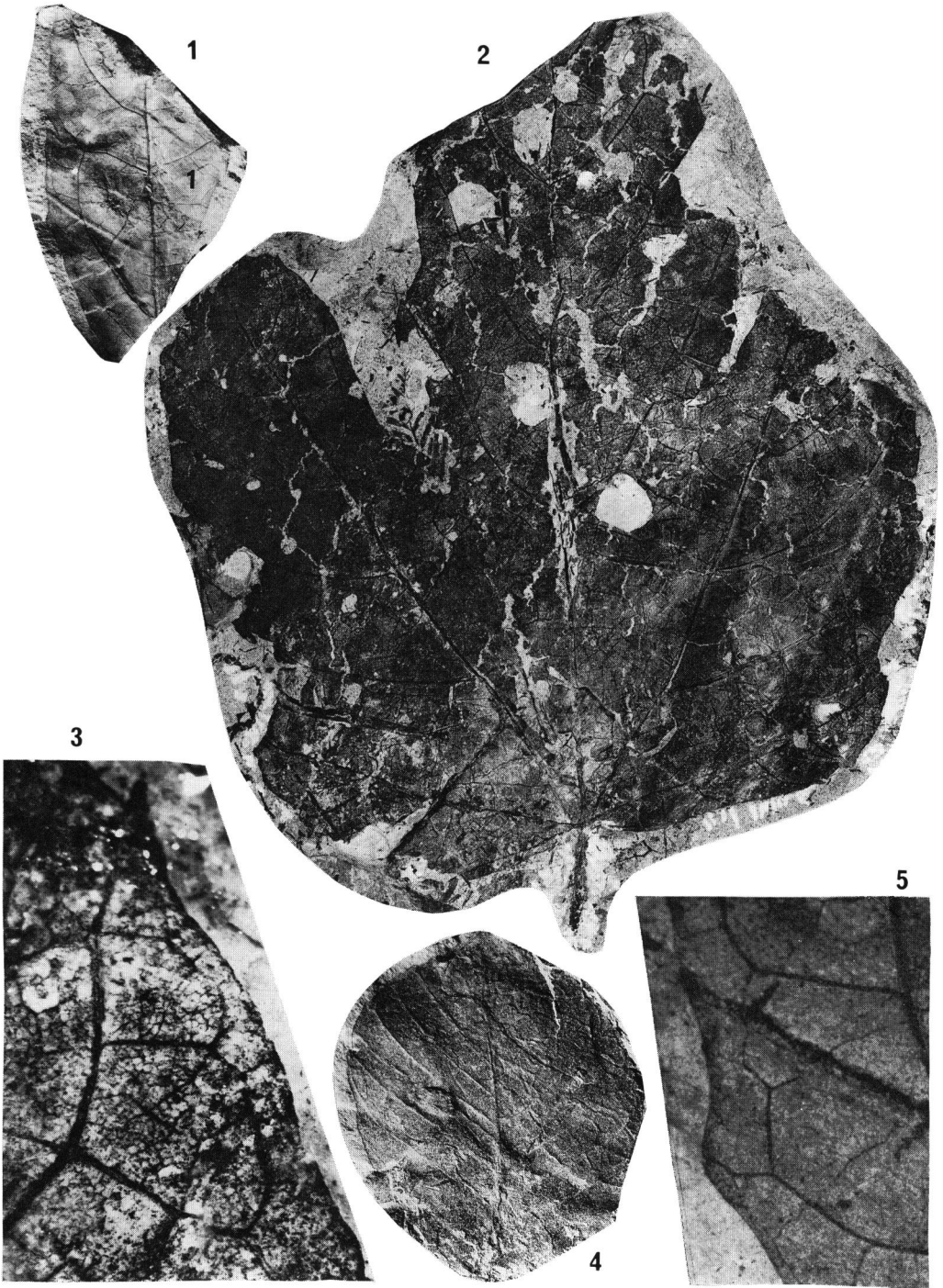
Type species: *Huziokaea eoutilus* (ENDO) TANAI.

Description: Leaves elliptic, acute both at the apex and base; margin entire but having sparsely minute protuberance; venation pinnate; 6 or 7 secondary veins irregularly spaced, diverging at acute angles, markedly ascending up, forming angular loops whose apical sides are typically perpendicular to the midvein; a basal pair of secondary veins weak; intercostal tertiary veins irregularly percurrent with wide distance, approximately perpendicular to the midvein; quaternary veins from the marginal loops sometimes craspedodromous and ending in marginal protuberances; areoles large, intruded by once or twice branching veinlets.

Discussion: The irregularly spaced secondary veins forming loops whose apical sides are perpendicular to midvein, a pair of weak basal secondary veins, widely spaced and irregularly percurrent tertiary veins, and quaternary veins from marginal loops sometimes ending in protuberances, are the characteristics of several genera of the Icacinaceae such as *Apodytes*, *Gomphandra*, *Merrilliodendron* and *Pyrenacantha*. Leaves of

Plate 5. (All figures in natural size unless otherwise stated)

Fig. 1. *Pyrenacantha* sp. NSM PP 10362 (Ic-9). Fig. 2. *Phytocrene ozakii* TANAI. Holotype NSM PP 10359 (Ic-9). Fig. 3. Showing the marginal venation feature of left lateral lobe of *Phytocrene ozakii* TANAI (Fig. 2). $\times 3$ Fig. 4. *Hura* sp. NSM PP 10347b (Ur-1). Fig. 5. Showing the marginal venation feature of *Pyrenacantha* sp. (fig. 1). $\times 6$



these extant genera are different from the fossil leaves in the extension of the second basal secondary veins and orientation of tertiary veins. The fossil leaves are also similar to *Gonocaryum* in venation features, especially to *G. obovatum* HOCHR. of Southeast Asia, although the extant leaves are less distinct in the marginal protuberance. The fossil leaves are assigned to a new genus of the Icacinaceae now considered to be extinct.

Huziokaea is named for Dr. Kazuo HUZIOKA, Professor Emeritus of Akita University, in recognition of his numerous contribution of Tertiary paleobotany of Japan and Korea.

Huziokaea eoutilis (ENDO) TANAI

(Pl. 2, fig. 4; pl. 4, fig. 2; Fig. 4-E, F)

Rhamnus eoutilis ENDO. 1968. Bull. Nat'n. Sci. Mus. 11(4): 438. pl. 18. fig. 1.

Glochidion japonicum TANAI. 1970. J. Fac. Sci., Hokkaido Univ. [4], 14(4): 485. pl. 13. figs. 1, 5.

Typus: Holotype NSM 10515 (PP 1931); Dam-site, Shimizusawa, Yubari, Hokkaido; Ikushunbetsu Formation (Late Eocene).

Description: Leaves elliptical, slightly inequilateral, 9.5 to 9.6 cm long and 4.5 to 4.6 cm wide; apex acute; base acute to cuneate; margin entire but having sparsely minute, glandular protuberances; texture thick; petiole missing. Venation pinnate; midvein moderate, nearly straight; secondary veins brochidodromous, in 6 or 7 pairs, opposite to subopposite, irregularly spaced, diverging at acute angles, broadly arcuate and steeply ascending up, forming angular loops with a set of percurrent tertiary veins; a pair of basal secondary veins thinner than other secondaries; second basal secondary veins sometimes present; intercostal tertiary veins irregularly spaced, somewhat flexuous in course, approximately perpendicular to midvein; quaternary and higher order veins reticulate in costal areas; marginal quaternary veins exmedially extending from secondary or tertiary loops to end in marginal protuberances; areoles 4 or 5 sided, large (1 to 1.5 mm across); freely ending veinlets thin, once or twice branching.

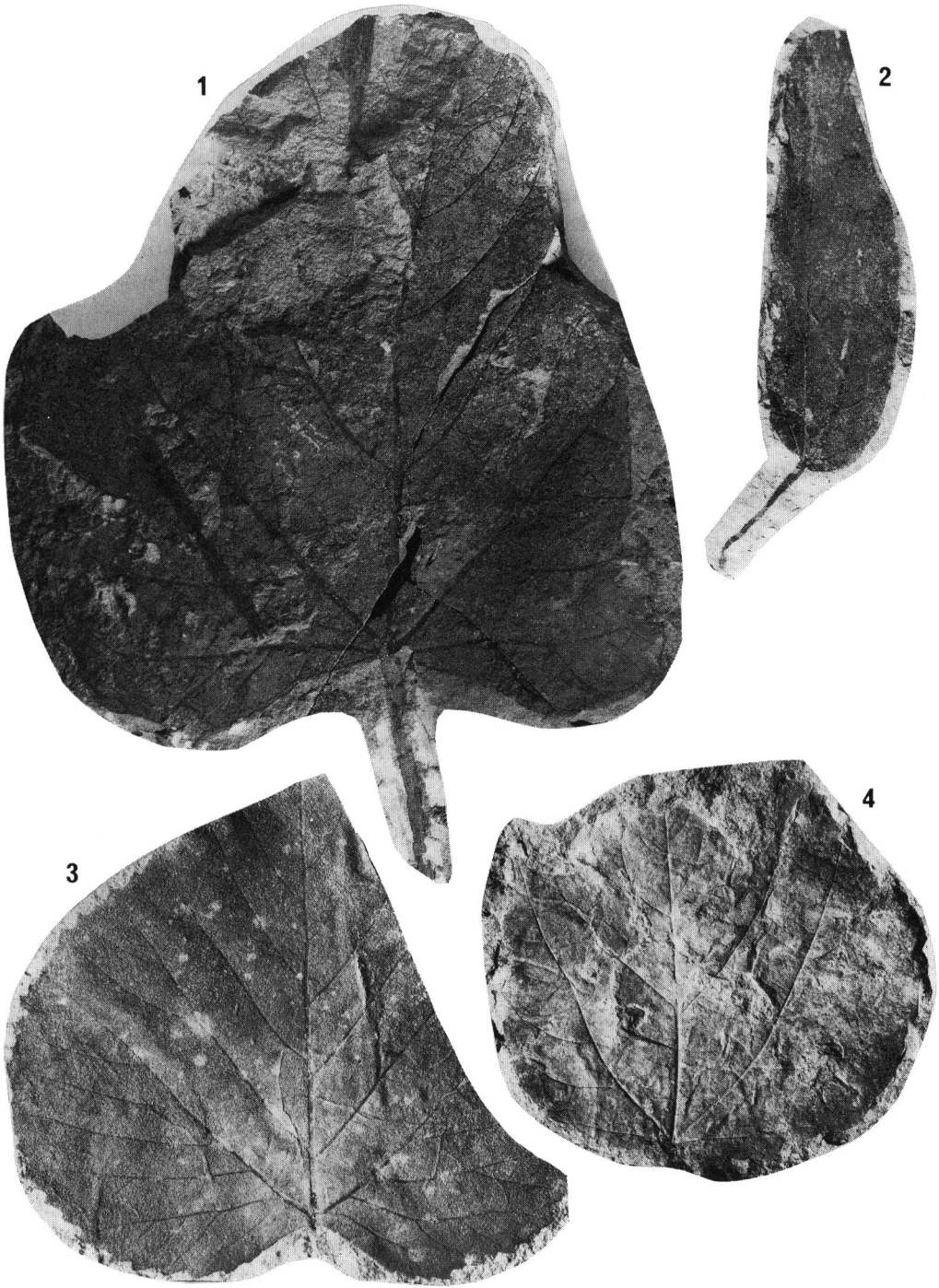
Discussion: The venation features and marginal protuberances indicate that ENDO's (1968) specimen and its counterpart are not referred to *Rhamnus* but to an extinct genus, *Huziokaea*, of the Icacinaceae. The reinvestigation of leaves described as *Glochidion japonicum* from the Kushiro coal field (TANAI, 1970) revealed that these leaves are not *Glochidion*, and are included in *H. eoutilis* in venation and marginal features.

Occurrence: Ishikari coal field Ic-11; Kushiro coal field Kh-1.

Collections: Holotype NSM PP 1831 (Ic-11); HUMP nos. 26977, 26978 (Kh-1).

Plate 6. (All figures in natural size unless otherwise stated)

Fig. 1. *Phytocrene ozakii* TANAI. Hypotype NSM PP 10360 (Ow-1). $\times 2/3$ Fig. 2. *Goweria bibaiensis* TANAI. Paratype NSM PP 10355 (Nc-1). Fig. 3. *Alchornea harutoriensis* (OISHI & HUZIOKA) TANAI. Hypotype NSM PP 10345 (Ic-10). Fig. 4. *Mallotus yubariensis* TANAI. Paratype NSM PP 10353 (Ic-9).



Genus *Merrilliodendron* KANEHIRA*Merrilliodendron ezoanum* TANAI sp. nov.

(Pl. 2, fig. 2; pl. 3, fig. 2; pl. 4, fig. 1; Fig. 4-L., M)

Magnolia sp., ENDO, 1968. Bull. Nat'n. Sci. Mus., pl. 25, fig. 1.

Typus: Holotype NSM 10657 (PP 1974); Dam-site, Shimizusawa, Yubari, Hokkaido; Ikushunbetsu Formation (Late Eocene).

Description: Leaves wide elliptic, 6 to 11 cm (estimated) long and 4.1 to 7 cm wide, length/width ratio 1.46 to 1.57; apex acute; base broadly acute; margin entire, recurved with thickening, but having sparsely minute protuberances on the upper part; petiole more than 7 mm long. Venation pinnate; midvein moderate, straight; secondary veins brochidodromous, somewhat irregularly spaced, 8 or 9 in pairs, subopposite, diverging at acute angles, gently curving up, connecting with superadjacent secondary veins; apical side of marginal loops approximately perpendicular to the midvein; a pair of basal secondaries weaker than others; slender intersecondary veins rarely present; intercostal tertiary veins irregularly and widely percurrent (4 to 7 mm distance), nearly perpendicular to the secondaries in both origin, somewhat sinuous in course, forking or unforking; marginal tertiary veins forming angular loops; quaternary veins in intercostal area perpendicular or parallel to the tertiaries to form large quadrangular meshes, marginal quaternary veins forming weak loops or ending in marginal protuberances; areoles four- or five-sided, intruded by more than twice branching.

Discussion: The irregularly spaced secondary veins forming marginal loops whose apical side is nearly perpendicular to the midvein, a pair of the secondaries weaker than others, widely spaced intercostal tertiary veins, and marginal quaternary veins forming loops or ending in marginal protuberances, are characteristics of the Icacinaceae. The wide-elliptic shape, and intercostal tertiary veins diverging perpendicular from the midvein and bending down to secondaries, indicate that the fossils are referable to *Merrilliodendron*. The fossil leaves also resemble *Gomphandra pauna* (BECC.) SLEUMER of New Guinea, but differs in the orientation of tertiary veins.

A single leaf illustrated as *Magnolia* sp. from Yubari by ENDO (1968) is included in *Merrilliodendron ezoanum* by features of secondary and tertiary veins and marginal protuberances, although Endo failed to give any description. *M. ezoanum* resembles *Huziokaea eoutilus* described above in many features, but is distinguishable in wider shape, somewhat much secondary veins, and the tertiary veins oblique to midvein. *Merrilliodendron* is a monotypic genus; *M. megacarpum* (HEMSL.) SLEUMER is living in Philippine and Macronesia islands.

Occurrence: Ishikari coal field Ic-2, Ic-11; Kabato coal field Ka-2.

Collection: Holotype NSM PP 1974 (Ic-11); paratype NSM PP 10356 (Ic-11); hypotypes NSM PP 10357 (Ka-2); NSM PP 1870, 2045, 2130 (Ic-11), 10358 (Ic-2).

Genus *Phytocrene* WALL.*Phytocrene ozakii* TANAI sp. nov.

(Pl. 5, figs. 2, 3; pl. 6, fig. 1; Fig. 4-A, B)

Typus: Holotype NSM PP 10359; Reisui-zan, Yubari, Hokkaido; Ikushunbetsu Formation (Late Eocene).

Description: Leaves pentagonal in general outline, palmately trilobed, broadly shallow-cordate, slightly inequilateral, 11 to 18 cm (estimated) long and 7 to 14 cm (estimated) wide; lobes ovate or oblong with acute apex; sinus narrow with rounded bottom; lateral lobes considerably inequilateral; margin entire but somewhat undulate, having sparsely minute protuberances; petiole thick but incomplete, more than 4.7 cm long. Venation basal actinodromous with 7 primary veins; midvein thick, nearly straight but slightly flexuous on apical part; the most apical lateral primary veins thick, diverging at 30° to 45°, nearly straight; a pair of second lateral primaries somewhat weak, extending at 70° to 90°, slightly arcuate, ending in marginal protuberance; a pair of basal primaries thin, extending at more than 90°, camptodromous; secondary veins more than 5 in opposite pairs, nearly parallel to apical primaries, ending in protuberances; six exmedial and three admedial secondary veins in lateral lobes diverging from apical lateral primaries at about 60°, gently curving up, ending in minute protuberances; six secondary veins emerging basally from second lateral primaries, gently curving up, forming loop or ending in marginal bumps; intercostal tertiary veins thin but distinct, distantly percurrent with irregularly spaces, nearly perpendicular to secondaries; marginal tertiary and quaternary veins forming two-orders looping; intercostal quaternary and higher order veins forming reticulation; areole somewhat irregular in size, four or five sided; freely ending veinlets thin, irregularly more than twice branching.

Discussion: The seven palmate venation, craspedodromous secondary veins that end in small marginal protuberances, irregularly spaced tertiary veins, and more than twice branching veinlets indicate that these trilobed leaves are closely similar to some leaves of *Phytocrene*, particularly to *P. bracteata* WALL. living in Southeast Asia. Leaves of the extant *P. bracteata* are typically ovate in shape, but are frequently trilobed with inequilateral lanceolate lobes. The fossil leaves appear to be hairy on the undersurface as in the case of the extant species, because the pattern of freely ending veinlets of the fossils are somewhat obscure on impression, despite of well-preserved specimen. *P. bracteata*, however, is more distinct in basal pair of primary veins and more deeply cordate at the base than in *P. ozakii*.

Two species of *Phytocrene* based on leaf specimens, have been described from the Eocene of California (MACGINITIE, 1941) and Alaska (WOLFE, 1977). However, these North American species are usually represented by non-lobed leaves. It is noteworthy that this tropical shrubs or vines were distributed in the both sides of the Northern Pacifics during the Eocene.

This species is named for the memory of late Dr. Kimihiko OZAKI of Yokohama

National University, whose many important contributions to Neogene floras of Japan were unfortunately closed by his accidental death.

Occurrence: Ishikari coal field Ic-9; Owada coal-bearing area Ow-1.

Collection: Holotype NSM PP 10359 (Ic-9); hypotype 10360 (Ow-1); NSM PP 10361 (Ic-9).

Genus *Pyrenacantha* HOOK. ex WIGHT.

Pyrenacantha sp.

(Pl. 5, figs. 1, 5; Fig. 4-1)

Discussion: This fossil leaf, although fragmentary, is assignable to *Pyrenacantha* by the following characteristics: widely and irregularly spaced, pinnate secondary veins that form large loops; a weak pair of basal secondary veins whose apical side of loops are oriented basally; marginal tertiary veins form angular loops or extend to small marginal protuberances; intercostal tertiary veins are widely spaced and sinuous; margin is undulate, slightly projecting at the marginal protuberances. The incomplete fossil leaf is related to *P. standtii* (ENGL.) ENGL. of Africa and *P. volubilis* WIGHT living in Hainan to India, especially to the former. The fossil, however, is too fragmentary to give a specific name.

Occurrence: Ishikari coal field Ic-9.

Collection: NSM PP 10362.

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