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LATE CRETACEOUS FLORAS FROM THE KUJI DISTRICT, NORTHEASTERN HONSHU, JAPAN

by

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(with 5 text-figures, 4 tables and 14 plates)

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Abstract

The Upper Cretaceous (Senonian) Kuji Group in northeastern Honshu is divided into three formations, the Tamagawa, the Kunitan and the Sawayama in ascending order. Well-preserved plants are included in the Tamagawa and Sawayama Formations. Fifty-one species of plants from 12 localities are identified; they are made up of 17 pteridophytes, 2 cycadophytes, 10 conifers and 22 angiosperms, all of which are taxonomically described. These two floras from the Kuji Group have many common species, but they are somewhat different in floristic composition. In the Sawayama flora angiosperms predominate in species and specimens, and are followed by various ferns and conifers. On the one hand, the Tamagawa flora is most predominant in ferns, and is less in angiosperms. These two floras are closely similar in composition and components to the "Gyliakian flora" of North Saghalien. Considering the floristic composition together with marine fossils of the Kunitan Formation, the Tamagawa flora is assignable to Santonian, and the Sawayama flora is to Early Campanian age.

Introduction

In northeastern part of the Kitakami massif the Upper Cretaceous and Paleogene sediments are distributed along the Pacific coast. Well-preserved plant fossils have been known to occur from the Cretaceous sediments, and were provisionally listed up by Sasa (1932), who did first a detailed geological investigation in this district. These plants represent one of Late Cretaceous floras which are uncommon in Japan, but they have been not yet taxonomically investigated with an exception of *Cibotium* (Ogura, 1933). On the other hand, the Cretaceous palynomorphs from this district were recently described by Tokunaga and Takase (1968), Sohma (1969) and Miki (1972, 1977); especially, Miki (1972) precisely discussed on composition and floristic sequence of pollen and spores through the Upper Cretaceous.

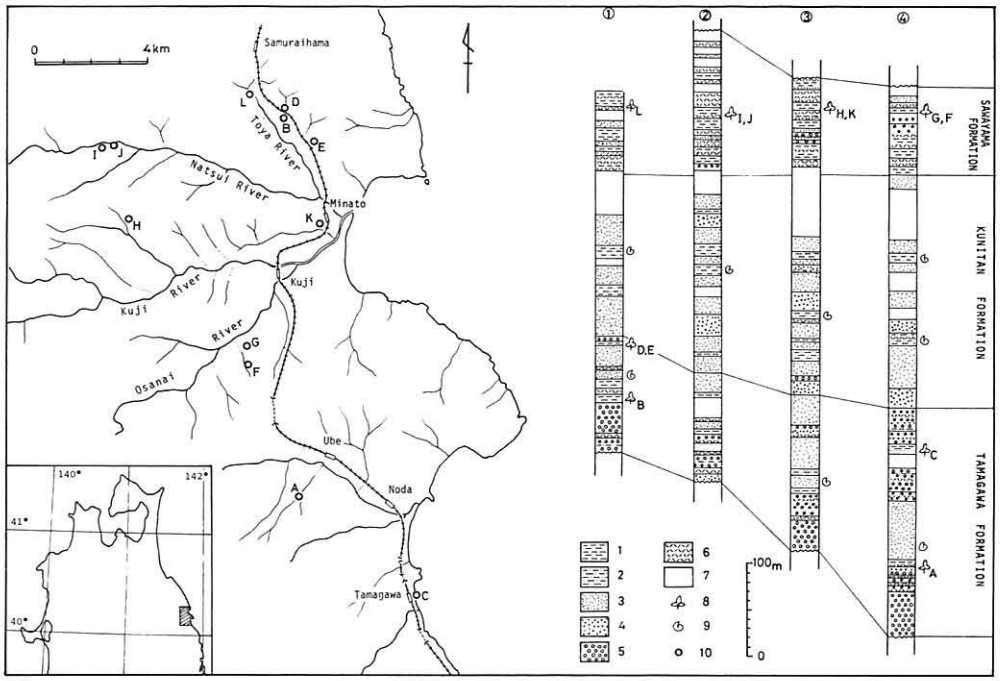
About ten years ago, Sawara (1967) collected a number of plant fossils from the Upper Cretaceous at several localities of the Kuji district through his extensive geological investigation. These plants contain several new materials interesting for Cretaceous phytogeography and biostratigraphy of East Asia. Since then, I have investigated these Cretaceous plants during these several years by collecting additional specimens. It is the purpose of this paper to describe these plants, and to discuss the floristic relationships with Late Cretaceous floras of East Asia.

I wish to express my gratitude to Mr. Norihiko Sawara, one of my former students, for offering his collection and geological informations of fossil localities. Acknowledgement is also to Dr. Azuma Iijima, Professor of Geology, the University of Tokyo, for his kind assistance of collecting fossils in the autumn of 1970.

Geographic and Geologic Settings

Twelve localities from which the Cretaceous plants were obtained, are scattered in the environs of the downtown of Kuji City in the northeastern part of Iwate Prefecture. As shown in Text-fig. 1, these localities are distributed from Kunitan in the north to the coastal cliff of Tamagawa village in the south, and also in Sawayama village in the west. This region is made up largely of hills with a highest peak of 271 m and their adjacent alluvial plains. These hills are bordered eastward by the steep cliffs from the Pacific Ocean, while they extend west- and southward with gradual increase in height, and connect with the Kitakami massif, which is composed of pre-late-Cretaceous terrane. The major drainage develops toward the east and northeast or southeast from the Kitakami massif, and enters the Pacific.

In the Kuji district the Upper Cretaceous sediments are distributed unconformably on the granitic rocks and the "Triassic–Lower Cretaceous sediments, and are covered unconformably by the Paleogene terrestrial sediments. The geology of this region was first investigated in detail by Sasa (1932), by whom the Upper Cretaceous and Paleogene stratigraphy was established. Since then, few reports on stratigraphy have been known up to the present, excepting for a geological sheet map, "Rikuchu-Noda", (Shimazu et al., 1962).



Text-fig. 1 Showing the localities of Late Cretaceous plants in the Kuji district and general stratigraphy of the Kuji Group. ① Columnar section along the Toya River ② columnar section along the Natsui River ③ columnar section along the Kuji River ④ columnar section in the area between Tamagawa coast and the Osanai River 1: siltstone 2: sandy siltstone 3: fine to medium grained sandstone 4: coarse grained sandstone 5: conglomerate 6: tuff 7: no exposure 8: plant fossils 9: animal fossils 10: plant fossil localities.

The Upper Cretaceous Kuji Group, is divided into three formations: the Tamagawa, the Kunitan and the Sawayama Formations in ascending order. The plant fossils described in this paper, are contained in the Tamagawa and the Sawayama Formations, as shown in Text-fig. 1.

The Tamagawa Formation: This formation is composed mainly of conglomerate, sandstone and siltstone, and is of brackish to neritic origin. This formation showing 130 to 240 m thickness, is subdivided into three members by lithology. The lower Member is composed principally of conglomerate, with interbeds of tuff, silstone and sandstone. From these tuff and silstone plant fossils occur at Chikyozawa (Loc. A) and at Kunitan (Loc. B). The middle member consisting of greenish sandstone, includes the *Ostrea*-bearing beds through this area. The upper Member is composed of conglomerate and sandstone, with intercalations of tuff and siltstone. At Kunitan (Loc. D) and Tamaga coastal cliff (Loc. C) well-preserved plant fossils occur in blackish siltstone of this member.

The Kunitan Formation: This formation consists mainly of fine- to medium-grained sandstone, with interbedding sandy siltstone and conglomerate. This formation of 170 to 250 m thickness, is of neritic origin, and contains molluscan and ammonite fossils at its lower and middle part, though ill-preserved.

The Sawayama Formation: This formation consists of alternation of tuffaceous sandstone and siltstone, intercalating many rhyolitic tuff beds. This formation is largely terrestrial in origin, and contains several brown coal seams. Because the Tertiary overlies the Upper Cretaceous with unconformity, the Sawayama Formation varies from 70 to 150 m in thickness. Plant fossils are included in the tuff and siltstone of the upper half of this formation, especially abundant at the localities along the Natsui river (Loc. I and J).

The Kuji Group gently dips toward the Pacific with 10–20 degrees and forms a half-basin structure. This group is covered unconformably by the Oligocene Noda Group, which is composed of conglomerate, sandstone and siltstone. The Noda Group contains several coal seams, which were once mined, and yields also a number of plant fossils. The Tertiary plants are quite different from those of the Kuji Group, and they shall be reported in a later paper.

Floristic Composition

The Cretaceous plants of the Kuji Group found from the Tamagawa and Sawayama Formations, are composed of 17 pteridophytes, 12 gymnosperms and 22 angiosperms. Of these 51 plants, ten species are new, five are new combination, and the remaining are the species described elsewhere in the Cretaceous. The floras from these two formations are somewhat different in their composition, although many species are common.

The Tamagawa flora is made up of 27 plants, which include 11 pteridophytes, 6 conifers and 10 angiosperms (Table 1). It is noteworthy that the lower Tamagawa florule contains no angiosperm which is recorded from the Upper Tamagawa. The Lower Tamagawa florule is represented by ferns such as *Gleichenites* and *Asplenium,* excepting for *Araucarites.* On the other hand, the Upper Tamagawa florule is also common in ferns such as *Asplenium, Sachalinia* and *Cladophlebis,* while it contains many dicotyledons such as *Dryophyllum, Platanus, Magnolia* and *Cissus,* and a few conifers such as *Araucarites, Taxodium* and

Glyptostrobus. It is characteristic to contain the genus *Rogersia,* which is characterized by leaf of ill-developed higher-order venation. The genus *Rogersia* established by Fontaine (1889), was known from the Late Cretaceous Potomac Group of the eastern United States.

The Sawayama flora is composed of 42 plants, which are distributed in 12 pteridophytes, 2 cycadophytes, 8 conifers and 20 angiosperm. All the ferns from the Sawayama Formation are common with those of the Tamagawa with a few exceptions. It is interesting to yield *Zamiopsis,* which leaves show intermediate features of cycads and ferns in pinnules and venation. Cycadophytes represented by *Nilssonia* and *Otozamites* are uncommon in the Sawayama flora, but they are not included in the Tamagawa. Compared with the Tamagawa flora, the Sawayama flora contains commonly conifers and angiosperms; espespecially, the latter is abundant in number of species and specimens. Of 7 conifers, Araucarian foliage shoots yield abundantly in the rhyolitic tuff of the Upper Sawayama Formation, sometimes associated with detached cones. Taxodiaceae are not always abundant in the specimens, but it is represented by *Glyptostrobus, Metasequoia* and *Taxodium,* all of which are common in the Tertiary. Angiosperms, as far as I could identify, are common in such families as the Salicaceae, Fagaceae, Dilleniaceae, Lauraceae and Platanaceae in number of specimens. Though being a few specimens respectively, such families as the Trochodendraceae,

Table 1. Systematic List of the Tamagawa Flora

Pteridophyta
- Sphenopsida
  - Equisetaceae
    - *Equisetum* sp.
- Pteropsida
  - Osmundaceae
    - *Osmunda asuwensis* Matsuo
  - Gleicheniaceae
    - *Gleichenites crenata* (Krysht.) Tanai
    - *G.* cf. *giesekiana* (Heer) Seward
    - *G. lineariformis* (Krysht.) Tanai
  - Aspleniaceae
    - *Asplenium dicksonianum* Heer
  - Filicales insertae sedis
    - *Cladophlebis acuta* Fontaine
    - *C. borealis* (Brong.) Krysht.
    - *C. oerstedti* (Heer) Seward
    - *Sachalinia sachalinensis* Vachrameev
    - *Sphenopteris onkilonica* Krysht.

Spermatophyta
- Gymnospermae
  - Taxodiaceae
    - *Glyptostrobus vachrameevii* Svenish.
    - *Taxodium* ? sp.
  - Araucariaceae
    - *Araucarites longifolia* (Lesq.) Dorf
    - *Dammarites borealis* (Heer) Seward
  - Gymnospermae insertae sedis
    - *Brachyphyllum* cf. *crassam* Lesq.
    - *Protophyllocladus subintegrifolius* (Lesq.) Berry
- Angiospermae
  - Magnoliaceae
    - *Magnolia* cf. *lakesii* Knowlton
  - Platanaceae
    - *Platanus cuneifolia* (Bronn) Krysht.
  - Fagaceae
    - *Dryophyllum subfalcatum* Lesq.
  - Salicaceae
    - *Salix lancencis* Berry
  - Sapindaceae
    - *Sapindophyllum quercifolium* (Hollick) Tanai
  - Vitaceae
    - *Cissus marginata* (Lesq.) Brown
  - Angiospermae insertae sedis
    - *Carpolithes arcticus* (Heer) Hickey
    - *Debeya tikhonovichii* (Krysht.) Krassilov
    - *Dicotylophyllum iwateanum* Tanai
    - *Rogersia angustifolia* Fontaine

Menispermaceae, Magnoliaceae, Rhamnaceae and Trapaceae are well represented with definite evidences. Beside these families, there are many angiosperms which are uncertain in the modern relationships.

The quantative appraisal of the Tamagawa and Sawayama floras is based on 868 specimens from 12 localities as shown in Table 3. This count is too small to preclude the possibility that certain rare species may have been more numerous in Late Cretaceous time in this district than in suggested by these figures. However, it seems probable that the proportionate representation of the dominants would not be greatly changed by a larger

Table 2. Systematic List of the Sawayama Flora

Pteridophyta
- Sphenopsida
  - Equisetaceae
    - *Equisetum* sp.
- Pteropsida
  - Schizaeaceae
    - *Anemia elongata* (Newb.) Knowlton
  - Gleicheniaceae
    - *Gleichenites gracilis* (Heer) Tanai
  - Aspleniaceae
    - *Asplenium dicksonianum* Heer
  - Salviniaceae
    - *Salvinia mildeana* Goeppert
  - Filicales insertae sedis
    - *Adiantopteris eximium* (Saporta) Boureau & Doubinger
    - *Cladophlebis borealis* (Brong.) Krysht.
    - *C. frigida* (Heer) Seward
    - *C. oerstedti* (Heer) Seward
    - *Sachalinia sachalinensis* Vachrameev
    - *Sphenopteris onkilonica* Krysht.
    - *Zamiopsis* cf. *pinnatifida* Fontaine

Spermatophyta
- Gymnospermae
  - Williamsoniaceae
    - *Otozamites schenckii* (Heer) Tanai
  - Nilssoniaceae
    - *Nilssonia variabilis* Pyrnada
  - Taxodiaceae
    - *Glyptostrobus vachrameevii* Sveshin.
    - *Metasequoia* sp.
    - *Taxodium* ? sp.
  - Araucariaceae
    - *Araucarites longifolia* (Lesq.) Dorf
    - *Araucarites kujiensis* Tanai
  - Cuppressaceae
    - *Thuja cretaceae* (Heer) Newberry
  - Coniferales insertae sedis
    - *Cyparissidium gracile* (Heer) Heer
    - *Protophyllocladus subintegrifolius* (Lesq.) Berry
- Angiospermae
  - Magnoliaceae
    - *Liriodendron iijimae* Tanai
    - *Magnolia* cf. *lakesii* Knowlton
  - Lauraceae
    - *Cinnamomophyllum* sp.
    - *Laurophyllum kujianum* Tanai
  - Menispermaceae
    - *Menispermites kujiensis* Tanai
  - Trochodendraceae
    - *Trochodendron kujiense* Tanai
  - Platanaceae
    - *Platanus cuneifolia* (Bronn) Krysht.
  - Fagaceae
    - *Dryophyllum subfalcatum* Lesq.
  - Dilleniaceae
    - *Dillenites lanceolatus* Tanai
  - Salicaceae
    - *Salix lancencis* Berry
  - Sapindaceae
    - *Sapindophyllum quercifolium* (Hollick) Tanai
  - Rhamnaceae
    - *Ziziphus kujiensis* Tanai
  - Trapaceae
    - *Hemitrapa angulata* (Newb.) Matsuo
  - Angiospermae insertae sedis
    - *Carpolithes arcticus* (Heer) Hickey
    - *C. kujiensis* Tanai
    - *Cuplicarpus kujiensis* Tanai
    - *Debeya tikhonovichii* (Krysht.) Krassilov
    - *Dicotylophyllum iwateanum* Tanai
    - *Trochodendroides arcticus* (Heer) Berry
    - *Monocotylophyllum* sp.

Table 3 Numerical Representation of Sawayama and Tamagawa Species

Formation and localities	Tamagawa Formation					Sawayama Formation							Total	
	Lower		Upper										Tamagawa	Sawayama
Species	A	B	C	D	E	F	G	H	I	J	K	L		
Equisetum sp.		1				6	8		8	11			1	33
Osmunda asuwaensis				1									1	
Anemia elongata							1							1
Gleichenites crenata		10											10	
G. cf. *giesekiana*		1											1	
G. gracilis							1			1				2
G. lineariformis		5											5	
Asplenium dicksonianum		5	12	11		14	26	16	28	23	24	14	28	145
Salvinia mildeana						21			3	2				26
Adiantopteris eximium									2	6				8
Cladophlebis acuta				1									1	
C. borealis			1	2					3	7	3	6	3	19
C. frigida							6		2	6	1			15
C. oerstedti			3				1			8			3	9
Sachalinia sachalinensis				5			3		11	3	3		5	20
Sphenopteris onkilonica				2		8							2	8
Zamiopsis cf. *pinnatifida*										6				6
Otozamites schenkii										1		1		2
Nilssonia variabilis							1			2		1		4
Glyptostrobus vachrameevii			6				6						6	6
Matasequoia sp.										1				1
Taxodium ? sp.			3				8						3	8
Araucarites longifolia	5		2				13	5	8	48			7	74
A. kujiensis								10						10
Dammarites borealis					2								2	
Thuja cretacea							2		18	6				26
Cyparissidium gracile										3				3
Brachyphyllum cf. *crassam*			2										2	
Protophyllocladus subinterifolius			4				9						4	9
Liriodendron iijimae							12							12
Magnolia cf. *lakesii*			3			3							3	3
Cinnamomophyllum sp.							2			5				7
Laurophyllum kujianum							36			6				42
Menispermites kujiensis							2	1	3	7				13
Trochodendron kujiense											2			2
Platanus cuneifolia			12					6	5	5			12	16
Dryophyllum subfalcatum			8	6		3			12	19	6		14	40
Dillenites lanceolatus									8	3				11
Salix lancensis				2				16		13			2	29
Sapindophyllum quercifolium			2						3				2	3
Cissus marginata			3										3	
Ziziphus kujiensis						1	7	2	1					11
Hemitrapa angulata						3	1	1		3		3		11
Carpolithes arcticus			3			3	2		1	4		1	3	11
C. kujiensis						1	1							2
Cuplicarpus kujiensis									1					1
Debeya tikhonovichii			2						1	4			2	5
Dicotylophyllum iwateanum			3				5		14	5			3	24
Rogersia angustifolia				1									1	
Trochodendroides arcticus							1			3				4
Monocotylophyllum sp.						8	13		21	14	3			59
Total	5	22	69	31	2	71	167	57	153	223	42	26	129	739

Localities. A: Chikyozawa B: Kunitan-A C: coastal cliff near Tamagawa D: Kunitan-B E: Utsume F: Hikagezawa G: Hikage H: Edanarizawa I: Oashi J: Kadonosawa K: Minato L: Hishikura

count. Actually, the percentages of several dominant species did not change through collections of several times. Thus, Table 3 seems to make possible to give some insight into the floristic characters of Late Cretaceous time in northeastern Honshu.

Correlation and Age Discussion

Compared with abundant occurrence of Tertiary floras, Late Cretaceous floras have been poorly known in Japan. It is due mainly to the fact that most of the Upper Cretaceous sediments are of marine origin. These marine sediments are widely distributed in Hokkaido, and central and western Honshu; their stratigraphic correlation and age-assignment have been done mostly by ammonites, inoceramids and other marine mollucs (Matsumoto, 1954, 1959). Recently, Matuso (1964, 1970) summarized the Late Cretaceous floras of Japan; however, his age-discussion and correlation seem to contain several misunderstanding, because of taking insufficient account of the relationships with marine formations.

In the continental region of East Asia, the Upper Cretaceous terrestrial sediments well develop, and yield a number of plant fossils. These Late Cretaceous floras have been investigated in detail by Russian paleobotanists, and their floristic changes and sequences were recently discussed (Vachrameev, 1966; Krassilov, 1975). However, these floristic sequences were not always established on the basis of relationships with marine faunas, excepting for the case of Saghalien.

Late Cretaceous terrestrial sediments of East Asia are unfortunately not yet determinable in their reliable age only by fossil floras. Accordingly, the age discussion on the Tamagawa and Sawayama floras is unavoidable to be preceded by the stratigraphical and faunal evidences included in the Kuji Group. With the full investigation of these two floras, it is hoped that sufficient evidence may be available to establish their age relationships.

Stratigraphic and Faunal Evidences

The Kuji Group is composed of three formations; the middle Kunitan Formation is of marine origin, while the lower Tamagawa and the upper Sawayama Formations are brackish or terrestrial in origin. These three formations are successively superposed without any hiatus; the Kuji Group represents a major cycle of deposition in a Late Cretaceous sedimentary basin of northeastern Kitakami region.

The Kunitan Formation contains sometimes marine invertebrate and shark tooth fossils in its middle silty facies; according to Sasa (1932) and Shimazu et al. (1962), this fauna is mainly composed of *Nucula* sp., *Portlandia* sp., *Glycymeris* sp., *Inoceramus japonicus* Nagao & Matsumoto, *I. naumanni* Yokoyama, *Lucina* cf. *fallax* Forbes, *Panopea* sp., *Polyptychoceras subundulatum* (Yokoyama), *Gaudryceras denseplicatum* (Jimbo), and *Texanites amakusense* (Yabe). These fossils, especially *Inoceramus japonicus,* indicate that the Kunitan Formation is assignable to Late Santonian age (Matsumoto, 1954). Accordingly, the Tamagawa Formation underlying the Kunitan without hiatus, was dated as Early Santonian to Coniacian age, while the Sawayama Formation successively overlying the Kunitan was dated as Campanian age. Based on the current investigation, Matsumoto (1977) summarized briefly the zonal correlation of the marine Upper Cretaceous in Japan with some revisions.

According to him, the Kuji Group is also dated as Late Coniacian (K5a2) to Early Campanian (K6a1).

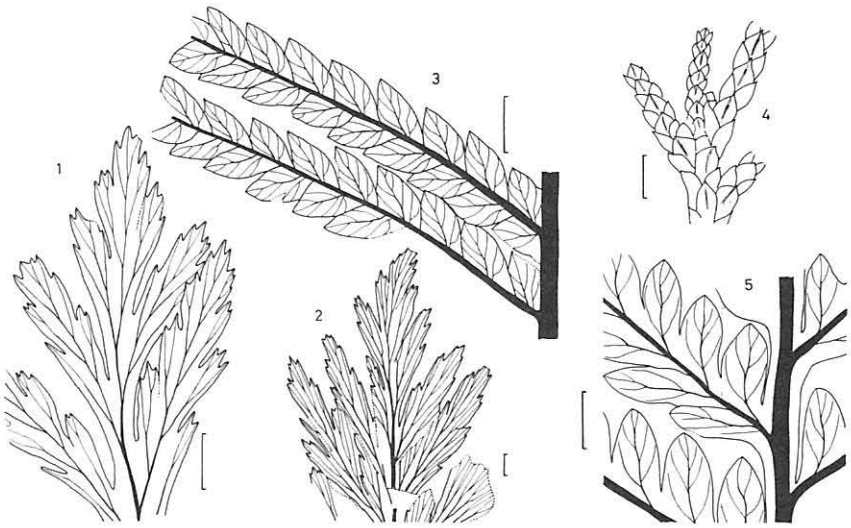
Evidence of Floristic Composition

The Sawayama flora is composed mainly of ferns, conifers and angiosperms, fewly associated by cycadophytes and horsetail. Of these plants, angiospermous plants occupy nearly a half of the total species and about 41 per cent of the total specimens collected, while 11 ferns and 8 conifers occupy about 35 and 18 per cent of the total specimens respectively. Such floristic composition and relative abundance are consistent with those of Senonian floras in East Asia and other regions. However, it is noteworthy that the Sawayama flora contains several older species such as *Adiantopteris eximium, Otozamites schenkii, Cyparissidium gracile* and *Nilssonia variabilis,* which were known in the Upper Jurassic or Lower Cretaceous. These older species seem the relict plants because of their scarce specimens. On the other hand, cycadophytes are very rare in number of species and specimen in the Sawayama flora, though the genus *Nilssonia* shows a common occurrence in Senonian floras of the Northern Hemisphere. It may be due to the ecological condition during the Sawayama time different from other regions.

The Tamagawa flora consists also mainly of ferns, conifers and angiosperms. Compared with the Sawayama flora, angiosperms show less percentages for the total species and specimens. On the other hand, ferns composed of 10 species occupy about 46 per cent of the total specimens. Of ferns, *Gleichenites* and *Cladophlebis* occupy a prominent position in the flora, as they do in Early Cretaceous flora. Such floristic composition and relative occurrence of species indicate that the Tamagawa flora is evidently older than the Sawayama, although the collection from the Tamagawa Formation is far poorer in number of specimens. Especially, no angiosperm was collected from the lower Tamagawa Formation; it seems due principally to less collection, but partly to poor angiosperm during the Tamagawa time.

Late Cretaceous plant-bearing deposits of Saghalien are most well known in East Asia, regarding the floristic composition and the relationships with marine intercalations. Based on abundant materials of northwestern Saghalien (Cape de la Jonkiere, Mgach and Erikson coal mine), Kryshtofovich (1918) divided these plant-bearing sediments into three series in ascending order: the Ainuan (Albian-Aptian), the Gyliakian (Cenomanian – Early Turonian) and the Orokkian (Late Turonian – Senonian). These plants of Saghalien were later revised taxonomically or added by him (Kryshtofovich, 1930; Kryshtofovich & Baikovskaya, 1960), but the age-discussion followed his 1918's opinion. Baikovskaya (1959) summarized comprehensively Late Cretaceous floras of East Asia with the illustrations of the representative fossils; the correlation of these floras was based on Kryshtofovich's scheme, which is now partly incorrect as discussed below.

The Sawayama and Tamagawa floras share many species with the Gyliakian flora of Mgach, Saghalien. Of 42 species including the Sawayama flora 8 ferns, 3 gymnosperms and 7 angiosperms are common with the Gyliakian, and furthermore there are closely related species of 2 conifers and 4 angiosperms. On the one hand, the Tamagawa 27 species contain the Gyliakian species of 8 ferns, 3 conifers and 6 angiosperms, and 3 closely related species.



Text-fig. 2 Showing the venation or leaf arrangement of some ferns and a conifer. Line for scale in each figure represents 2 mm.
1, 2. *Asplenium dicksonianum* Heer. H.U.M.P. nos. 26003a, 25997. 3. *Gleichenites gracilis* (Heer) Tanai. H.U.M.P. no. 25990. 4. *Thuja cretacea* (Heer) Newberry. H.U.M.P. no. 26065. 5. *Gleichenites gracilis* (Heer) Tanai. H.U.M.P. no. 25991.

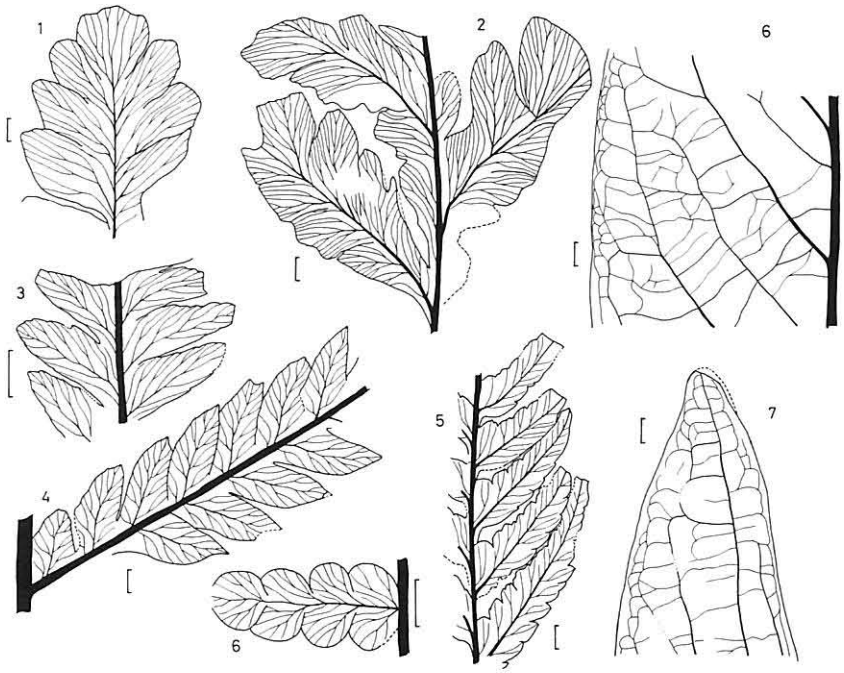
Because the identified species are very different in number between the Sawayama and Tamagawa floras, it is difficult to determine only by the above comparison which flora is closer to the Gyliakian. It is, however, evidently acceptable that the two floras from the Kuji Group are closely similar to the Gyliakian flora of Saghalien in composition.

The Ainuan and Orokkian floras are not known in detailed composition, excepting for the preliminary list (Kryshtofovich, 1918), and they are difficult to compare precisely with the Sawayama and Tamagawa floras. The plants from the Cape de la Jonquiere were also listed by Yabe and Shimizu (1924), and they belong to the Orokkian. Combined these two lists, the Orokian flora consists of 18 plants, in which angiosperms are most abundant and ferns are not common. Most of these Orokkian ferns and conifers are common with those of the Gyliakian. The Sawayama flora is also similar to the Orokkian flora, although far abundant in ferns and conifers.

As frequently cited by many authors, Late Cretaceous floras of West Greenland described first by Heer (1868–1874), have been compared with those of other continents. These two floras of the Kuji Group are similar with many common species to the Atane and Pautut floras of West Greenland. However, the comparison is here not done, because these plant-bearing deposits of Greenland were greatly confused in the stratigraphy as critically reviewed by Koch (1969).

Age of "Gyliakian Series" in North Saghalien

The Upper Cretaceous of west coast of North Saghalien was also investigated by many Japanese geologists, especially Yabe and his collaborator. The "Gyliakian Series" proposed



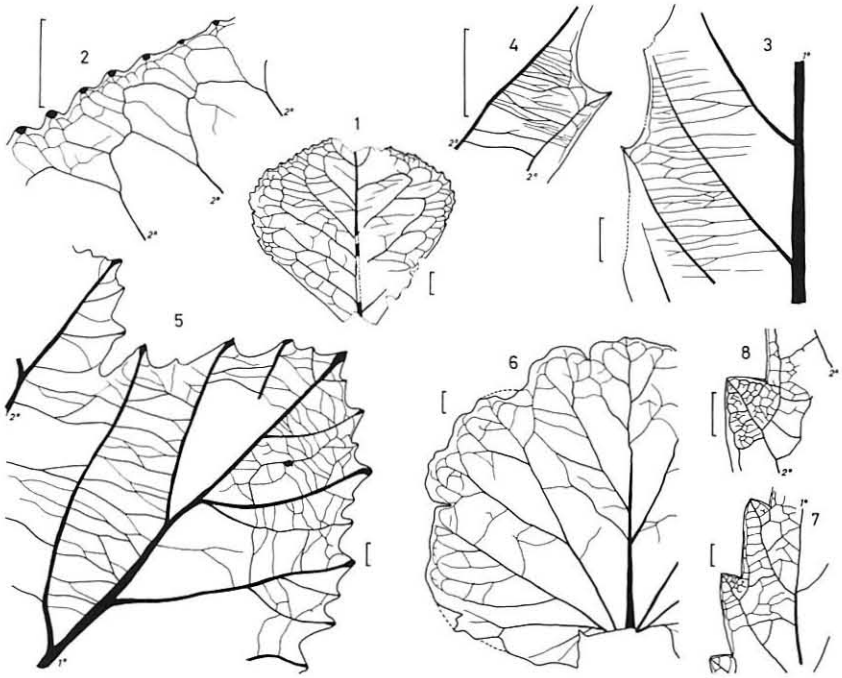
Text-fig. 3 Showing the venation of some ferns and dicotyledonous leaves. Line for scale in each figure represents 2 mm.
1, 2. *Sachalinia sachalinensis* Vachrameev. H.U.M.P. nos. 26003b, 26031. 3. *Zamiopsis* cf. *pinnatifida* Fontain. H.U.M.P. no. 26038. 4. *Cladophlebis borealis* (Brong.) Kryshtofovich. H.U.M.P. no. 26018. 5. *Cladophlebis oerstedti* (Heer) Seward. H.U.M.P. no. 26027. 6. *Sphenopteris onkilonica* Kryshtofovich. H.U.M.P. no. 26036. 7. *Liriodendron iijimae* Tanai. H.U.M.P. no. 26076. 8. *Laurophyllum kujianum* Tanai. H.U.M.P. no. 26085.

by Kryshtofovich (1918) was later adopted as an intra-Japanese stage of the Cenomanian to the Turonian by Yabe (1927), because the marine intercalation* near the type locality contains a number of molluscs such as *Trigonia subovalis* Jimbo var., *T. pocilliformis* Yokoyama var. and *Inoceramus hobetsuensis* Nagao & Matsumoto (Yabe and Nagao, 1925). The "Gyliakian Series" is largely of marine origin in Japan and South Saghalien, as typically distributed in Hokkaido. Since then, the "Gyliakian Series" had been used mainly for the marine deposits of Late Cenomanian-Turonian age in Japan (Matsumoto, 1954), until the recent time when the intra-Japanese stage names were abandoned by Matsumoto (1977).

Late Cretaceous floral sequence in the Pacific coastal region of U.S.S.R. was recently revised by Vachrameev (1966) and Krassilov (1973, 1975), in the relationships with marine faunas (Vereshagin, 1970). Though their works were not always fully accompanied by taxonomical revisions and floristic list, they include many important suggestions for ages of the previously-known floras. Of five floristic zones in North Saghalien revised by Krassilov (1975), the Ajnussian, Gyliakian and Jonkiaerian** in ascending order, are recognized in

* These mollusca- and plant-bearing deposits exposed between Alexandrosk and Cape Rogaty, were named as the Werblud Group (Yabe and Shimizu, 1924).

** The Jonkiaerian flora seems equivalent with the Orokkian proposed by Kryshtofovich (1918).



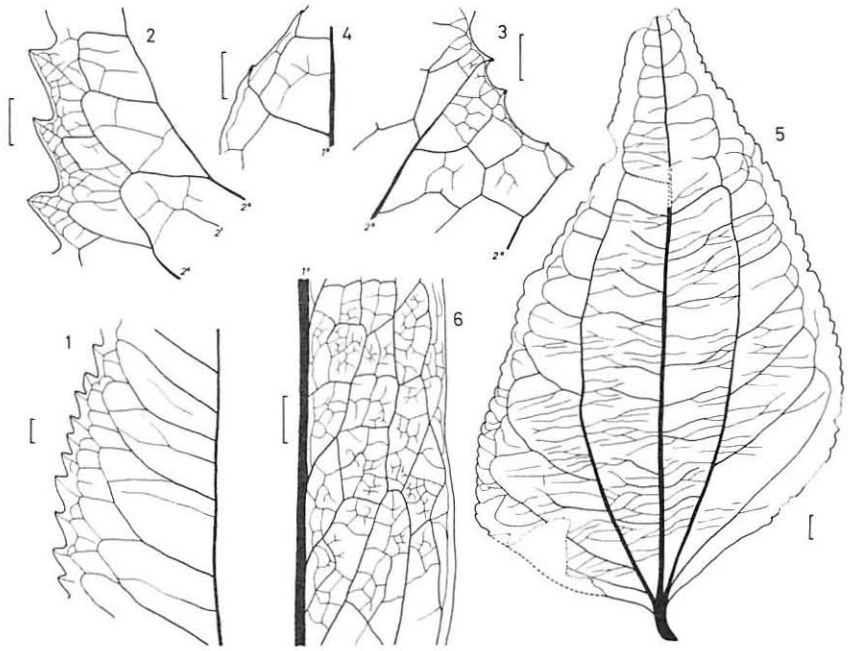
Text-fig. 4 Showing the venation and marginal features of some dicotyledonous leaves. Line for scale in each figure represents 2 mm.
1, 2. *Trochodendron kujiense* Tanai. H.U.M.P. no. 26095. 3, 4. *Dillenites lanceolatus* Tanai. H.U.M.P. no. 26105. 5. *Platanus cuneifolia* (Bronn) Krysht. H.U.M.P. no. 26097. 6. *Menispermites kujiensis* Tanai. H.U.M.P. no. 26092. 7, 8. *Sapindophyllum quercifolium* (Hollick) Tanai. H.U.M.P. no. 26116.

Alexandorvsk-Voshiyakovo district, which includes Kryshtofovich's localities.

From the deposits including the Ajnussian plants was recorded *Inoceramus uwajimensis* Yehara indicating Early Coniacian age (K5a1). The Gyliakian plant-bearing deposits have the marine intercalation including *Inoceramus naumanni* Yokoyama which ranges from Early Santonian (K5b1)* to Early Campanian (K6a1), and they are covered conformably by the paralic deposits including the Early Campanian *Anapachydiscus naumanni* (Yokoyama) (K6a1). The Jonkiaerian plant-bearing deposits are overlain with conformity by the paralic deposits including many ammonites and Inoceramids such as *I. schmidti* Michael and *I. orientalis* Sokolow, as also earlier described by Yabe and Shimizu (1924). These Inoceramids indicate Campanian age (K6a1–K6a2). Considering these marine fossils, the above-noted three floristic zones are dated as follows, similar to Krassilov's description: the Ajnussian is of Coniacian, the Gyliakian is principally of Santonian, and the Jonkiaerian is of Early Campanian age respectively. Such age-relationships of the three floras in Saghalien are nearly consistent with the fact that the floras of the Coniacian-Campanian Kuji Group are closely similar to the Gyliakian floras.

The "Gyliakian" plants described from North Saghalien by Kryshtofovich, were

* These symbols show the biostratigraphic units of the Japanese Cretaceous designated by Matsumot (1977).



Text-fig. 5 Showing the venation and marginal features of some dicotyledonous leaves. Line for scale in each figure represents 2 mm.
1, 2. *Dicotylophyllum iwateanum* Tanai. H.U.M.P. no. 26131a. 3, 4. *Cissus marginata* (Lesq.) Brown. H.U.M.P. no. 26119. 5. *Ziziphus kujiensis* Tanai. H.U.M.P. no. 26121. 6. *Rogersia angustifolia* Fontaine. H.U.M.P. no. 26135.

collected from 56 localities (Kryshtofovich, 1930); but it is uncertain whether or not these plants came stratigraphically from same horizon. Furthermore, the Ainuan and Orokkian (Krassilov's Jonkiaerian) floras are not yet described with full list of the components. Accordingly, it is now difficult to compare more precisely the Sawayama and Tamagawa floras with the floristic sequence of North Saghalin.

Comparison with Late Cretaceous floras of Japan

In Japan are scarcely known Late Cretaceous floras which were dated with certainity. The near-shore sediments widely distributed in Hokkaido and others, are very sparse and incomplete in plant fossils, with some exceptions.

Of the previously well-known floras of Late Cretaceous time, the Asuwa flora from north-central Honshu (Matsuo, 1962) is most similar to the Sawayama flora in composition. However, ferns are less in the Asuwa, while *Nilssonia* is very abundant in number of species and specimens. Such abundant occurrence of *Nilssonia* seems due to an ecological condition. The Asuwa flora has been considered to be of Turonian-Cenomanian age, because it was compared with "Gyliakian flora" of Saghalien. However, the Asuwa flora is probably contemporaneous with or somewhat younger than the Sawayama, and is dated probably as Campanian age. Thus, the so-called "Nohi Acidic rocks" overlying the Asuwa Group may be partly younger than the previously-considered age.

The Omichidani flora (Matsuo, 1970), about 40 km northeast of Asuwa locality, is closely similar to the Asuwa flora in composition and component, though it contains many conifers such as Pinaceae and Taxodiaceae which were common in the Middle Tertiary. This flora is evidently younger than the Asuwa as noted by Matsuo (1970); however, it is not of Coniacian age as previously considered, but is rather of Late Campanian age or slightly younger.

Two floras were known from the Upper Cretaceous of Hokkaido; these investigations, although the classic works, are important contributions, because the plant-bearing sediments are well-dated by marine fossils. The Hakobuchi flora (Endo, 1925; Oishi, 1940) is composed of some ferns, abundant *Nilssonia* and many angiosperms; it is closely similar to the Asuwa flora in composition and components, and is younger than the Sawayama flora. The Hakobuchi Group including the plants in its middle part, are of neritic to littoral origin in Yubari district (plant locality), and is assigned to Campanian-Maastrichian age by molluscan fauna (Matsumoto, 1954, 1977). Considering the composition and stratigraphic position, the Hakobuchi flora is probably assignable to Latest Campanian. Another Cretaceous flora from Hokkaido was described by Stopes and Fujii (1910) on the basis of fragmentary plant materials included in the calcareous nodules. These specimens are uncertain in the localities of Yubari district, and are also doubtful to collect in a certain horizon. However, these nodules seem to have been collected from the Upper Ezo Group, because they were accompanied mostly with ammonites as described by Stopes and Fujii. The Upper Ezo Group in Yubari is of marine origin, and is assignable principally to Coniacian-Santonian age. The above specimens composed mainly of cones and woody fragments, include many interesting plants, but they are difficult to compare with the Tamagawa flora.

Table 4 Correlation of Late Cretaceous Floras of Japan and Saghalien

Age		West Honshu	North-cetral Honshu	Kuji	Cetral Hokkaido	North Saghalien
Maastrichtian	$K6b_2$					
	$K6b_1$	Izumi				
Campanian	$K6a_3$		Omichidani		Hakobuchi	
	$K6a_2$					
	$K6a_1$		Asuwa	Sawayama		Jonkiaerian
Santonian	$K5b_2$					Gyliakian
	$K5b_1$					
Coniacian	$K5a_2$			Tamagawa	"Upper Ezo"	
	$K5a_1$					Ajnussian

The letter symbols show the Japanese zonation, based on marine fauna (Matsumoto, 1977).

Beside the above-noted floras, several Late Cretaceous floras were reported, though most of them are poor in number of species or in the preservation of fossils. Several species from the middle Izumi Group of western Honshu were described by Koriba and Miki (1951) and Matsuo (1966); these plants are composed of a cycad, a conifer and a few angiosperms. The Izumi flora, though very poor in composition, is dated as Early Maastrichtian by the associated marine fauna. The Oarai flora from northern Kwanto region (Oyama, 1961) and the Kozuki flora from Tsushima Island of Kyushu (Tateiwa, 1933) are composed mainly of various angiosperms. The specimens described from these two localities, are too ill-preserved to discuss their taxonomy. These two floras are rather doubtful to be of Late Cretaceous time.

The floristic comparison discussed above, is concluded as shown in the correlation table of Late Cretaceous floras of Japan, considering the marine fossils partly associated in the plant-bearing deposits. However, further precise taxomical investigation is necessary for the discussion of Late Cretaceous vegatation and floristic sequence in Japan.

Systematic Description

Most of the specimens both from the Tamagawa and Sawayama Formations are represented by leaf impressions, and some specimens have carbonized materials which are suitable for cuticle analysis. Three conifers, two cycadophytes and some angiosperm leaves were possible to investigate their stomatal or cell structures as discussed in the descriptive part. However, most angiospermous leaves with thin textures were unsuccessful for maceration. In the following descriptions, the angiospermous genera are arranged by Takhtajan's system (1969). All the specimens, excepting one, are deposited in the Museum of Paleontology, Hokkaido University (the abbrebiation: H.U.M.P.), and the type numbers refer to those of the Museum.

Division Pteridophyta
Class Sphenopsida
Family Equisetaceae
Genus *Equisetum* Linn.
Equisetum sp.
(pl.1, figs.1, 3)

Description: Stem unbranched, 4 to 6 mm across; surface having 4 to 5 longitudinal ridges; nodal region slightly swollen; sheath 4 to 5 mm long, but not well preserved. Rhizome 2 to 3 mm across; internodes 3 to 3.5 cm long, with 2 to 3 strong longitudinal ridges; tubers one or two in each node, rounded to oval in shape, 7 mm long and 4 mm wide.

Discussion: A number of fragmentary stems and rhizomes of *Equisetum* are commonly found in the Sawayama formation, but they have no sufficient characters to give a specific determination.

Occurrence: Kunitan-A, Kuji City (Tamagawa Formation); Sawayama, Hikagezawa, Hikage, Oashi and Kadonosawa, Kuji City (Sawayama Formation).

Collection: H.U.M.P. nos. 25981–25983.

Class Pteropsida
Family Osmundaceae
Genus *Osmunda* Linn.
Osmunda asuwensis Matsuo
(Pl.1, fig.7)

Osmunda asuwensis Matsuo. 1962. Sci. Rept. Kanazawa Univ. 8(1): 197. pl.4. f.1, 2, 7c; pl.5, f.2a, 2b; pl.7. f.la; pl.9. f. 5a; text-f. 7a.

Discussion: A single incomplete frond from the Tamagawa formation is doubtlessly referable to the genus *Osmunda* by its venation and subauriculate base of pinnae. This specimen is referred to *O. asuwensis* from the Asuwa flora of central Honshu, although its pinnae are somewhat narrower and longer than those of the original specimens figured by Matsuo (1962). Our specimen may represent a terminal part of the frond, because it is similar to a slender, terminal frond of *O. japonica* living in East Asia.

In Japan pinnules of *Osmunda* are commonly found through the Paleogene, and *O. asuwensis* is closely similar to *O. sachalinensis* Kryshtofovich from Hokkaido and Saghalien (Tanai, 1970; Borsuk, 1956).

Occurrence: Kunitan B, Kuji City (Tamagawa Formation).

Collection: Hypotype, H.U.M.P. no. 25984.

Family Schizaeaceae
Genus *Anemia* Sw.
Anemia elongata (Newb.) Knowlton
(pl.1, fig.2)

Anemia elongata (Newb.) Knowlton. 1922. U.S. Geol. Survey Prof. Paper (130): 112. pl.11. f.2.
Sphenopteris elongata Newberry. 1863. J. Boston Soc. Nat. Hist. 7: 511.

Discussion: A single incomplete frond from one locality is referable to *Anemia* by the following characters. The pinnules are alternately arranged, linear-lanceolate in shape, acute at the apex, and are remotely serrate with sharp, upward-pointing teeth on the margin. The secondary veins are numerous, diverging at acute angles from the midvein, and are forking. The Kuji specimen is identical with *A. elongata* from the Upper Cretaceous of North America (Knowlton, 1922), and represents a part of the terminal frond. *A. elongata* is separable in margin and shape of pinnules from *A. subcretacea* (Saporta), which was described from the British Eocene (Gardner & Ettingshausen, 1879–'82).

Occurrence: Hikage, Kuji City (Sawayama Formation).

Collection: Hypotype, H.U.M.P. no. 25985.

Family Gleicheniaceae
Genus *Gleichenites* Goeppert
Gleichenites crenata (Kryshtofovich) Tanai, comb. nov.
(pl.1, figs.8, 12)

Gleichenia crenata Kryshtofovich. 1937. Cretaceous flora of Saghalien. p.38, pl.1, f.2-4.
Kryshtofovich & Baikovskaya 1960. Cretaceous flora of Saghalien. p.15, pl.3, f.1-3.

Discussion: These characteristic ferns from the Tamagawa Formation are referred to

Gleichenia crenata by narrowly linear pinnae and their crenate margin. The pinnae are densely arranged, nearly perpendicular to the rachis, and are highly variable in size, ranging from 1 to 5 cm in length and from 2 to 5 mm in width. These specimens well match the Saghalien species in the foliar shape, which were described from the Gyliak flora by Kryshtofovich (1937), although our specimens are ill-preserved in the venation characters. A fragmentary frond described as *Trapeinidium* ? *undulatum* from the Upper Ezo Group (Coniacian-Santonian) of Hokkaido (Oishi, 1940) is closely similar to our specimens, and is included in *G. crenata.*

Occurrence: Kunitan A, Kuji City (Tamagawa Formation).

Collection: Hypotypes, H.U.M.P. nos. 25986, 25987; no. 25988.

Gleichenites cf. *giesekiana* (Heer) Seward

(Pl.1, fig.5)

Compared with:

Gleichenites gieseckiana (Heer) Seward. 1926. Philos. Trans. Soc. London. [B], 215: 69, pl.5, f.1-4, 6-14, 16, 17; pl.10, f.96; pl.12, f.118; text-f.2 (see synonymy and discussion)

Gleichenia zippei (Corda) Heer. acut. non Kryshtofovich & Baikovskaya. 1960. Cretaceous flora of Saghalien. p.18, pl.2, f.5; pl.4, f.3, 3a (see synonymy).

Discussion: A single pinnae from the Tamagawa Formation is probably referred to *"Gleichenia zippei"* by the shape of pinnules and venation, though it is ill-preserved. This specimen is similar to *G. sachalinensis* Krysht. described from the Gyliak flora of Saghalien (Kryshtofovich, 1937), but differs in rather acute apex of pinnules.

The epithet *"zippei"* has been used for the above fern by most authors, since Heer (1868) transferred the Bohemian species, *"Pecopteris zippei* Corda", to *Gleichenia* on the basis of Arctic Cretaceous specimens. Investigating extensively the Arctic specimens together with Heer's original materials, Seward (1926) proposed the epithet *"giesekiana"* in place of *"zippei",* because he doubted Corda's Bohemian specimen was identical to Heer's Greenland specimens. The Kuji specimen is represented only by a poorly-preserved pinnae which is unable to add any new information. However, *G. giesekiana* is mostly once forking in secondary veins of the pinnules, and it is distinguishable from *G. gracilis.*

Occurrence: Kunitan A, Kuji City (Tamagawa Formation).

Collection: H.U.M.P. no. 25989.

Gleichenites gracilis (Heer) Tanai, comb. nov.

(pl.2, figs.1, 9; text-fig.2-3, -5)

Gleichenia gracilis Heer. 1874. Kongl. Svens. Vet. Aka. Handl. 12(6): 52. pl.10, f.1-4, 6-11.

Gleichenia delicatula Heer. 1874. ibid. p.54, f.11e, 11f; pl.10, f.16, 17.

Velenovsky and Viniklar. 1926. Flora Cretacea Bohemiae. 3: 3. pl.17, f.8, 9.

Discussion: Two incomplete fronds and several detached pinnae from two localities are referable to *Gleichenia gracilis* described from the Upper Cretaceous in Kome and Avkrusak, Greenland by Heer (1874). The pinnae of this Greenland species are usually linear with very small, ovate pinnules, which are sometimes slightly overlapped. Furthermore, if correctly illustrated by Heer, the pinnules of the Greenland specimens do not dichotomize in the secondary venation. The Kuji specimens are well conistent with the Greenland specimens in foliar shape, size and venation, although the sorus are not preserved.

Some of the specimens illustrated as *G. gracilis* by Heer (1874) are fertile frond; the sporangia-bearing pinnules were shown in figure 8 of plate 10. However, these soral characters seem to be different from those of the extant species of *Gleichenia.* Therefore, the Greenland species, *G. gracilis,* is better to refer to the form-genus *Gleichenites.* Heer (1868, 1874) established too many species of *Gleichenia* from the Cretaceous of Arctic region, but Seward (1910, 1926) pointed out that some of them may be rather synonymized. Of these species of *Gleichenia, G. delicatula* is included in *G. gracilis* by the shape, size and venation of pinnules.

Occurrence: Hikage and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 25990, 25991.

Gleichenites lineariformis (Kryshtofovich) Tanai, comb. nov.

(pl.1, figs.4, 10, 11)

Gleichenia lineariformis Kryshtofovich. 1937. Cretaceous flora of Saghalien. p.40, pl.1, f.6.

Gleichenia rigida Heer. auct. non Kryshtofovich. 1918. Jour. Coll. Sci. Imp. Univ. Tokyo. 40(8):27, f.1.

Discussion: These small pinnae, having linear pinnules, are identical to *G. lineariformis,* which was described from the Gyliak flora of northern Saghalien (Kryshtofovich, 1937). Our specimens somewhat resemble the small pinnae of the above-noted *G. crenata,* but differs in nearly entire margin. *G. lineariformis* is similar to the living *Dicranopteris linearis* (Burm. f.) Und. of Southeast Asia.

Occurrence: Kunitan A, Kuji City (Tamagawa Formation).

Collection: Hypotypes, H.U.M.P. nos. 25992-25994; nos. 25995, 25996.

Family Aspleniaceae

Genus *Asplenium* Linn.

Asplenium dicksonianum Heer

(pl.2, figs.2, 4, 6, 10; pl.3, figs.2, 7, 8; text-fig.2-1, -2)

Asplenium dicksonianum Heer. 1874. Kongl. Svens. Vet. Akad. Handl. 12(6): 31. pl.1, f.1-5, 1874.

Endo. 1925. Sci. Rep. Tohoku Imp. Univ. [2]. 7: 61, pl.16, f.13-15.

Kryshtofovich & Baikovskaya. 1960. Cretaceous Flora of Saghalien. p.11, text-f.2-4; pl.1, f.1-6; pl.2, f.1-4 (see synonymy and discussion).

Discussion: These characteristic fronds identical to *Asplenium dicksonianum* are most abundantly found from nearly all localities. This species was first described from northern Greenland by Heer (1874), and thereafter it was widely reported from the middle and upper Cretaceous of the Northern Hemisphere by various authors. *A. dicksonianum* is characterized by lobed pinnae, coarsely serrate margin of pinnules, and several times forking veins, although the pinnae are highly variable in size and shape. Actually, some of the Kuji specimens with narrow pinnae may be misidentified as *Onychyopsis,* if the venation are not preserved.

As already pointed out by Kryshtofovich and Baikovskaya (1960), *A. johnstrupi* Heer from Greenland (Heer, 1874) is unseparable from *A. dicksonianum.* From the Cretaceous of Japan, *A. dicksonianum* was rarely described; several fragmentary pinnae reported as *A. dicksonianum* (?) from the Hakobuchi Group of Hokkaido (Endo, 1925) are included in this species, though ill-preserved. On the other hand, a specimen figured as *A.* cf. *dicksonianum*

from the Neocomian Akaiwa Formation of Central Honshu (Kimura & Sekido, 1976) is excluded from this species in shape of pinnules and venation, if it was accurrately illustrated.
Occurrence: Kunitan A and B, coastal cliff near Tamagawa, Kuji City (Tamagawa Formation); Hikage, Hikagezawa, Edanarizawa, Oashi, Kadonosawa, Minato and Hishikura, Kuji City (Sawayama Formation).
Collection: Hypotypes, H.U.M.P. nos. 25997–26003 a; nos. 26004–26005.

Ordo Salviniales
Family Salviniaceae
Genus *Salvinia* Sequier
Salvinia mildeana Goeppert
(pl.1, figs.6, 9; pl.2, figs.5, 7, 8)

Salvinia mildeana Goeppert. 1855. Die tertiäre flora von Schossnitz in Schlesien. p.5, pl.1, f.21-33.
Schaparenko. 1956. Palaeobotanika. 2: 30. pl.1, f.1-4 (see synonymy).

Discussion: A number of *Salvinia* foliages are found from the Sawayama formation, though ill-preserved. These specimens are referred to *S. mildeana* by their venation characters. The hair-bases (tubercles) in our specimens are arranged in two rows, and they are within the rectangular or polygonal, small meshes. These characters well match those of *S. formosa* Heer which was discussed in detail by Florin (1940). Schaparenko (1956) investigated in detail the foliages of the living and fossil *Salvinia* in the world, and classified them into four sections. According to him, *S. formosa* originally described by Heer (1859) is included in *S. mildeana,* and belongs to the section Carinatae.
Occurrence: Hikagezawa, Kadonosawa and Oashi, Kuji City (Sawayama Formation).
Collection: Hypotypes, H.U.M.P. nos. 26009–26013; no. 26014.

Filicales Insertae Sedis
Genus *Adiantopteris* Vasilevskaya
Adiantopteris eximium (Saporta) Boureau & Doubinger
(pl.4, figs.5, 8)

Adiantopteris eximium (Saporta) Boureau & Doubinger. 1975. Traite de Paleobotanique. 4(2): 659. f.565, 566.
Adiantum eximium Saporta. 1894. Flora Mesozoique du Portugal. p.164, pl.28, f.18; pl.31, f.6.
Teixeira. 1948. Flora Mesozoica Portuguesa. 1: 85, pl.33, f.3.
Teixeira. 1952. Rev. Fac. Sci. Lisboa. [2,C]. 2: 144.
Adiantum tenellum Saporta. 1894. Flora Mesozoique du Portugal. p.163, pl.29, f.12; pl.31, f.4.

Discussion: An incomplete pinnae and several detached pinnules from two localities appear to resemble some extant species of *Adiantum*, though the pinnules are larger. These fossil pinnules are obovate with thick stalk in general outline, and are alternately arranged on the rachis. The veins of lamina originating from two veins of stalk, radiate with several times forking, and reach the dentate margin. These characters show the Kuji specimens are indentical with *Adiantum eximium* described from the Albian-Cenomanian of Portugal.

The *Adiantum*-like fronds from the Jurassic and Cretaceous of the Northern Hemisphere were described under the genera such as *Adiantites* or *Adiantum,* but they are doubtful to be referable to the extant *Adiantum.* On the one hand, the form genus *Adiantites* was limited

to some type of Carboniferous pteridosperms (Kidston, 1923; Novik, 1952). Thus, Vasilevskaya (1968) proposed a form genus *Adiantopteris* for the *Adiantum*-like fronds of the Late Mesozoic. Judging from fine but stout venation of the Kuji specimens, *Adiantopteris* may belong not to fern but to gymnosperm.
Occurrence: Kadonosawa and Oashi, Kuji City (Sawayama Formation).
Collection: Hypotypes, H.U.M.P. nos. 26-15, 26016.

Genus *Cladophlebis* Brongniart
Cladophlebis acuta Fontaine

(pl.3, fig.6)

Cladophlebis acuta Fontaine. 1889. U.S. Geol. Survey Mongr. 15: 75, pl.5, f.7; pl.7, f.6; pl.10, f.6, 7; pl.156, f.5.
Kryshtofovich. 1936. Cretaceous Flora of Saghalien. p.51, pl.6, f.4.
Kryshtofovich & Baikovskaya. 1960. Cretaceous Flora of Saghalien. p.22, pl.3, f.5-7; text-f.7.

Discussion: Several incomplete pinnae, though ill-preserved, are referred to *Cladophlebis acuta* by their slightly falcate and elongate form of pinnules. This species was originally described from the Potomac flora of the United States, and later was reported from the Late Cretaceous flora of Saghalien (Kryshtofovich, 1936). *C. acuta* is closely similar to *C. virginiensis* Fontaine and *C. falcata* Fontaine from the Potomac flora (Fontaine, 1889), especially more close to the latter. However, the pinnules of *C. acuta* are frequently united at the base, while those of *C. falcata* are usually separated.
Occurrence: Kunitan B, Kuji City (Tamagawa Formation).
Collection: Hypotype, H.U.M.P. no. 26017.

Cladophlebis borealis (Brongniart) Kryshtofovich

(pl.4, figs.7, 10; text-fig.3-4)

Cladophlebis borealis (Brongn.) Kryshtofovich. 1937. Cretaceous flora of Saghalien. p.54, pl.7, f.3.
Kryshtofovich & Baikovskaya. 1960. Cretaceous flora of Saghalien. p.24, pl.5, f.7, 7a, 10; text-f.8.
Pecopteris borealis Brongniart. 1828. Histoire de végétaux fossile. 1: 351, pl.119, f.1, 2.
Heer. 1868. [part] Flora fossilis arctica. 1: 81, pl.1, f.14.

Discussion: Several fragmentary fronds and pinnae are referable to *Cladophlebis borealis* in their overlapped arrangement of ovate pinnules, which are entire on margin and mostly once forking in the secondary veins. These specimens resemble *C. frigida* (Heer) Seward in general appearance; but the pinnules of *C. frigida* are usually larger and more elongate in shape, and are slightly arcuate in midvein. *C. borealis* has been known from the Upper Cretaceous of the Arctic region and Saghalien.
Occurrence: Kunitan B, Kuji City (Tamagawa Formation); Minato, Oashi, Kadonosawa and Hishikura, Kuji City (Sawayama Formation).
Collection: Hypotypes, H.U.M.P. nos. 26018, 26019; no. 26020.

Cladophlebis frigida (Heer) Seward

(pl.4, figs.3, 4)

Cladophlebis frigida (Heer) Seward, 1926. Philos. Trans. Royal Soc. London. [B]. 215: 87.
Kryshtofovich and Baikovskaya. 1960. Cretaceous flora of Saghalien. p.26, pl.5, f.8, 9; pl.6, f.3; text-f.9.

Matsuo. 1962. Sci. Rep. Kanazawa Univ. 8 (1): 201, pl.5, f.1; pl.20, f.2b; pl.22, f.4; text-f.8a (see synonymy and discussion).

Pecopteris frigida Heer. 1882. Flora fossilis Grönlandica. 1: 25, pl.6, f.5b; pl.10, f.1-4; pl.11; pl.12, f.2.

Discussion: This species is represented by an incomplete frond and many detached pinnae from two localities. The linear-lanceolate pinnae attach to the rachis at moderate angles, oppositely or suboppositely, and are nearly straight at the lower part but slightly curving up at the apical. The pinnules are elongate-triangular with acute apex, slightly falcate in general outline, and are serrate on their upper margin. The secondary veins are thin, and are usually once forking. These characters of the Kuji specimens match well those of *Cladophlebis frigida* which were described from the Cretaceous of Greenland, North America and East Asia by various authors.

Occurrence: Oashi, Minato, Kadonosawa and Hikage, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26021, 26022; no. 26023–26025.

Cladophlebis oerstedti (Heer) Seward

(pl.4, figs.11, 12; text-fig.3-5)

Cladophlebis oerstedti (Heer) Seward. 1926. Philos. Trans. Royal Soc. London. [B]. 215: 86, pl.7, f.32, 34, 35; text-f.9.

Kryshotofovich & Baikovskaya. 1960. Cretaceous Flora of Saghalien. p.30, pl.6, f.1, 4-7; pl.7, f.3; text-f.11-13 (see synonymy).

Discussion: Several fragmentary fronds with lanceolate pinnae are referred to *Cladophlebis oerstedti,* which was reported from the Late Cretaceous flora of the Arctic region, Saghalien and others. The pinnules of this species are frequently variable in shape and size; but they are confluent at the base, and are simple or once forking in the lateral veins. Our pinnae specimens are remotely serrate with obtuse apex on the margin or divided into broader segments with obtuse tip; they match the larger pinnae figured by Seward (1926) from western Greenland.

Occurrence: Kadonosawa and Hikage, Kuji City (Sawayama Formation); coastal cliff near Tamagawa (Tamagawa Formation).

Collection: Hypotypes, H.U.M.P. nos. 26026, 26027; 26028.

Genus *Sachalinia* Vachrameev

Sachalinia sachalinensis Vachrameev

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

Sachalinia sachalinensis Vachrameev. 1968. Geol. Inst. Acad. Sci. USSR. Trans. 191: 12, pl.2, f.1, 2; pl.3, f.1, 2; pl.4, f.4; text-f.3, 4.

Discussion: Many incomplete fronds with lobed pinnae are identical to *Sachalinia sachalinensis* in their characteristic foliar feature and venation, as shown in text-fig. 3–1 and 3–2. This new genus was established by Vachrameev (1968) on the basis of the specimens from the Upper Cretaceous of North Saghalien. *Sachalinia* is somewhat similar in general appearance to some type of *Sphenopteris,* but it is distinguishable in the venation character of pinnae. *S. sachalinensis* resembles *Thinnfeldia sachalinensis* from the Upper Cretaceous of Saghalien (Kryshtofovich & Baikovskaya, 1960), but differs in its lobation.

Occurrence: Kunitan B, Kuji City (Tamagawa Formation); Minato Hikage, Oashi and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26003b, 26029–26031; nos. 26032–26034.

Genus *Sphenopteris* Brongniart

Sphenopteris onkilonica Kryshtofovich

(pl.3, fig.3; pl.4, fig.6; text-fig.3-6)

Sphenopteris onkilonica Kryshtofovich. 1958. Palaeobotanika. 3: 27, pl.2, f.8, 9; text-f.6, 7.
Kryshtofovich & Baikovskaya. 1960. Cretaceous flora of Saghalien. p.35, text-f.18.

Discussion: Two very small pinnae with ovate segments, though fragmentary, are referable to *S. onkilonica,* described from the Late Cretaceous floras of northern Saghalien and Andyr region. The pinnules of this species are very small with rounded tip, and show characteristic venation, which is somewhat irregularly, several times dichotomously forking. *S. onkilonica* is similar at a glance to *Scleropteris belidula* Heer from the Upper Cretaceous of northern Greenland (Heer, 1874), but is distinguishable in venation. *Sphenopteris holttumii* Seward from the Cretaceous of western Greenland (Seward, 1926) also resembles *S. onkilonica,* but it differs in acute apex of pinnules.

Occurrence: Kunitan B, Kuji City (Tamagawa Formation). Hikagezawa, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26035, 26036.

Genus *Zamiopsis* Fontaine

Zamiopsis cf. *pinnatifida* Fontaine

(pl.4, figs.1, 9, 13; text-fig.3-3)

Zamiopsis pinnatifida Fontaine. 1889. U.S. Geol. Survey Monogr. 15: 161, pl.61, f.7; pl.62, f.5; pl.64, f.2; pl.67, f.2.

Discussion: Several fragmentary pinnae from the Sawayama Formation are leathery in texture, and are with pinnate, toothed pinnules. As shown in Text-fig. 3–3, the secondary venation of the pinnules is asymmetrical in its arrangement. These pinnae may belong to fern; they seem to resemble some of *Sphenopteris,* but they are not referable to any species of this genus already known.

The Kuji specimens are probably identical to *Zamiopsis pinnatifida* which was described from the Potomac flora of the eastern United States, although they are somewhat smaller than the original specimens. According to Fontaine (1889), the genus *Zamiopsis* is an unique plant which shows intermediate features of cycads and ferns in pinnules and venation. The Kuji specimens are too ill-preserved to give additional characters to this curious type of fern.

Occurrence: Kadonosawa, Kuji City (Sawayama Formation).

Collection: H.U.M.P. nos. 26037a–26039; no. 26040.

Division Spermatophyta

Subdivision Gymnospermae

Class Cycadopsida

Family Williamsoniaceae

Genus *Otozamites* F. W. Braun

Otozamites schenckii (Heer) Tanai, comb. nov.

(pl.5, figs.7, 8; pl.9, figs.4, 5)

Glossozamites schenkii Heer. 1874. Kongl. Svensk. Vet. Akad. Handl. 12(6): 69, pl.16, f.5-8.

Supplementary description: Pinnate leaves closely arranged on the both side of stem, alternate in arrangement; leaves thick in texture, elongate-lanceolate or linear-lanceolate, 2 to 2.5 cm long and 4 to 5 mm wide, nearly straight, the upper margin proximally straight, the lower margin nearly straight but distadly convex, ending at obtuse apex; leaf asymmetrical, somewhat auriculate, attached on the upper side of stem, overlapped with base of opposite leaves; anterior basal part markedly auriculate, posterior basal part rounded; veins densely crowded, thin, radially diverging from the base, passing obliquely with forking to the margin.

Discussion: A single incomplete foliage with pinnate leaves, though ill-preserved, is doubtlessly referred to the genus *Otozamites* in characteristic arrangement of leaves and the radiated veins. *Otozamites* has been widely described from the Triassic to the Lower Cretaceous in the world, especially abundant in the Jurassic, while it has been very rare from the Upper Cretaceous. The pinnae of the Kuji specimen are narrower, compared with their length, than those of Jurassic species.

The Kuji specimens is unseparable from the fronds described as *Glossozamites schenkii* from the Upper Cretaceous of Greenland (Heer, 1874). Heer's specimens are referable to the genus *Otozamites* in their venation and attaching features of leaves, although they are less markedly auriculate at the base of leaves than those of the Kuji specimens. Among a number of *Otozamites* earlier described, *O. schenkii* is closely similar to *O. graphicus* (Leck.) Schimper from the Jurassic of Europe (Seward, 1917; Delle, 1967), and to *O. bechei* Brongniart from the Jurassic of France (Seward, 1917).

Occurrence: Kadonosawa and Hishikura, Kuji City (Sawayama Formation). collected by Y. Sasa.

Collection: Hypotype, H.U.M.P. no. 26041.

Family Nilssoniaceae

Genus *Nilssonia* F. W. Braun

Nilssonia variabilis Pyrnada

(pl.5, fig.5)

Nilssonia variabilis Pyrnada. 1933. Trans. United Geol. Prosp. Serv. USSR. 261: 22, pl.2, f.10.
Delle. 1967. Palaeobotanika. 6: 96, pl.20, f.1-5; pl.23, f.9.

Nilssonia mediana (Lack. ex Bean) auct. non Seward. Pyrnada. 1933. Trans. United Geol. Prosp. Serv. USSR. 261: 21. pl.2, f.9.

Discussion: Several incomplete fronds with large, lanceolate segments from the Sawayama Formation are doubtlessly referable to *Nilssonia* in the attachment of lamina to the rachis and venation character. The lamina shows clearly the attachment to the upper surface of the rachis which is covered by it. The veins are simple, parallel each other, at obtuse angle to the rachis, and are numerous, about 12 in a breadth of 5 mm. The segments reaching more than 6.5 cm in length and 1.2–1.8 cm in width, are slightly falcate with obtuse apex, and are entire on margin; the upper margin is nearly straight, and the lower margin is also generally straight excepting for the apical convex part.

The above-noted characters show the Kuji specimens are identical to *N. variabilis* described from the Middle Jurassic of the Tkvarcheli coal-basin, Caucasus (Pyrnada, 1933;

Delle, 1967), though the specimens are incomplete. Leaves of the genus *Nilssonia* are generally variable in shape and size even in a species; especially the dimension may be difficult to use as a specific character. In the sense of large, lanceolate segments, *N. variabilis* resembles some Jurassic species such as *N. acuminata* (Presl.) Goeppert (Gothan, 1914; Oishi, 1932) and *N. compta* (Phill.) Bronn (Harris, 1964), but it is distinguishable in the apex of segments. *N. variabilis* is blade-shaped in the distal margin of segments, while *N. acuminata* and *N. compta* are truncate as in the most species of *Nilssonia.*

Occurrence: Kadonosawa, Hishikura and Hikage, Kuji City (Sawayama Formation).

Collection: Hypotype, H.U.M.P. no. 26042; no. 26043.

Class Coniferopsida

Family Taxodiaceae

Genus *Glyptostrobus* Endl.

Glyptostrobus vachrameevii Svenishikova

(pl.5, figs.1, 2)

Glyptostrobus vachrameevii Svenishikova. 1967. Palaeobotanika. 6: 195, pl.9, f.8, 9; pl.10, f.1-6; pl.11, f.1.

Glyptostrobus groenlandica Heer. auct. non Hollick. 1930. U.S. Geol. Survey Prof. Pap. 159: 60, pl.10, f.3c; pl.24, f.2.

Discussion: Several shoots with slender, small leaves from two localities are referred to *Glyptostrobus* with some hesitation. They are also similar to some foliage shoots reported under the name of *Sequoia* or *Sequoiites* from the Cretaceous of Greenland and Alaska: for instance, *Sequoia fastigiana* Heer from Alaska (Hollick, 1930) closely resembles the Kuji specimen. Actually, it is sometimes difficult to distinguish the fossil foliage shoots of *Glyptostrobus* from those of *Sequoiadendron* only by the external characters.

Though a further investigation may need, the Kuji specimens are referable to *Glyptostrobus vachrameevii* recently described from the Upper Cretaceous of Yakita, Siberia (Svenishikova, 1967). This species is closely similar to *G. europaeus* (Brong.) Heer widely distributed in the Tertiary of the Northern Hemisphere, but Tertiary species is more slender in leaves.

Occurrence: Coastal cliff near Tamagawa, Kuji City (Tamagawa Formation); Hikage, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26044, 26045; no. 26046.

Genus *Metasequoia* Miki ex Hu and Cheng

Metasequoia sp.

(pl.8, fig.8)

Discussion: A single incomplete foliage shoot shows a decussate arrangements of slender leaves, and is referable to *Metasequoia* with confidence. This specimen seems somewhat more slender than Tertiary species such as *M. occidentalis* (Newb.) Chaney. Though too ill-preserved to be assigned to a definite species, it is worthy to record a existence of this genus in the Upper Cretaceous of Japan.

Occurrence: Kadonosawa, Kuji City (Sawayama Formation).

Collection: H.U.M.P. no. 26047.

Genus *Taxodium* Rich.

Taxodium ? sp.

(pl.5, figs.6, 9)

Discussion: Several foliage shoots from two localities, though fragmentary, are probably referred to *Taxodium* by the slender leaves and their spiral arrangements on stems. They are, however, too incomplete to afford a specific identification.

Occurrence: Hikage (Sawayama Formation) and coastal cliff near Tamagawa (Tamagawa Formation), Kuji City.

Collection: H.U.M.P. nos. 26048, 26049.

Family Araucariaceae

Genus *Araucarites* Presl.

Araucarites longifolia (Lesquereux) Dorf

(pl.6; pl.7, figs.1, 4; pl.9, fig.1)

Araucarites longifolia (Lesquereux) Dorf. 1942. Carnegie Inst. Wash. Publ. (508): 130, pl.4, f.9, 12, 13; pl.5, f.1-6 (see synonymy for North American specimens).

Sequoia longifolia Lesquereux. 1878. U.S. Geol. Survey Terr. Rept. 7: 79, pl.7, f.14, 14a; pl.61, f.28, 29.

Araucarites anadyrensis Kryshtofovich. 1958. Palaeobotanika. 3: 37, pl.6, f.2-5; text-f.17.

Sequoia sternbergi (Goeppert) Heer. auct. non Matsuo. 1962. Sci. Rept. Kanazawa Univ. 8: 224, pl.19, f.3.

Araucarites microphyllus Sveshinikova. 1967. Palaeobotanika. 6: 183, pl.1, f.1.

Discussion: More than one hundred specimens of Araucarian foliage shoots were collected from several localities; especially, they are abundantly and well preserved in the ryolitic tuff of the Sawayama Formation. Such a large suite of specimens includes variable types of length and disposition of leaves on the twigs. Especially, there are two contrasting types of leaves: one type is the branches with long, awl-like leaves which are closely set but open, and the other is the branches densely covered by short, considerably incurved leaves which are overlapping. However, the preparation of cuticles indicates that these variable leaves belong to the same conifer. Thus, these various types of foliage shoots show several stages of growth with long or short leaves.

Most of the Kuji specimens with long leaves are identical with *Araucarites anadyrensis* Kryshtofovich described from the Upper Cretaceous of Anadyr region. U.S.S.R. (Kryshtofovich, 1958). They are, however, also indistinguishable from some type of *A. longifolia* (Lesq.) Dorf, which was redesignated on the basis of the Upper Cretaceous Lance materials (Dorf, 1942). The epithet *"longifolia"* has priority for these Araucarian shoots.

In the external characters the long-leafed shoots of *A. longifolia* closely resemble the juvenile shoots of the extant *Araucaria heterophylla* (Salisb.) Franco living in Norfolk Islands, while the shoots with dense, short leaves are similar to older or fertile shoots of *A. heterophylla.* Although the cuticle characters closely resemble those of the extant *Araucaria,* especially the species included in the section Eutacta, the Kuji specimens were unable to determine their reference to the extant genus with confidence.

Because the carbonized films of the fossil leaves split into small fragments under the treatment, I could not determine the upper or lower surfaces of leaves examined. But all the specimens show usually similar characters of epidermis as far as examined. The stomata are

arranged in 2 to 4 rows, which are parallel to the leaf axis. The stomatal apparatuses are amphicyclostic, and are perpendicularly or obliquely oriented to the leaf elongation. The subsidiary cells are usually 4 in number, and are somewhat cutinized. They are surrounded by 5 polygonal, subsidiary cells. The guard cells are sunken below the surface, and stomatal pores are often wide and visible. Epidermal cells of non-stomatal region are mostly rectangular with nearly straight walls, and are arranged longitudinally. These stomatal characters are closely similar to those of the extant. *A. heterophylla* (Salisb.) Franco and *A. cunninghamii* Sweet, though the stomatal apparatuses of the extant species are twice larger than those of the fossil specimens.

The Araucarian leafy shoots were widely described from the Mesozoic and Older Tertiary of the World. Though they are difficult to compare only by external characters, but *A. longifolia* resembles closely *A. sternbergi* Goeppert from the Tertiary of Europe (Goeppert, 1850) and *A. ruei* Seward and Conway from the Tertiary of the Kerguelen Archipelago (Seward & Conway, 1934). A foliage shoots described as *Sequoia sternbergi* from the Late Cretaceous Asuwa flora (Matsuo, 1962) is unseparable from *A. longifolia. A. microphylla* Svenishikova from the Upper Cretaceous of Siberia (Sveshinikova, 1967) seems to represent a short-leafed shoot of *A. longifolia.*

Occurrence: Kadonosawa, Edanarizawa, Hikage and Oashi, Kuji City (Sawayama Formation); Chikyo-zawa and coastal cliff near Tamagawa, Kuji City (Tamagawa Formation).

Collection: Hypotypes, H.U.M.P. nos. 26050–26051; nos. 26052–26057.

Araucarites kujiensis Tanai, sp. nov.

(pl.7, figs.2, 3)

Discription: Cones spheroidal or oval in shape, 3 to 3.5 cm long and 2 to 2.5 cm wide; central axis stout, 4 to 5 mm wide, covered by spirally disposed deep pits; these pits showing cavities in the proximal end of scales; numerous imbricated scales attached laterally to the central axis; scales 1 to 1.2 cm long and 1 mm thick on the longitudinal section, distal portion curving upward, with sharp tip; a single seed embedded on each scale, 5 to 7 mm long and 2 to 3 mm thick.

Discussion: Many incomplete cones from one locality are closely similar to the strobili of the Araucariaceae in their shape, stout axis and cone-scale with single seed. They may be immature strobili of the Araucariaceae, because those of the extant species are usually larger. These fossil cones resemble those of *Araucaria cunninghamii* Sweet living in Australia, although they are far smaller. *A. kujiensis* may represent the cone of the above-described *A. longifolia* which is based on leafy shoots, because the both materials occur in the same locality. However, it is now better to treat these two as the independent species respectively until the cone-bearing shoot shall be found.

The Araucarian strobili were also widely described since the Jurassic of the world. *A. kujiensis* is somewhat similar in general outline to *A. pojarkova* Krassilov from the Danian-Maastrichtian flora of Amur region (Krassilov, 1976). Another similar species is *A. insulinensis* Fliche from the Albian flora of Argonne, France (Fliche, 1896).

Occurrence: Edanarizawa, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26058; paratype no. 26059; nos. 26060–26062.

Genus *Dammarites* Presl. ex Sternberg
Dammarites borealis (Heer) Seward
(pl.8, fig,9)

Dammarites borealis (Heer) Seward. 1919. Fossil plants. 4: 249, text-f.733.
Seward. 1926. Phil. Trans. Roy. Soc. London. [B]. 215: 98, pl.10, f.89.
Dammara borealis Heer. 1882. Die fossile Flora Groenlands, 1: 54, pl.36, f.5.
Agathis borealis (Heer) Kryshtofovich and Baikovskaya. Cretaceous flora of Saghalien. p.53, pl.11, f.6, 7 (see synonymy).

Discussion: A single small cone scale from one locality identical to *Dammarites borealis* which was frequently described from the Upper Cretaceous of Europe, Greenland, North America and East Asia. These specimens named as *D. borealis* by various authors, seem to include some different features; they may be doubtful to belong to a single species, and further to be related with the extant *Agathis.*

The Kuji specimen is fan-shaped with lower linear end, 1 cm high and 1 cm wide, and rucurved on the upper rounded margin. Many fine grooves on the surface converged toward the linear ends, while a conspicuous furrow crosses with these grooves on the scaly part. These superficial characters suggest that the Kuji specimen is similar to the genus *Sciadopitys* rather than *Agathis.*

Occurrence: Utsume, Kuji City (Tamagawa Formation).
Collection: Hypotype, NSM-PP-16799.

Family Cuppressaceae
Genus *Thuja* Linn.
Thuja cretacea (Heer) Newberry
(pl.8, figs.1, 2, 8; pl.9, figs.2, 3; text-fig.2-4)

Thuja cretacea (Heer) Newberry. 1896. U.S. Geol. Survey Monogr. 36: 53, pl.10, f.1, 1a.
Kryshtofovich & Baikovskaya. Cretaceous flora of Saghalien. p.65, pl.13, f.6, 7; text-f. 23 (see synonymy and discussion).
Sveshinikova 1967. Palaeobotanika. 6: 198, pl.11, f.9-11; pl.12, f.1-4.
Libocedrus cretacea Heer. 1882. Die fossile Flora Grönlands. 1: 49, pl.29, f.1-3; pl.43, f.1d.

Discussion: A number of the foliage shoots from the Sawayama Formation are identical to *Thuja cretacea* in their characteristic twigs covered with small, closely appressed leaves. These scale-like leaves overlap in four ranks of two opposite sets as usually observed in Cuppressaceae. The Kuji specimens are doubtlessly distinguishable from the extant *Calocerdrus* in the shorter leaves and wider branching angles of twigs. A preparation of the somewhat ill-preserved cuticle shows cyclocytic subsidiary cells and stomata similar to some of the extant *Thuja,* although the stomata are sparsely distributed, comparing with the extant species.

T. cretacea had a wide range and distribution in Cretaceous floras of Arctic region, North America and East Asia. Several fragmentary foliage shoots described as *Libocedrus sabiniana* Heer from the Late Cretaceous Hakobuchi Group of Hokkaido (Endo, 1925) are included in *T. cretacea,* because several similar specimens were collected from the same locality by me. Seward (1926) transferred Heer's Greenland species to the form genus

Cuppressinocladus because of difficulty of identification to a extant genus of the Cuppressaceae. However, a specimen illustrated as *C. cretacea* from Greenland (Seward, 1926: text-fig. 13) is different from the Kuji specimens in longer leaves. Actually, the cuppressineous shoots are difficult to afford satisfactory evidence for fossil taxonomy, and a further investigation needs for *"Thuja cretacea"* by collecting better specimens.
Occurrence: Oashi, Kadonosawa and Hikage, Kuji City (Sawayama Formation).
Collection: Hypotypes, H.U.M.P. nos. 26063–26065; nos. 26066–26068.

Coniferales Incertae Sedis
Genus *Cyparissidium* Heer
Cyparissidium gracile (Heer) Heer
(pl.8, fig.7)

Cyparissidium gracile Heer. 1874. Kgl. Svensk. Vet. Aka. Handl. 12(6): 74, pl.17, f.5b, 5c; pl.19, f.1-11; pl.20, f.1d, 1e; pl.21, f.9b, 10d.
Seward. 1926. Phil. Trans. Royal Soc. London. [B] 215: 111, pl.10, f.100; pl.11, f.107; text-f.20.
Seward and Conway. 1935. Kgl. Svensk. Vet. Aka. Handl. 15(3): 16, pl.4, f.19.
Widdringtonia gracilis Heer. 1868. Fossil Flora Arctica. 1: 83, pl.43, f.le, 3c, 3f, 3g.

Discussion: This species is represented by a specimen of many foliage shoots which are overlapped each other. These slender branches are covered by spirally-disposed, small leaves, which are appressed to axis with only the apex free. Leaves are mostly elongate with acute apex. Some branches bear a minute cone on their terminals; these cones are covered by spirally-disposed scales, and may be the male strobili. This specimen is similar to some of the Taxodiaceae such as *Sequoiadendron* and *Glyptostrobus,* and also to some of the Cuppressaceae. It is here difficult to determine its extant affinity only by the above-noted characters. However, these leafy twigs from the Kuji field are identical to *Cyparissidium gracilis* originally described from the Cretaceous of Greenland (Heer, 1874).

C. gracilis may be suggestive to be related with the Cuppressaceae such as *Callistris:* however, its modern relationship has been not yet ascertained, though the cuticular characters of the Greenland specimens were examined by Seward and his collaborator. The specimens under the name of *Widdringtonia* from the Cretaceous of North America (Newberry, 1895) are nearly identical to *C. gracilis.*
Occurrence: Kadonosawa, Kuji City (Sawayama Formation).
Collection: Hypotype, H.U.M.P. no. 26069.

Genus *Brachyphyllum* Brongniart
Brachyphyllum cf. *crassam* Lesquereux
(pl.4, fig.2)

Brachyphyllum crassam Lesquereux. 1892. U.S. Geol. Survey Monogr. 17: 33, pl.2, f.5.

Discussion: A single, incomplete shoot covered by scale-like leaves is probably referable to *Brachyphyllum crassam* described from the Cretaceous of North America. The leaves are rhomboidal, comparatively large, appressed to the branch, and are spirally arranged. This specimen is distinguishable from the short-leafed shoot of *Araucarites longifolia* (Lesq.) Dorf in thicker and rhomboidal leaves. The genus *Brachyphyllum* was reported mostly from the Jurassic to the Lower Cretaceous of the Northern Hemispere, but its modern relationship is

yet uncertain.

Occurrence: Coastal cliff near Tamagawa, Kuji City (Tamagawa Formation).

Collection: H.U.M.P. no. 26070.

Genus *Protophyllocladus* Berry

Protophyllocladus subintegrifolius (Lesq.) Berry

(pl.5, figs.3, 4, 10; pl.9, fig.6)

Protophyllocladus subintegrifolius (Lesq.) Berry. 1903. Bull. Torrey Bot. Club. 30: 440.
Berry. 1904, ibid. 31: 69, pl.1, f.5.
Hollick. 1906. U.S. Geol. Survey Monogr. 50: 36, pl.5, f.1-6.
Berry. 1916. Upper Cretaceous. Maryland Geol. Survey. p.796, pl.56, f.2.
Kryshtofovich. 1918. J. Coll. Sci. Imp. Univ. Tokyo. 40(8): 41, text-f.6.
Hollick. 1930. U.S. Geol. Survey Prof. Pap.159: 51, pl.14, f.1-3.
Seward & Conway. 1935. Kgl. Svensk Vet. Akad. Handl. 15(3): 17, pl.6, f.30; text-f.13.
Teixeira. 1950. Flora Mosozoica Portuguesa. pt.2, p.20, pl.12, f.4-7, 9-10.
Phyllocladus subintegrifolius Lesquereux. 1874. U.S. Geol. Survey Terr. Rept. 6: 54, pl.1, f.12.
Lesquereux. 1892. U.S. Geol. Survey Monogr. 17: 34, pl.2, f.1-3.
Protophyllocladus polymorphus (Lesq.) Berry. 1903. Bull. Terrey Bot. Club. 30: 442.
Hollick. 1930. U.S. Geol. Survey Prof. Pap. 159: 51, pl.14, f.7.
Kryshtofovich. 1937. Cretaceous flora of Saghalien. p.67, pl.9, f.3-8; pl.10, f.1-6.
Kryshtofovich & Baikovskaya. 1960. Cretaceous flora of Saghalien. p.51, pl.11, f.2-5a; pl.13. f.2.
Seward & Conway. 1935. Kgl. Svensk. Vet. Aka. Handl. 15(3): 18, pl.6, f.32.
Salisburea polymorpha Lesquereux. 1878. U.S. Geol. Survey Terr. Rept. 7: 84, pl.60, f.40, 41.
Thinnfeldia polymorpha (Lesq.) Knowlton. 1893. U.S. Geol. Survey Bull. 105: 47, pl.5, f.1-4.
Thinnfeldia lanceolata Knowlton. 1893. ibid. p.49, pl.5, f.5.
Protophyllocladus lanceolatus (Knowlton) Berry. 1903. Bull. Torrey Bot. Club. 30: 442.
Protophyllocladus obesus Hollick. 1930. U.S. Geol. Survey Prof. Pap. 159: 51, pl.14, f.6.
Protophyllocladus simplex Hollick. 1930. ibid. p.52, pl.14, f.4, 5.

Discussion: Several incomplete foliage specimens are referable to the genus *Protophyllocladus* in their shape and venation, although they are somewhat variable in size and marginal characters. This genus was proposed by Berry (1903) for the Cretaceous fossils from North America, which were previously included in *Thinnfeldia.* Based on the morphological resemblance, he considered these fossils to be related to phylloclades of *Phyllocladus,* a conifereous genus now distributed in Malaysia, Tasmania and New Zealand.

The Kuji specimens are lanceolate to oblanceolate in general outline, cuneate at the base with a short, thick petiole, and are from nearly entire to irregularly undulate or dentate on the margin. The midvein is thick up to about the middle of phylloclade, and then is thinning out abruptly to the apex. The secondary veins are simple, numerous, making acute angles with the midvein, and reach the margin. Most of the specimens are lacking in the apical part, but they are probably obtuse. One of the specimens is deeply emarginate with divided, two rounded tips at the apical part.

The above-described characters show that the Kuji specimens are closely similar to *P. subintegrifolius, P. polymorphus* and *P. lanceolatus,* especially referable to the first species. These three species of *Protophyllocladus* recognized by Berry (1903) are closely allied as pointed out by Seward and Conway (1935), although variable in size and marginal feature. Kryshtofovich and Baikovskaya (1960) claimed that these three species are conspecific, along with two species later described from the Alaskan Cretaceous (Hollick, 1930), and that they are represented by *P. polymorphus.* I agree with them that the above-noted five species

are conspecific, because the specimens with various size and shape were collected even from a same locality of Kuji area. However, we have one problem on the specific epithet for these specimens.

The name of *Saliburea polymorpha* was first given by Lesquereux (1859) to some incomplete specimens from the Cretaceous of Nanaimo, Vancouver Island, but it was unaccompanied by full description and illustration. This species was later fully described on the specimens from Montana by him (Lesquereux, 1878). Accordingly, the epithet *"polymorphus"* is apparently later synonym of *"subintegrifolius"*. All the specimens in the above synonymy list are included in *P. subintegrifolius.*

Based on superficial resemblance, Berry (1903) compared four species of *Protophyllocladus* with a conifer, *Phyllocladus.* Later, Seward and Conway (1935) investigated the cuticlar structure of *P. subintegrifolius* from Greenland, and they clarified that the stomatal opening is surrounded by four subsidiary cells as seen in conifers and cycads. The genus *Protophyllocladus* is still unknown in its definite relationship with the extant plants, though it is not a fern.

Occurrence: Hikage, Kuji City (Sawayama Formation); coastal Cliff near Tamagawa, Kuji City (Tamagawa Formation)

Collection: Hypotypes, H.U.M.P. nos. 26071–26073.

Subdivision Angiospermae

Family Magnoliaceae

Genus *Liriodendron* Linne

Liriodendron iijimae Tanai, sp. nov.

(pl.10, figs.1, 3, 5; text-fig.3-7)

Description: Leaves oval to rectangular with nearly vertical sides in general outline, emarginate at apex, divided into two oblong lobes by deeply acute sinus attaining to the about one-third of blade length from the base; base broadly rounded to truncate; height 5 to 7.5 cm but reaching probably about 9 cm in one incomplete specimen; width 4 to 8 cm; two lobes somewhat inequilateral, obtuse at apex; midvein stout, straight from base to emarginate apex; secondary veins pinnate, stout, 3 or 4 subopposite pairs, diverging from the midvein at acute angles; only an uppermost pair of the secondaries reaching near the apex of each lobe; beside these secondaries slender subsecondary pairs diverging from the midvein at the uppermost and suprabasilar part of blade respectively; all the secondaries gently curving up, near the margin connecting with a branch from the superadjacent secondaries to form prominent arches which are enclosed by tertiary and quaternary loops; the uppermost subsecondary veins extending up along the inner margin near the middle of lobe, then forming loops with branches of the uppermost secondary; the suprabasilar subsecondary veins extending along the basal margin, then forming loops, giving off several comptodrome branches from their outsides; the tertiary veins among the intercostal areas irregularly percurrent, convex or sometimes forking; the higher order veins forming four- or five-sided areolation; veinlets ill-preserved but probably branching more than twice; margin entire; petiole thick, but nearly missing; texture chartaceous.

Discussion: These peculiar, butterfly-like shaped leaves show a resemblance to some leaves of

the Leguminosae: the legumen leaves or leaflets are sometimes emarginate at the apex, although they are pinnate in the secondary venation. In actual, many emarginate-tipped leaves with the pinnate venation were described as *Dalbergites* from the Cretaceous and Lower Tertiary. *Dalbergites simplex* (Heer) Seward from Greenland and North America (Seward and Conway, 1935) is similar in general outline to the Kuji specimens, although the apical sinus is far shallower and widely opened. However, *D. simplex,* as compared with the extant *Amicia zygomeris* Mocc. & Sesse, is different from the Kuji specimens in more secondary veins and marginal looping. Especially, the uppermost stout secondary pair which reaches near the apex of lobes, distinguishes the Kuji specimens from the emarginate leaflets with pinnate venation of the Leguminosae.

The truncate base and the above-described venation character show that the Kuji specimens are most close to the genus *Liriodendron,* although leaves of this extant genus are usually shallower in apical sinus. Leaves of *Liriodendron* are, as well known, highly variable in foliar shape: they are mostly two-lobed on each side, but are rarely lacking in the basal pair of lobe (pl. 10, fig. 2). Thus, the Kuji peculiar leaves are referable to *Liriodendron* with some hesitation, and may show the ancestral type of the extant species.

Many species of *Liriodendron* and its allied genera were described from the Cretaceous of the world, but some of them were later excluded from this genus. Of these previously known species, *L. iijimae* is most similar to *L. laramiense* Ward (Berry, 1925) from the Late Cretaceous Ripley Formation of Mississippi in general outline and venation, but is distinguishable in deeper apical sinus. *Liriophyllum populoides* Lesq. from the Dakota Group of Colorado (Lesquereux, 1883) and *L. sachalinensis* Krysht. from the Gyliakian flora of Saghalien (Kryshtofovich, 1937) are somewhat similar to *P. iijimae* in deep apical sinus and venation; but the Dakota specimens are rhombic in shape, and the Gyliakian specimens are too incomplete.

This new species is named in honour of Professor A. Iijima who kindly assisted me to collect fossils.

Occurrence: Hikage, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26074; paratypes nos. 26075, 26076; no. 26078.

Genus *Magnolia* Linn.

Magnolia cf. *lakesii* Knowlton

(pl.8, figs.4, 6)

Magnolia lakesii Knowlton. 1922. U.S. Geol. Survey Prof. Paper (130): 142, pl.13, f.2.
Dorf. 1938. Carnegie Inst. Wash. Publ. (508): 62, pl.10, f.2.

Discussion: Two incomplete leaves are leathery in the texture, and are brochidodromous in the secondary venation. The reference of these specimens to the genus *Magnolia* is somewhat questionable. The slender venation and indistinct secondary veins seem to show evergreen leaves of *Magnolia.* These leaves are tentatively referred to *M. lakesii* from the Upper Cretaceous of the Rocky Mountain region.

Occurrence: Coastal cliff near Tamagawa, Kuji City (Tamagawa Formation); Hikagezawa, Kuji City (Sawayama Formation).

Collection: H.U.M.P. nos. 26079, 26080; no. 26081.

Family Lauraceae

Genus *Cinnamomophyllum* Kräusel et Weyland

Cinnamomophyllum sp.

(pl.8, figs.4, 6)

Discussion: Several incomplete, lanceolate leaves from two localites are tri-plinerved with long petiole (more than 2 cm). A pair of the acrodromous secondary veins are basal or suprabasal at the originating position, and extends up near the apex. A pair of slender subsecondary veins originating from the base, arises up along the margin to the one-third height of the blade, and then connects with large marginal arches which are formed by the tertiary veins branching from the secondaries. The intercostal tertiary veins are closely spaced, and are nearly perpendicular to the midvein.

The above-noted venation character suggests that these fossil leaves belong to the Lauraceae, probably to the genus *Cinnamomum.* In actual, these fossil leaves are closely similar in shape and major venation to leaves of the extant *C. zeylanicum* Nees and *C. randaiense* Hayata of tropical East Asia, although these extant leaves are further shorter in petiole. *Cocculus laurifolius* DC. shows also a superficial resemblance to the fossil leaves, but it is distinguishable in tertiary venation. A definite identification with an extant genus is not possible because of the ill-preserved fine venation. Therefore, these cinnamon-like leaves are referred to the form-genus *Cinnamomophyllum.*

Cinmomomum linifolium Knowlton from the Upper Cretaceous of Wyoming (Dorf, 1938) resembles the Kuji specimens in foliar shape and tri-plinervation. However, I hesitate to refer my specimens to the Wyoming species without investigation of the original specimen, because the Wyoming specimens are uncertain to be a true cinnamon.

Occurrence: Kadonosawa and Hikage, Kuji City (Sawayama Formation).

Collection: H.U.M.P. nos. 26082–26084.

Genus *Laurophyllum* Goeppert

Laurophyllum kujianum Tanai, sp. nov.

(pl.11, figs.1, 2, 4-8; text-fig.3-8)

Discription: Leaves elongate-elliptical in shape, acute at apex and base, entire on margin, 5.5 to 16 cm long and 2 to 4 cm wide; midvein stout, nearly straight or slightly arcuate; secondary veins rather slender, 10 to 12 subopposite pairs, somewhat irregularly spaced, diverging from the midvein at angles of 35 to 55° (generally 45 to 50°), gently curving upwards, joining the secondary above to form large marginal loop; a subsecondary vein among the intersecondary spaces sometimes extending about one-second or two-third the distance to the margin, and connecting with the tertiaries; the tertiary veins in marginal areas forming the middle-sized loops which are enclosed by small arches of the higher order veins; the tertiary veins in the intercostal areas irregularly percurrent, simple or sometimes forked, nearly perpendicular or oblique to the secondaries; the heigher order veins forming irregular-sized, four- or five-sided meshes; areoles generally imperfect; veinlets branching several times, showing complicated pattern; texture coriaceous; petiole stout, 0.8 to 2.1 cm long.

Leaves hypostomatic. Upper epidermis consisting of cells with straight to slightly curved

lateral walls; upper epidermal cells isodiametric to somewhat elongate in shape with 4 or 5 sides, irregularly disposed except on veins where they are elongate with axes of cells paralleling the vein axis; stomata quite absent on the upper epidermis, but a few hair bases present with a group of relatively isodiametric cells. Lower epidermis composed of polygonal cells with 4 to 6 sides, which walls are straight to slightly curved; lower epidermal cells isodiametric to elongate with acute angles; numerous stomata and few hair-bases present excepting for on the veins; a hair-base somewhat cutinized, generally surrounded by 6 angular cells. Stomata randomly oriented, scattered as 10–12 per 10 x 10μ, paracytic; guard cells slightly separated in general, cutinized, 15 to 20μ long, extending to the length of two subsidiary cells which overlie the guard cells; the stoma and subsidiary cells surrounded by 4 or 5 epidermal cells.

Discussion: These elliptical leaves with thick texture are abundantly found in one locality; they are mostly incomplete, but they are easily restored in their general characters because of abundant materials. These leaves are closely similar in foliar shape and the characters of the major venation to some leaves of the Lauraceae such as *Actinodaphne, Litsea, Lindera* and *Machilus.* Especially, these fossil leaves show most superficial resemblance to leaves of *Actinodaphne lancifolia* (S. et Z.) Meissn. and *Machilus japonica* S. et Z., which are living in southern Japan and southward. However, the above-noted genera of the Lauraceae are quite different from the fossils in fine venation: the veinlets are usually single or none in the ultimate areoles in the extant leaves, while they ramify several times in somewhat incomplete areolation in the fossils. Leaves of *Persea* resemble the Kuji specimens in general feature and veinlets characters, although the secondary veins of *Persea* are usually stronger and more prominent on the undersurface of blade. Some leaves of the Rubiaceae such genera as *Randia* and *Tarena,* are also similar superficially, but are different in fine venation.

The cuticular features support to place these fossil leaves in the Lauraceae. As discussed extensively on leaves of the modern species of the Lauraceae (Bandulska, 1926; Metecalf & Chalk, 1950; Shakryl, 1965), this family is characterized by the fact that stomata are confined to the lower surface, and that the subsidiary cells are always paracytic. These characters exclude other families such as the Rubiaceae and Euphorbiaceae, some leaves of which families are superficially similar to the Kuji specimens. Thus, combined the venation pattern with the cuticular characters, the Kuji specimens discussed here represent leaves of the Lauraceae, although they are difficult to refer to the extant genus.

Several form- or organ-genera were proposed for the fossil leaves similar to some leaves of the Lauraceae by various authors; for instance, they are *Laurophyllum* (Goeppert, 1854), *Lauriphyllum* (Nathorst, 1888), *Lauraceaephylloderma* (Sturm, 1971) and *Lauroceophyllum* (Sturm, 1971). If followed Sturm's definition, the Kuji specimens may be referable to the organ-genus *Lauraceaephylloderma.* However, most of the Late Cretaceous and Tertiary plants is still inevitable to identify only on the basis of leaf impressions. Therefore I prefer to retain the classical name *"Laurophyllum"* for the fossil lauraceous leaves which are definitely not assignable to an extant genus.

Occurrence: Hikage and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26085; paratypes nos. 26086–26088; nos. 26089–26091.

Family Menispermaceae
Genus *Menispermites* Lesquereux
Menispermites kujiensis Tanai, sp. nov.
(pl.11, fig.3; pl.12, figs.1, 2; text-fig.4-6)

Description: Leaves reniform, 2.7–4 cm (estimated) long and 3.3–6.2 cm wide; apex rounded; base truncate or broadly cordate; primary veins palmately five, leaving the base, slightly flexuous; inner pair of lateral primaries more than thrice forking to form marginal loops; outer pair of lateral primaries branching downward 4 or 5 secondaries which form marginal loops along the margin; secondary veins from the midvein nearly parallel to inner primaries, once or twice forking to form loops; slender intersecondary veins sometimes diverging from the midvein, connecting with the tertiaries or branches of secondaries; tertiary vein thin but distinct, irregularly transverse; the high order veins indistinct; margin irregularly undulate; petiole thik, peltate, more than 1 cm.

Discussion: Most of the specimens are missing in base, but they seem due to peltate character, inferring from the broken condition of one specimen. The lateral primaries appear to reach near the margin, although gradually thinning. These leaves are closely similar to those of the Menispermaceae in shape and venation. However, it is difficult to afford the generic assignment, due to the ill-preservation, and it is now referred to the form genus *Menispermites.*

A number of species belonging to Menispermaceae have been described from the Upper Cretaceous of the Northern Hemisphere, but no leaves are identical to this new species. *M. kujiensis* is somewhat similar in venation to *Menispermites sachalinesis* Kryshtofovich from the Upper Cretaceous of Saghalien (Kryshtofovich and Baikovskaya, 1960), but differs in general outline and margin. Another similar species is *M. septentrionalis* Hollick from the Cretaceous of Alaska (Hollick, 1930).

Occurrence: Edanarizawa, Oashi, Hikage and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26092; hypotypes nos. 26093, 26094.

Family Trochodendraceae
Genus *Trochodendron* Sieb. et Zucc.
Trochodendron kujiense Tanai sp. nov.
(pl.10, figs.6, 7; text-fig.4-1, -2)

Description: Leaves small, oboval to oval in general outline, 1.7 to 3 cm long and 1.8 to 2.8 cm (estimated) wide; apex rounded with abruptly pointed tip; base broadly cuneate to rounded and abruptly cuneate; midvein stout, nearly straight; secondary veins about 7 subalternate pairs, irregularly spaced, diverging from the midvein at angles of 45° to 55°, at the about two-third or three-fourth of their course to the margin forking to form somewhat angular loops, then further once or twice forking to form smaller loops at the marginal area; tertiary veins thin, oblique to the secondary; a branch from the outer small loops entering the glandular teeth; margin crenate except basal half part, teeth somewhat irregularly spaced; sinus broadly rounded; petiole thick but neary missing.

Discussion: The above-described venation character and marginal serration indicate that these small leaves are allied to the genus *Trochodendron,* although these fossils are wider

than leaves of the extant *T. aralioides* Sieb. et Zucc. The medial vein entering a glandular tooth is accompanied by two converging thin veins, which also enter the tooth apex or connect with medial vein below apex. These marginal teeth belong to the Chlorantoid type, designated by Hickey and Wolfe (1975), which represents the Trochodendraceae.

Berry (1922) proposed a form genus of *Trochodendroides* for the leaves, which are related not to the genus *Trochodendron* but to the Trochodendraceae in the old sense, including *Cercidiphyllum* and *Tetracentron.* Thereafter a number of leaves similar superficially to *Cercidiphyllum, Tetracentron* and *Populus,* have been described under the name of *Trochodendroides* from the Upper Cretaceous and Paleocene by various authors; most of these leaves are actinodromous in venation and crenate or undulate in margin. However, *Trochodendroides* is not attributable to a single extant genus, and includes many leaf types of the different families in the early angiosperm history, as pointed out by Krassilov (1973). Furthermore, the extant leaves of *Trochodendron* is not acrodromous but pinnate in venation, although the secondary veins leave the midvein at acute angles. Our two small leaves represented by pinnate venation are quite distinguishable from the so-called *"Trochodendroides".*

Occurrence: Minato, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26095; hypotype no. 26096.

Family Platanaceae

Genus *Platanus* Linn.

Platanus cuneifolia (Bronn) Krysht.

(pl.12, figs.12; pl.13, figs.9, 10; text-fig.4-5)

Platanus cuneifolia (Bronn) Kryshtofovich. 1914. Discovery of angiosperm floral remains from the Cretaceous of Ural region. p.604.

Ablaev. 1974. Late Cretaceous flora of eastern Sikhote-Alin. p.92, pl.10, f.4, 5; pl.11, f.1-3.

Knappe and Rüffle. 1975. Wissenschaft. Zeitschr. Humboldt-Univ. Berlin. Math. -Nat. R. 24: 488, pl.1, f.1-4.

Credneria cuneifolia Bronn. 1837. Lethea geognostica oder Abbildungen und Beschreibungen. 1: 583, pl.28, f.11.

Rüffle. 1968. Palaeontogr. [B] 123: 138, pl.27, f.6; pl.29, f.1-8 (see synonymy).

Discussion: Several trilobed leaves with dentate margin, although incomplete, are doubtlessly referable to the genus *Platanus* by the following characters: the acuminate or attenuate teeth separated by arcuate sinus; the primaries and most of the secondaries terminating at glandular apices of teeth, the well-defined percurrent tertiary veins and decurrent base. The teeth of our leaves apparently belong to the Platanoid type (Hickey and Wolfe, 1975); the

Explanation of Plate 1

(all natural size unless otherwise stated)

Figs. 1, 3 *Equisetum* sp. H.U.M.P. nos. 25981, 25982 (Oashi).

Fig. 2 *Anemia elongata* (Newb.) Knowlton. Hypotype, H.U.M.P. no. 25985 (Hikagezawa)

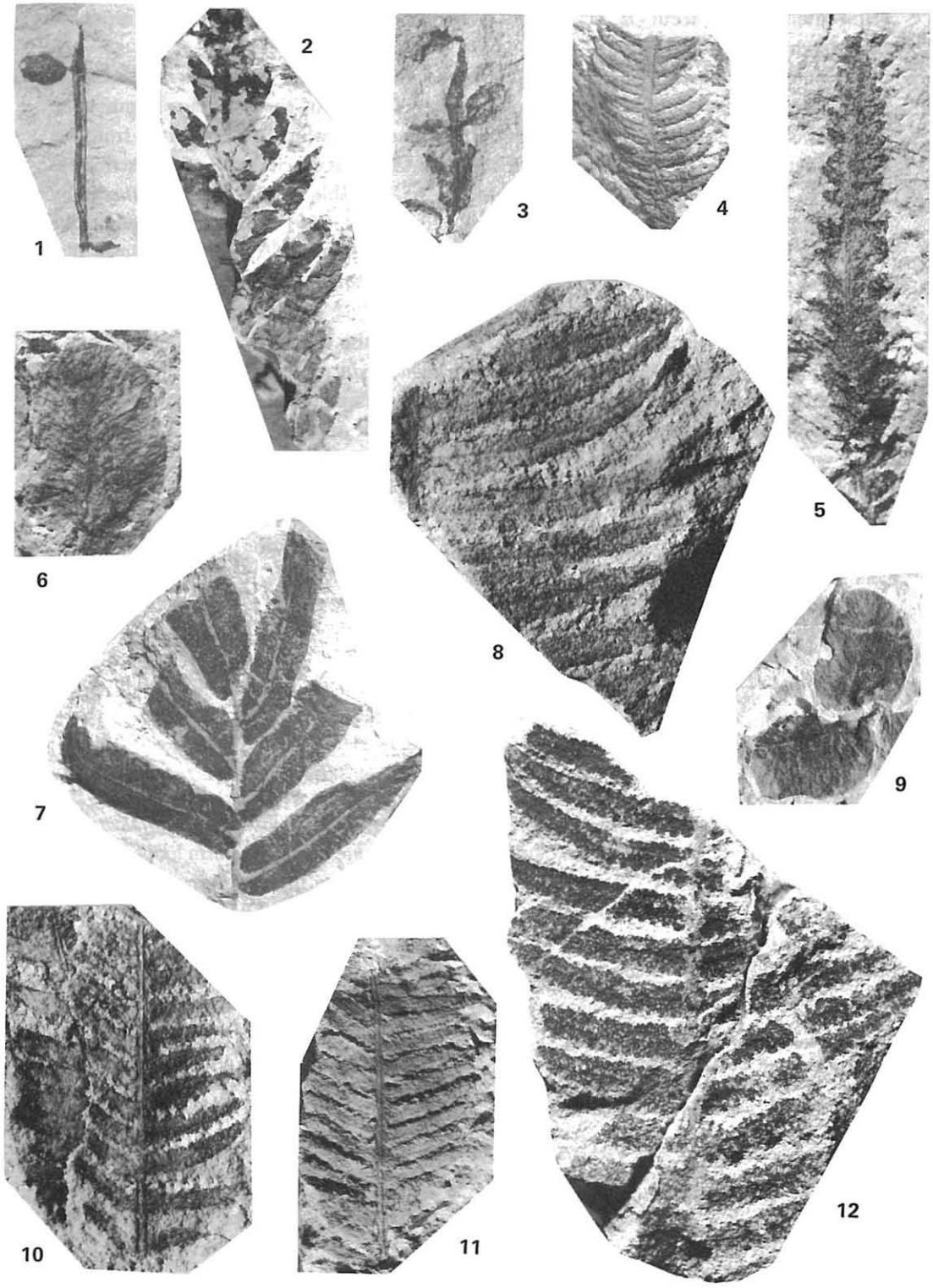
Figs. 4, 10, 11 *Gleichenites lineariformis* (Krysht.) Tanai. Hypotypes, H.U.M.P. nos. 25992-25994 (Kunitan-A)

Fig. 5 *Gleichenites* cf. *giesekiana* (Heer) Seward. ×1.5 H.U.M.P. no. 25989 (Kunitan-A).

Figs. 6, 9 *Salvinia mildeana* Goeppert. ×2 Hypotypes, H.U.M.P. nos. 26009, 26010 (Hikagezawa)

Fig. 7 *Osmunda asuwensis* Matsuo. Hypotype, H.U.M.P. no. 25984 (Kunitan-B).

Fig. 8, 12 *Gleichenites crenata* (Krysht.) Tanai. Hypotypes, H.U.M.P. nos. 25986, 25987 (Kunitan-B)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vein entering the teeth is accompanied by high order veins forming a series of brochidodromous loops.

A number of plane-tree-like species have been described under the genera of *Platanus* or *Credneria* from the Upper Cretaceous and Lower Tertiary of the Northern Hemisphere. Among them our leaves are referable to *Platanus cuneifolia,* which were reported from the Upper Cretaceous of Europe, Kazakhstan and East Asia. This species, originally described as *Credneria* by Bronn (1837), was considered to be referable to the extant *Platanus* by Kryshtofovich (1914), Vakhrameev (1952), Baikovskaya (1956) and others. Based on the epidermis characters of Cenomanian leaves from Niederschöna, Rüffle (1968) claimed that the genus *Credneria* is distinguishable from the extant *Platanus,* considering together with similar leaf shape of different families. However, he (1975), jointed with Knapp, retracted his opinion on the distinction of these two genera, because the epidermis structure shows a gradual change from Tertiary *Platanus* to Cenomanian *Credneria.*

Some species of older Tertiary plane-trees closely resemble *P. cuneifolia,* and especially *P. raynoldsi* Newberry common in the Paleocene of North America seems to be most related to *P. cuneifolia. Menispermites pachyllus* Ablaev described from the Upper Cretaceous (Ablaev, 1974) appears to be a stipule of *Platanus,* and may be included in *P. cuneifolia,* which leaves were described in the same flora.

Occurrence: Coastal cliff, Tamagawa, Kuji City (Tamagawa Formation); Edanarizawa, Oashi and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26097, 26098; no. 26099.

Family Fagaceae

Genus *Dryophyllum* Debey ex Saporta

Dryophyllum subfalcatum Lesquereux

(pl.10, figs.4, 8; pl.12, fig.8)

Dryophyllum (Quercus) subfalcatum Lesquereux. 1878. U.S. Geol. Survey Terr. Rept. 7: 163, pl.63, f.10. Dorf. 1938. Carnegie Inst. Wash. Publ. (508): 51, pl.5, f.1, 2, 6 (see synonymy).

Discussion: Many leaves from several localities are referred to *Dryophyllum subfalcatum* in their shape and venation character. The secondary veins are arcuate to form loops along the lower entire margin, while they are semicraspedodromous on the upper serrate margin. *D. subfalcatum* originally described from the Upper Cretaceous of Wyoming (Lequereux, 1878), was later discussed in detail by Dorf (1938), including many synonyms. This species is superficially similar to some species of the modern *Quercus* or *Lithocarpus* as already

Explanation of Plate 2

(All natural size unless otherwise stated)

Fig. 1 *Gleichenites gracilis* (Heer) Tanai. ×1.5 Hypotype H.U.M.P. no. 25990 (Kadonosawa).

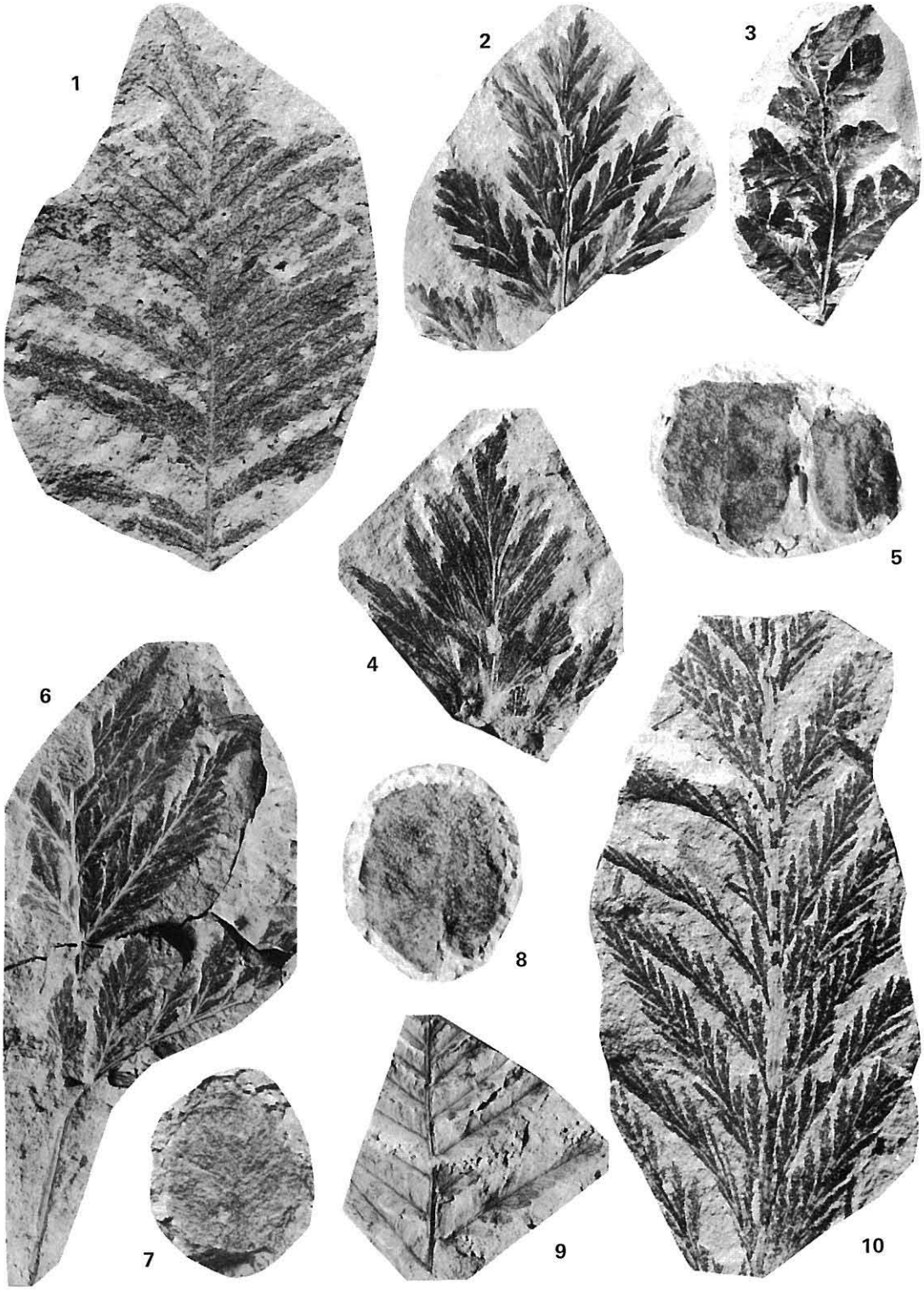
Figs. 2, 4 *Asplenium dicksonianum* Heer. ×1.5 Hypotypes, H.U.M.P. nos. 26003a (Oashi), 25997 (Minato).

Fig. 3 *Sachalinia sachalinensis* Vachrameev. Hypotype, H.U.M.P. no. 26029 (Oishi).

Fig. 5, 7, 8 *Salvinia mildeana* Goeppert. ×2 Hypotypes, H.U.M.P. nos. 26011-26013 (Hikagezawa).

Fig. 9 *Gleichenites gracilis* (Heer) Tanai. Hypotype, H.U.M.P. no. 25991 (Hikage).

Figs. 6, 10 *Asplenium dicksonianum* Heer. Hypotypes, H.U.M.P. nos. 25998 (Kunitan-B), 25999 (Kadonosawa).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pointed out by Dorf., but it has no sufficient evidence to be referable to these modern genera.

Occurrence: Coastal cliff near Tamagawa and Kunitan B, Kuji City (Tamagawa Formation); Hikagezawa, Oashi, Kadonosawa and Minato, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26100–26102; nos. 26103, 26104.

Family Dilleniaceae

Genus *Dillenites* Berry

Dillenites lanceolatus Tanai, sp. nov.

(pl.13, figs.2, 3; text-fig.4-3, -4)

Description: Leaves lanceolate in general shape, 7 to 7.5 cm long (estimated) and 1.1 to 1.4 cm wide; apex gradually narrowed, attenuate; base cuneate, slightly decurrent; midvein stout, nearly straight; secondary veins thin but distinct, 12 to 14 pairs, subparallel, rather regularly spaced, opposite to subopposite, diverging from the midvein at very narrow angles then soon at 30° to 35°, nearly straight, abruptly curving up along the margin, connecting with the tertiary veins to form distinct marginal loop; a subsecondary vein from each secondary branching off near the margin, entering the glandular tooth; tertiary veins thin, closely spaced, percurrent, nearly straight or sometimes forking, perpendicular to the midvein; the fourth- and fifth-order veins forming rectangular or polygonal areoles; veinlets indistinct; margin regularly serrate excepting basal entire part; the tooth slightly concave on the apical side and straight or slightly concave on the basal side; sinus broadly rounded; petiole missing.

Discussion: These specimens are characterized by closely-spaced tertiary veins perpendicular to the midvein and the semicraspedodromous secondaries. As shown in text-fig. 4–4, the teeth character represent the Dillnioid type, designated by Hickey and Wolfe (1975). These characters suggest that the Kuji leaves belong to the Dilleniaceae. In actual, these leaves are similar to some leaves of *Dillenia* and *Tetracera* in venation and marginal characters, although they are further smaller than the modern leaves.

Berry (1916) described four species under the form-genus *Dillenites,* based on leaves similar to those of the Dilleniaceae from the Wilcox flora of southwestern United States. The Kuji specimens are distinguishable from these four Wilcox species in general shape and venation. However, our leaves are referred to *Dillenites* in the sense that they are assignable to the Dilleniaceae.

Occurrence: Oashi and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26105; paratype no. 26106.

Explanation of Plate 3

(All natural size unless otherwise stated)

Figs. 1, 4 *Sachalinia sachalinensis* Vachrameev. x1.5 Hypotypes, H.U.M.P. nos. 26003b, 26030 (Oashi)

Fig. 2 *Asplenium dicksonianum* Heer. Hypotype. H.U.M.P. no. 26000

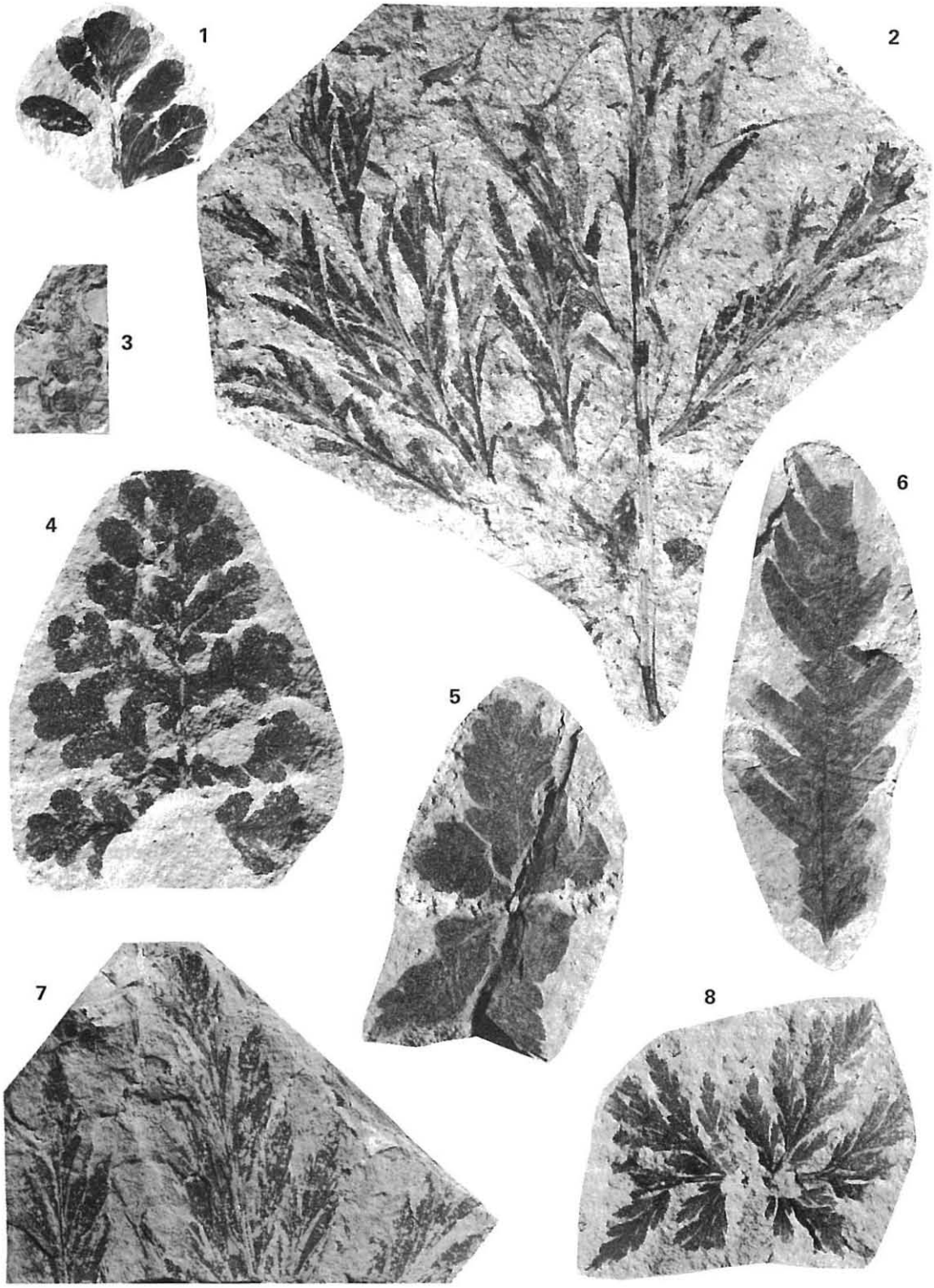
Fig. 3 *Sphenopteris onkilonica* Kryshtofovich. x2 Hypotype, H.U.M.P. no. 26035 (Hikagazawa).

Fig. 5 *Sachalinia sachalinensis* Vachrameev. Hypotype, H.U.M.P. no. 26031 (Kunitan-B).

Fig. 6 *Cladophlebis acuta* Fontaine. Hypotype, H.U.M.P. no. 26017 (Kunitan-B).

Fig. 7 *Asplenium dicksonianum* Heer. Hypotype, H.U.M.P. no. 26001 (Kunitan-B).

Fig. 8 *Asplenium dicksonianum* Heer. x1.5 Hypotype, H.U.M.P. no. 26002 (Oashi).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Family Salicaceae
Genus *Salix* Linn.
Salix lancensis Berry
(pl.13, figs.3, 4, 6-8)

Salix lancensis Berry. 1934. U.S. Geol. Survey Prof. Paper. (185-F): 130, pl.25, f.8.
Dorf. 1942. Carnegie Inst. Wash. Publ. (508): 134, pl.7, f.2, 5, 7, 8; pl.8, f.3.

Discussion: A number of linear or lanceolate leaves, though ill-preserved, are referable to *Salix lancensis* which is originally described from the Late Cretaceous Lance flora of Wyoming (Berry, 1934). These leaves are numerous and slender in the secondary veins, and remotely serrate with minute, glandular teeth in margin. Their affinity to the genus *Salix* is probably reliable.

Occurrence: Edanarizawa and Kadonosawa, Kuji City (Sawayama Formation); Kunitan-B, Kuji City (Tamagawa Formation).

Collection: H.U.M.P., hypotypes nos. 26107–26110; nos. 26111–26115.

Family Sapindaceae
Genus *Sapindophyllum* Ettingshausen
Sapindophyllum quercifolium (Hollick) Tanai, comb. nov.
(pl.12, figs.4, 6; pl.14, fig.1; text-fig.4-7, -8)

Rulac quercifolium Hollick. 1930. U.S. Geol. Survey Prof. Paper (159): 100, pl.29, f.1a; pl.77, f.1-10; pl.78, f.7b.
Kryshtofovich. 1938. Late Cretaceous plants from the Kolym River Basin. p.17, pl.2, f.3
Kryshtofovich. 1958. Palaeobotanika. 3: 59, text-f.43, 44.
Kryshtofovich & Baikovskaya. 1960. Cretaceous flora of Saghalien. p.103, pl.20, f.4; pl.21, f.1.

Discussion: These linear-oblong leaves with large teeth, though fragmentary, are referable to *"Rulac quercifolium"* originally described from the Upper Cretaceous of Alaska (Hollick, 1930). *"Rulac"* was an old generic name used for the box-elder, when *Acer negundo* was once treated as an independent genus. However, the Kuji specimens are quite distinguishable from leaves of the extant box-elder in slender, not-percurrent tertiary veins and a clear glandular apex of tooth. As shown in Text-fig. 4–7 and –8, the principal vein entering tooth sends a branch to the sinus or to the superadjacent tooth; the tooth and vein characters show that the Kuji specimens have a Cunonioid tooth type designated by Hickey and Wolfe (1975). Considering the above-noted characters together with sparse glands on under-surface of blade, the Kuji specimens belong to the Sapindaceae, and especially resemble some leaves

Explanation of Plate 4
(All natural size unless otherwise stated)
Figs. 1, 13 *Zamiopsis* cf. *pinnatifida* Fontaine. x2 H.U.M.P. nos. 26038, 26037a (Kadonosawa).
Fig. 2 *Brachyphyllum* cf. *crassam* Lesquereux. x2 H.U. M.P. no. 26070 (Tamagawa).
Figs. 3, 4 *Cladophlebis frigida* (Heer) Seward. Hypotypes, H.U.M.P. nos. 26021, 26022 (Kadonosawa).
Figs. 5, 8 *Adiantopteris eximium* (Saporta) x2 Hypotypes, H.U.M.P. nos. 26015, 26016 (Kadonosawa).
Fig. 6 *Sphenopteris onkilonica* Kryshtofovich. x2 Hypotype, H.U.M.P. no. 26036 (Kunitan-B).
Fig. 7 *Cladophlebis borealis* (Brong.) Kryshtofovich. x2 Hypotype, H.U.M.P. no. 26019 (Kadonosawa).
Fig. 9 *Zamiopsis* cf. *pinnatifida* Fontaine. x1.5 H.U.M.P. no. 26039 (Kadonosawa).
Fig. 10 *Cladophlebis borealis* (Brong.) Kryshtofovich. Hypotype H.U.M.P. no. 26018 (Kunitan-B).
Figs. 11, 12 *Cladophlebis oerstedti* (Heer) Seward. fig. 11 x2, fig. 12 x1.5. Hypotypes, H.U.M.P. nos. 26026 (Hikage), 26027 (Kadonosawa).


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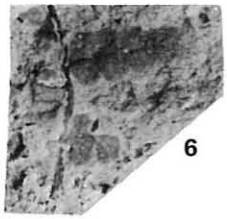
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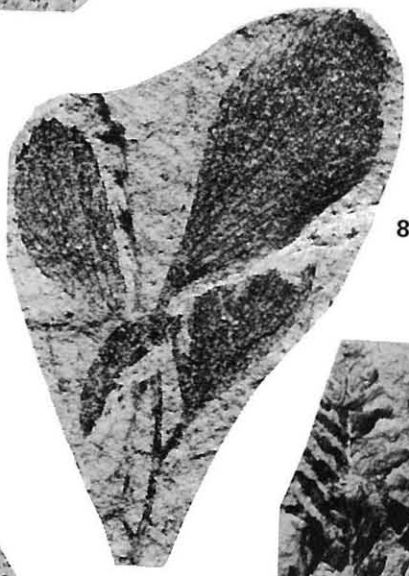
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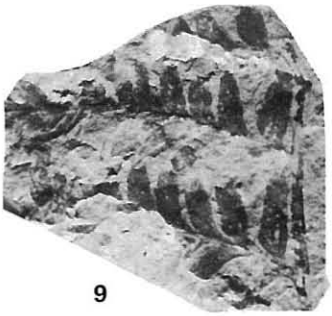
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of *Koelreuteria.* Thus, the Late Cretaceous leaves referred to *Rulac quercifolium* are better to transfer to the form genus *Sapindophyllum.*

Occurrence: Oashi, Kuji City (Sawayama Formation); coastal cliff near Tamagawa, Kuji City (Tamagawa Formation).

Collection: Hypotypes, H.U.M.P. nos. 26116–26118.

Family Vitaceae

Genus *Cissus* Linn.

Cissus marginata (Lesquereux) Brown

(pl.12, fig.7; text-fig.5-3, -4)

Cissus marginata (Lesquereux) Brown. 1962. U.S. Geol. Survey Prof. Paper (375): 79, pl.53, f.1-4, 6; pl.54, f.1-4; pl.55, f.4, 6, 7 (see synonymy).

Viburnum marginatum Lesquereux. 1878. U.S. Geol. Survey Terr. Rept. 7: 223, pl.37, f.11; pl.38, f.1-4.

Discussion: A single, rhombic leaf from the Tamagawa Formation is well-defined in tertiary venation, and is clearly glandular in the tooth apex. This fossil leaf is referred to *Cissus marginata,* which is common in the Paleocene and Late Cretaceous of North America (Brown, 1962). The Kuji specimen is somewhat similar to *Platanus cuneiformis* Krasser from the Upper Cretaceous of Bohemia, but the tooth of this specimen does not belong to the Platanoid type but to the Rosoid or the Cunonioid types as shown in Text-fig. 5–3 and 5–4. It needs to further reinvestigate the Kuji specimen whether or not assigment to the extant genus *Cissus* is acceptable.

Occurrence: Coastal cliff near Tamagawa, Kuji City (Tamagawa Formation).

Collection: Hypotype, H.U.M.P. no. 26119.

Family Rhamnaceae

Genus *Ziziphus* Mill.

Ziziphus kujiensis Tanai, sp. nov.

(pl.14, figs.5, 6; text-fig.5-5)

Description: Leaves three-plinerved, inequilaterally ovate in general shape, 4.8 to 5.5 cm long and 2.5 to 3 cm wide; apex gradually narrowed; base asymmetrically obtuse; midvein stout, nearly straight; a pair of lateral primaries stout, leaving slightly above base, making narrow angles (20°–25°) with midvein, curving arcuately, connecting with secondary vein at the two-third height from base; several secondaries diverging from midvein at right angle in the upper part of blade, brochidodromous; tertiaries branching exmedially from lateral primaries, forming loops along the margin; many slender tertiaries leaving midvein mostly at

Explanation of Plate 5

(All natural size unless otherwise stated)

Figs. 1, 2 *Glyptostrobus vachrameevii* Sveshinikova. ×2 Hypotypes, H.U.M.P. nos. 26044 (Tamagawa), 26045 (Hikage).

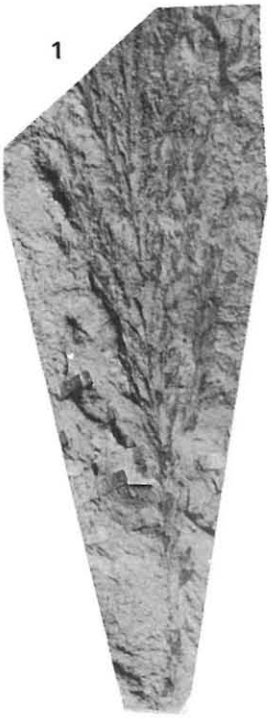
Figs. 3, 4, 10 *Protophyllocladus subintegrifolius* (Lesq.) Berry. Hypotypes, H.U.M.P. nos. 26071 (Hikage), 26072 (Hikage), 26073 (Tamagawa).

Fig. 5 *Nilssonia variabilis* Pyrnada. Hypotype, H.U.M.P. no. 26042 (Hikage).

Figs. 6, 9 *Taxodium* ? sp. ×2 H.U.M.P. nos. 26048, 26049 (Hikage).

Fig. 7 *Otozamites schenkii* (Heer) Tanai. Hypotype, H.U.M.P. no. 26041 (Kadonosawa).

Fig. 8 Showing the venation of the above specimen (no. 26041) by twice enlarging.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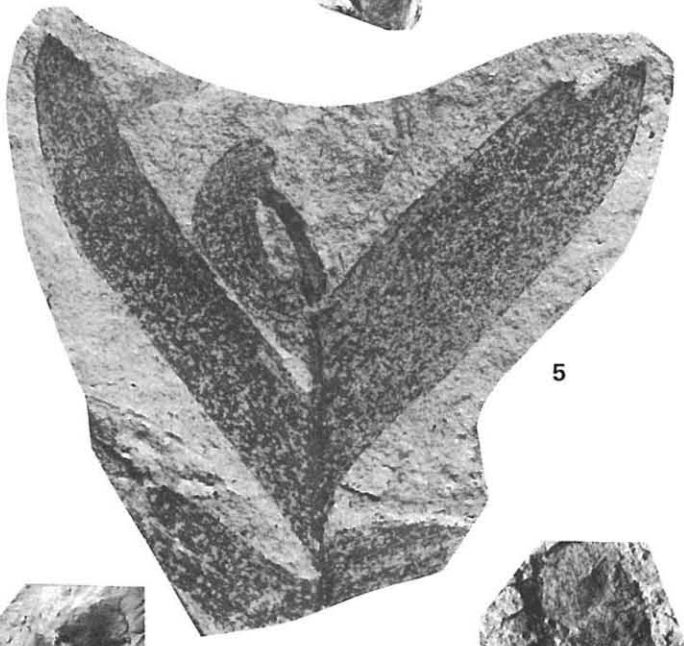
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right angles, closely spaced, branching once or twice, reaching lateral primaries; high order veins very thin, irregularly reticulate; margin finely crenato-serrate with incurved teeth which are separated by narrow acute sinus; a thin vein from marginal loop entering each tooth; petiole thick, 9 mm long.

Discussion: Several well-preserved leaves are doubtlessly referred to the genus *Ziziphus* by their characteristic venation and marginal serration. The leaves of *Ziziphus* are not rare in the Upper Cretaceous of the Northern Hemisphere, although some of them may be doubtful in generic assignment. *Z. kujiensis* is closely similar to *Z. ajatensis* Vachrameev from the Upper Cretaceous of Kazakhstan (Vachrameev, 1952) and also to *Z. rarytkinensis* Krysht. from the Upper Cretaceous of Anadyr region (Kryshtofovich, 1958), especially more close to the former.

Occurrence: Hikagezawa, Hikage, Edanarizawa and Oashi, Kuji City (Sawayama Formation).

Collection: Holotype, H.U.M.P. no. 26120; paratype no. 26121.

Family Trapaceae

Genus *Hemitrapa* Miki

Hemitrapa angulata (Newberry) Matsuo

(pl.12, figs.3, 5)

Hemitrapa angulata (Newberry) Matsuo. 1970. Trans. Proc. Palaeont. Soc. Japan, N.S. (80): 385, pl.42, f.20a; pl.43, f.22, 23 (see synonymy).

Neuropteris angulata Newberry. 1861. In Ives: Report upon the Colorado River of the West. p.131, pl.3, f.5.

Discussion: These *Trapa*-like foliages have been referred to various genera such as *Trapa* (?) *Nymphaeites, MacClintockia, Quereuxia, Nelumbites* and others. Most of the authors considered these foliages may belong to an aquatic plant. Lately Brown (1962) referred them to the extant *Trapa* on the basis of well-preserved compound foliage and fruits found from the Paleocene of the United States. However, these fruits show the characters of the extinct genus *Hemitrapa* in spindle-shape and slender appendages. As transferred by Matsuo (1970), these *Trapa*-like foliage should be referred to *Hemitrapa.* No new character could be added for this species, because the Kuji specimens are ill-preserved.

H. angulata was widely known from the Upper Cretaceous of East Asia and North America, and partly ranged up to the Palaeocene in the western United States.

Occurrence: Kadonosawa, Hishikura, Hikage and Hikagezawa Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. nos. 26037b, 26123a; no. 26121.

Genus *Carpolithes* Brongniart

Carpolithes arcticus (Heer) Hickey

(pl.14, figs.2, 3, 12)

Carpolithes arcticus (Heer) Hickey. 1977. Geol. Soc. Amer. Mem. (150): 151, pl.53, f.3-7.

Explanation of Plate 6

(Natural size)

Araucarites longifolius (Lesq.) Dorf. showing the occurrence of leafy shoots. Hypotype, H.U.M.P. no. 26050 (Kadonosawa).

Nyssa arctica Heer. 1869. Flora fossilis arctica. 4(4): 477, pl.43, f.12c; pl.50, f.5-7.
Trochodendrocarpus arcticus (Heer) Kryshtofovich. 1958. Palaeobotanika. 3: 113, pl.13, f.4 (see synonymy).
Carpites japonicus (Endo) Tanai. 1970. J. Fac. Sci. Hokkaido Univ. [4]. 14: 503, pl.15, f.5.

Discussion: These characteristic fruits, though not common, are found from both the Tamagawa and Sawayama Formations. These fruits widely known in the Upper Cretaceous and the Lower Tertiary of the Northern Hemisphere, have been referred to various genera such as *Cercidiphyllum, Trochodendron, Leguminosites, Nyssa* and others by various authors. Since these fruits were considered to represent the pod of *Cercidiphyllum* by Brown (1939), thereafter most of the authors have followed Brown's assignment. However, these fructifications are quite different from the pods of the extant *Cercidiphyllum* in the inflorescence morphology and in splitting into valves, and they were considered to belong to the extinct dicotyledonous plants (Chandler, 1961; Kryshtofovich, 1958; Mai, 1963, and others).

Kryshtofovich emphasized the marked difference of these characteristic fruits from those of *Cercidiphyllum* and *Trochodendron,* although some similarity was observed in morphology; he established a new genus *Trochodendrocarpus,* to which many specimen including the Heer's original were transferred. Krassilov (1973) described that *"Trochodendrocarpus"* may represent a extinct genus of Hamamelidaceous affinity, based on detailed discussion of the fructifications from the Upper Cretaceous of Amur region. However, the genus *Trochodendrocarpus* was unfortunately accompanied neither by type specimen nor by the description of new genus, and it is an invalid name, according to the Article 41 of the International Code of Botanical Nomenclature. Recently, Hickey (1977) transferred Heer's species, *"Nyssa arctica",* to the form genus *Carpolithes* due to lacking of its definitive evidence, though he inclined to support its affinity to the Cercidiphyllaceae.

The similar fructifications are also common through the Upper Cretaceous and the Paleogene of northern Japan. I prefer to treat the Kuji specimens as *"Carpolithes arcticus"* until the completion of a further detailed investigation.

Occurrence: Coastal cliff near Tamagawa, Kuji City (Tamagawa Formation); Hikagezawa, Hikage, Kadonosawa, Oashi and Hishikura, Kuji City (Sawayama Formation).

Collection: Hypotypes, H.U.M.P. no. 26123b–26125.

Carpolithes kujiensis Tanai, sp. nov.

(pl.12, fig.9)

Discription: Seed oval in general shape, somewhat flattened, pointed at apex, rounded at base, 5 to 6 mm long and 4 mm wide; surface ornamented by polygonal, crossing ridges.

Discussion: These small seeds were rarely found from two localities. Judging their state of preservation, seeds part may be woody, and composed of two valves. I have as yet no extant

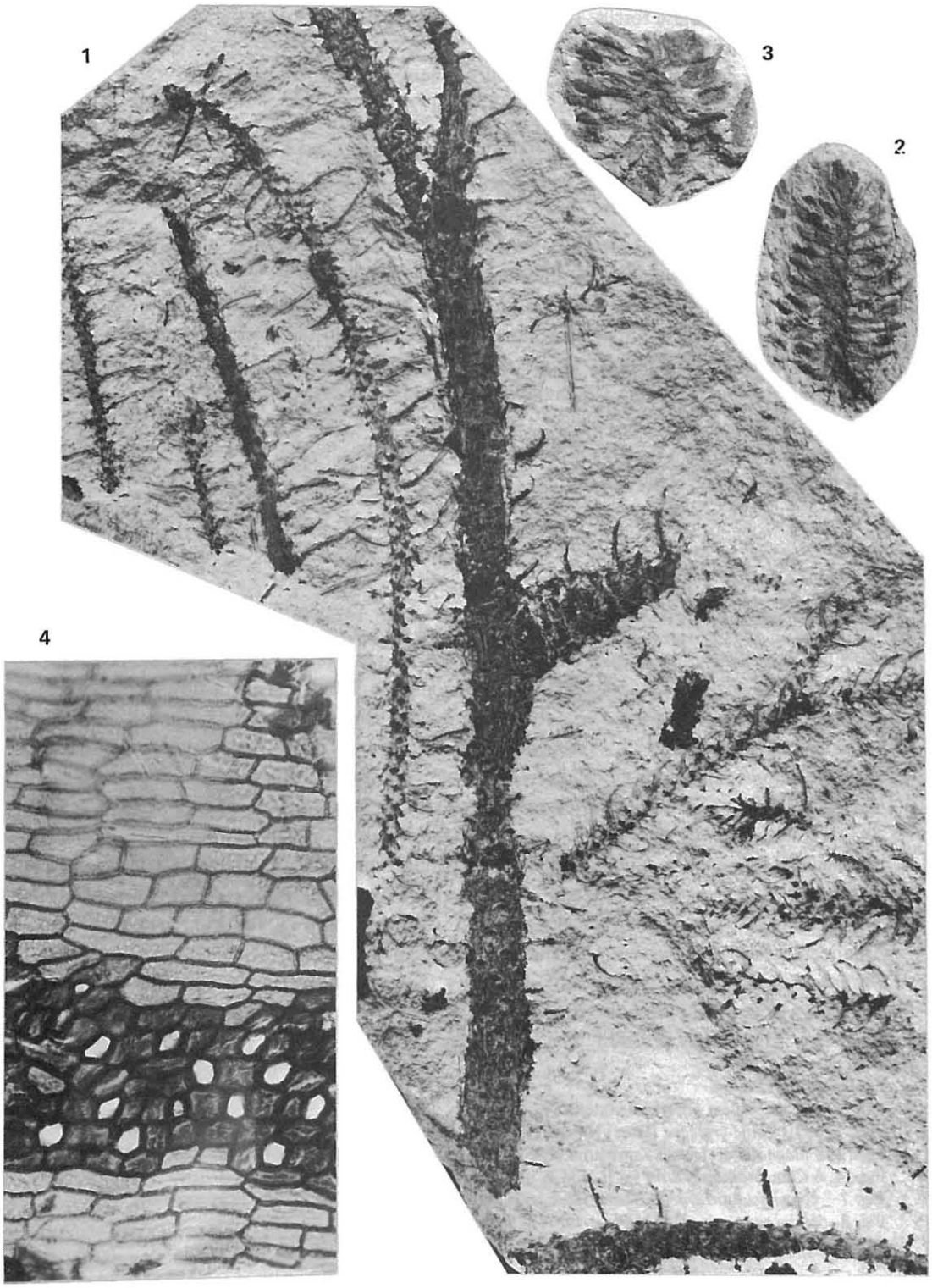
Explanation of Plate 7

(All natural size unless otherwise stated)

Fig. 1 *Araucarites longifolius* (Lesq.) Dorf. Hypotype, H.U.M.P. no. 26051 (Kadonosawa).

Figs. 2, 3 *Araucarites kujiensis* Tanai. Holotype, H.U.M.P. no. 26058 (Edanarizawa), paratype no. 26059 (Edanarizawa).

Fig. 4 *Araucarites longifolius* (Lesq.) Dorf. showing the stomatal band and epidermal cells of long leaf (cuticle from no. 26050). ×250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seeds comparable to these fossils. Those of some species of *Passiflora* show similar features in shape, size and surface ornamentation.
Occurrence: Hikage and Hikagezawa, Kuji City (Sawayama Formation).
Collection: Holotypes, H.U.M.P. nos. 26126, 26127.

Genus *Cuplicarpus* Velenovsky et Viniklar
Cuplicarpus kujiensis Tanai, sp. nov.
(pl.13, fig.5)

Description: Cupula-like specimen discoid in general outline, 1.4 cm in diameter, 4 mm in depth; outer surface covered by the imbricated bristle-like bracts.
Discussion: A single specimen from the Sawayama formation is closely similar to the acorn of the genus *Quercus,* but it is too ill-preserved to ascertain the generic relationship. This specimen somewhat resembles *Cupulicarpus fechtneri* Velenov. et Viniklar from the Cretaceous flora of Bohemia (Velenovsky & Veniklar, 1929), but differs in the ornamentation of outer margin.
Occurrence: Kadonosawa, Kuji City (Sawayama Formation).
Collection: Holotype, H.U.M.P. no. 26128.

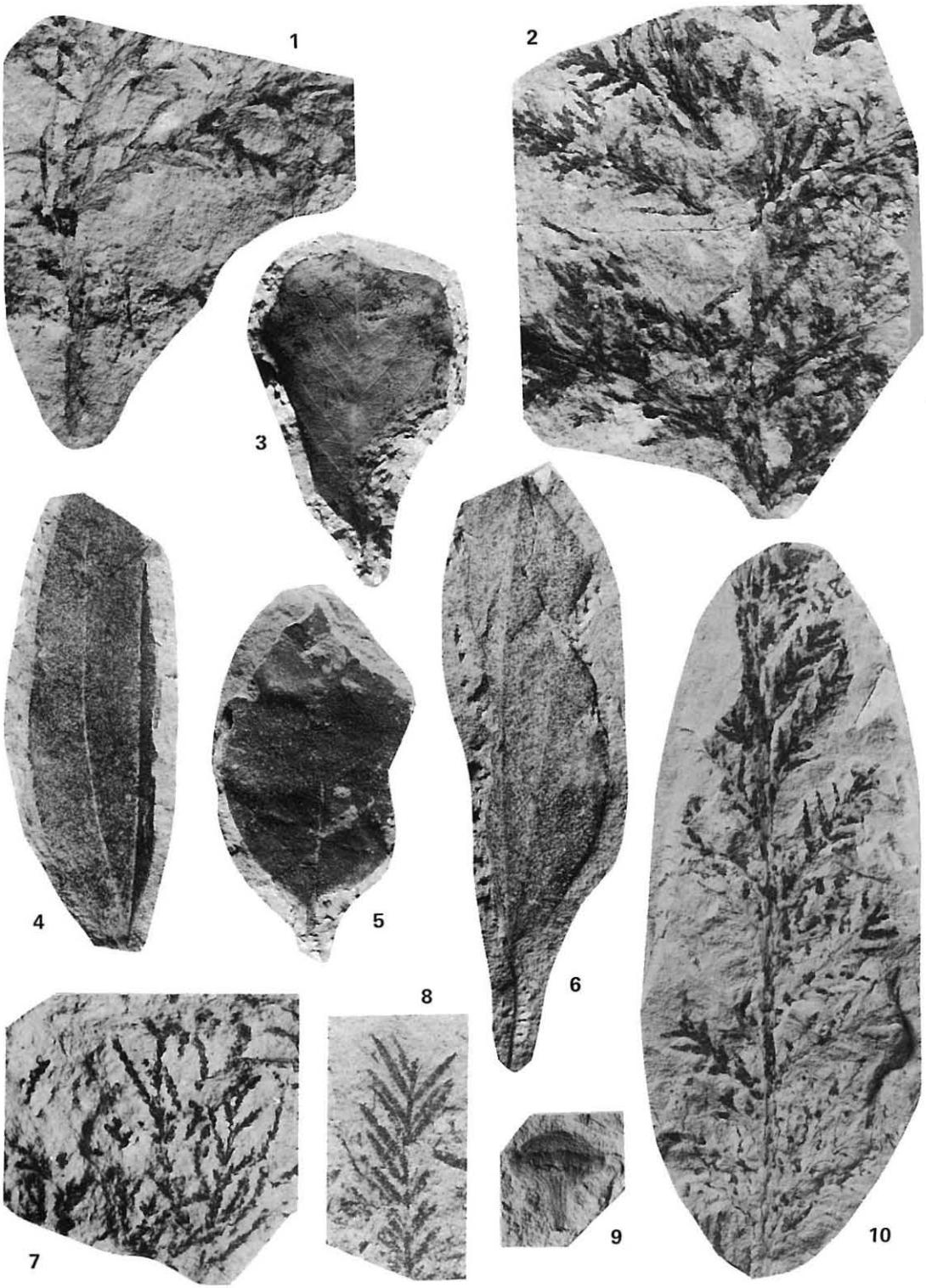
Genus *Debeya* Miquel
Debeya tikhonovichii (Krysht.) Krassilov
(pl.14, figs.9, 10)

Debeya tikhonovichii (Krysht.) Krassilov. 1973. Palaeontogr. [B] .142: 108, pl.21, f.26-34.
Krassilov. 1973. Fossil floras and phytostratigraphy of the Far East. p.70, pl.18, f.1-3; pl.19, f.1-6.
Aralia tikhonovichii Kryshtofovich. J. Coll. Sci. Imp. Univ. Tokyo. 40(8): 57, text-f.13.

Discussion: Several detached leaflets and an incomplete, lobed leaf (probably trilobed) are referable to *Debeya tikhonovichii* in their venation and marginal characters. Though the Kuji specimens are ill-preserved, the numerous secondary veins are very slender and comptodromous, and form elongate, irregular networks with intersecondaries. The marginal teeth are fine with upwardly pointed tips, which are clearly glandular.

D. tikhonovichii was known from the Senonian flora of Saghalien; its modern relationship is unknown. Knobloch (1964) recognized many species of *Debeya* on the basis of Cretaceous leaves of Europe and North America previously referred to *Araliaephyllum* and *Dewalquea.* The Saghalien species is distinguishable from all the European or North American species in the secondary venation and marginal serration.
Occurrence: Kadonosawa and Oashi, Kuji City (Sawayama Formation); coastal cliff near Tamagawa (Tamagawa Formation).
Collection: Hypotypes, H.U.M.P. nos. 26129, 26130.

Explanation of Plate 8
(All natural size unless otherwise stated)
Figs. 1, 2, 10 *Thuja cretacea* (Heer) Newberry. Hypotypes, H.U.M.P. nos. 26063-26065 (Oashi).
Figs. 3, 5 *Magnolia* cf. *lakesii* Knowlton. Hypotypes, H.U.M.P. nos. 26079, 26080 (Tamagawa).
Figs. 4, 6 *Cinnamomophyllum* sp. H.U.M.P. nos. 26082, 26083 (Hikage).
Fig. 7 *Cyparissidium gracile* (Heer) Heer. x1.3 Hypotype, H.U.M.P. no. 26069 (Kadonosawa).
Fig. 8 *Metasequoia* sp. H.U.M.P. no. 26047 (Kadonosawa).
Fig. 9 *Dammarites borealis* (Heer) Seward. x1.5 Hypotype, NSM-PP-16799 (Utsume).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Genus *Dicotylophyllum* Saporta

Dicotylophyllum iwateanum Tanai, sp. nov.

(pl.14, figs.7, 11; text-fig.5-1, -2)

Discription: Leaves lanceolate in general shape, 5 to 8 cm long (estimated) and 1.7 to 2.7 cm wide; apex attenuate with long-tapered tip; base cuneate to decurrently cuneate; margin finely serrate with acute teeth separated by rounded sinus; midvein stout, nearly straight; secondary veins very thin, numerous, diverging from the midvein at about 60°–65° and 5–8 mm at intervals, gently curving up, joining superadjacent secondary at acute angle, forming large marginal loops, enclosing smaller loops of the tertiary and quaternary veins along the margin; intersecondary veins thin, somewhat oblique or nearly parallel to the secondaries, sometimes forking; tertiary veins in costal areas very thin, irregularly reticulate; higher order veins indistinct; a branch from the marginal loops directly entering teeth, accompanied by high order laterals forming a series of brochidodromous loops; petiole rather slender, more than 1.5 cm long.

Discussion: These leaves commonly found in the Sawayama Formation, show the characteristic margin and semibrochidodromous venation, though they are mostly fragmentary. Leaves of such type have been frequently reported from the Upper Cretaceous of East Asia and North America, referring to the various genera such as *Celastrus, Juglans, Myrica* (or *Myriciphyllum*) and *Ternstroemites.* However, these modern relationships are based mostly on uncertain characters of the foliage. The Kuji specimens are difficult to refer to the modern genus, because they are lacking in the definite base of taxonomical comparison, due to the ill-preservation.

The Kuji specimens are similar superficially to *Myriciphyllum yokoyama* (Krysht.) Krassilov from the Senonian flora of Saghalien (Krassilov, 1973), and *Juglans newberryi* Knowlton from the Uppermost Cretaceous of Wyoming (Dorf. 1938).

Occurrence: Hikage, Oashi and Kadonosawa, Kuji City (Sawayama Formation); coastal cliff near Tamagawa (Tamagawa Formation).

Collection: Holotype, H.U.M.P. no. 26131a; hypotypes nos. 26131b–26132; nos. 26133, 26134.

Genus *Rogersia* Fontaine

Rogersia angustifolia Fontaine

(pl.13, fig.1; text-fig.5-6)

Rogersia angustifolia Fontaine. 1889. U.S. Geol. Survey Monogr. 15: 288, pl.143, f.2; pl.149, f.4, 8; pl.150, f.2-7.

Explanation of Plate 9

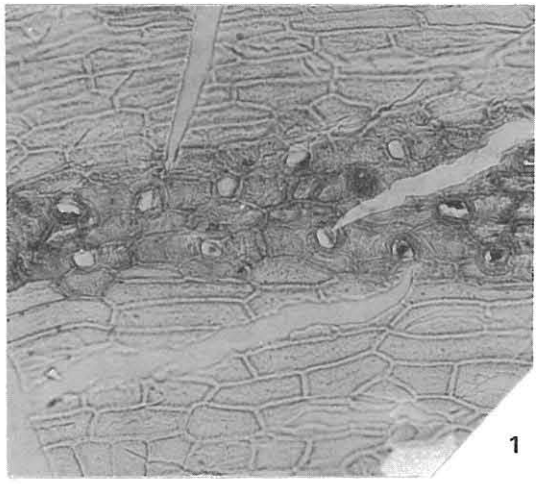
(All figures ×250)

Fig. 1 *A raucarites longifolius* (Lesq.) Dorf. showing the stomata and epidermal cells of long leaf (cuticle ? from no. 26051).

Figs. 2, 3 *Thuja cretacea* (Heer) Newberry. showing the stomata and epidermal cells (cuticle from no. 26065).

Figs. 4, 5 *Otozamites schenkii* (Heer) Tanai. showing the epidermal cells (cuticle from no. 26041).

Fig. 6 *Protophyllocladus subintegrifolius* (Lesq.) Berry. showing the epidermal cells (cuticle from no. 26073).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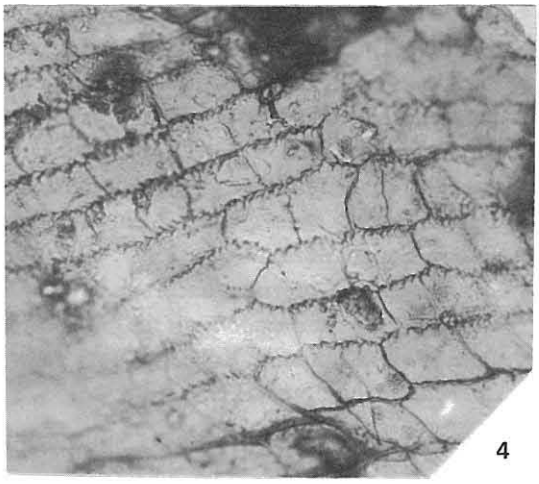
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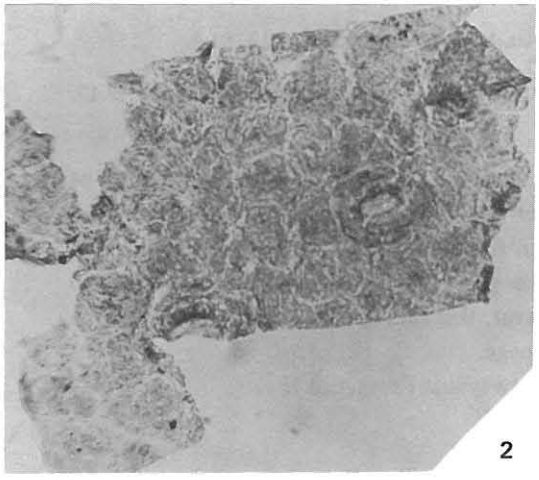
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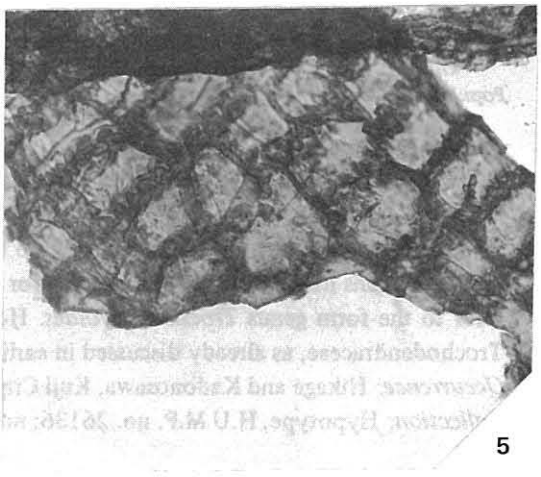
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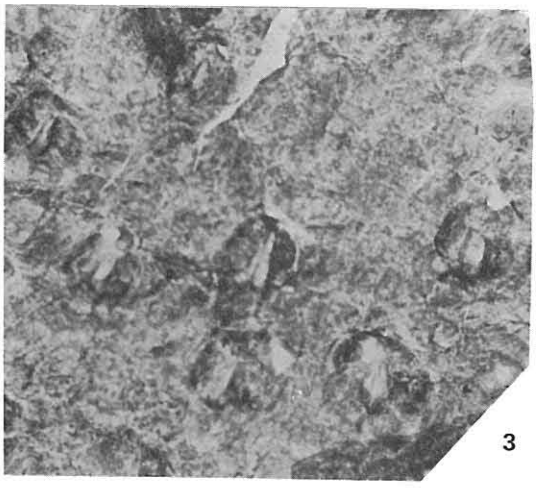
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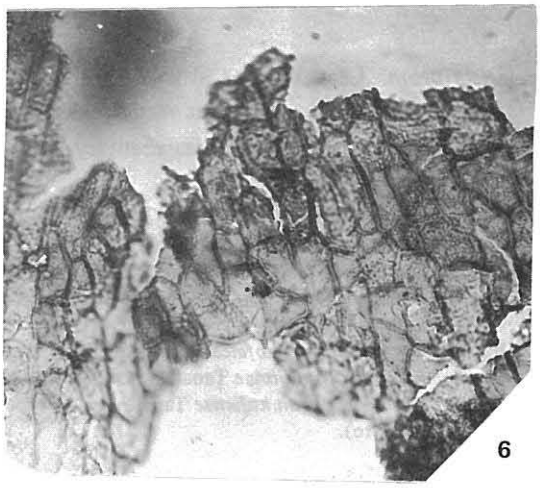
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Discussion: A single incomplete leaf from the Tamagawa Formation shows a characteristic venation. The midrib is very stout and prominent on the undersurface, while the secondary veins are slender but distinct, leaving the midrib at an acute angle, and gently arise up with somewhat flexuous course, nearly parallel to the margin. The secondary veins send off obliquely branches, which form eleongate-polygonal areoles along the margin. These venation characters indicate that our incomplete leaf is referable to the genus *Rogersia,* especially to *R. angustifolia,* which was originally described from the Potomac flora of the eastern United States.

The genus *Rogersia* is uncertain in the modern botanical affinity, but is was suggested to resemble the genus *Persoonia* of the Proteaceae by Fontaine (1889).

Occurrence: Kunitan-B, Kuji City (Tamagawa Formation).

Collection: Hypotype, H.U.M.P. no. 26135.

Genus *Trochodendroides* Berry

Trochodendroides arctica (Heer) Berry

(pl.14, fig.4)

Trochodendroides arctica (Heer) Berry. 1926. Candada Nat. Mus. Bull. (42): 109. pl.13, f.1-4.
Oishi. 1940. J. Fac. Sci. Hokkaido Univ. [4]. 5: 417, pl.48, f.8.

Populus arctica Heer. 1968. Flora fossilis arctica. 1: 100, pl.4, f.6a, 7; pl.5; pl.6, f.5, 6; pl.8, f.5, 6; pl.17, f.5a.
Endo. 1925. Sci. Rep. Tohoku Univ. [2]. 7: 68, pl.17, f.12, 17.

Discussion: These ill-preserved leaves from two localities are superficially similar to those of the extant *Populus* or *Cercidiphyllum,* and such leaves from the Upper Cretaceous and Paleogene of the Northern Hemisphere have been frequently referred to these genera. The Kuji specimens have no sufficient evidence for these generic assigment, and are here better to refer to the form genus *Trochodendroides.* However, this form-genus is not related with the Trochodendraceae, as already discussed in earlier page.

Occurrence: Hikage and Kadonosawa, Kuji City (Sawayama Formation).

Collection: Hypotype, H.U.M.P. no. 26136; no.26137.

Genus *Monocotylophyllum* Reid et Chandler

Monocotylophyllum sp.

(pl.14, fig.8)

Discription: Leaves linear, 4 to 23 mm wide, unknown in length, provided with numerous fine, parallel veins; cross veins very slender, transversed to stout veins.

Discussion: A number of fragmentary linear leaves were collected from the Sawayama

Explanation of Plate 10

(All natural size unless otherwise stated)

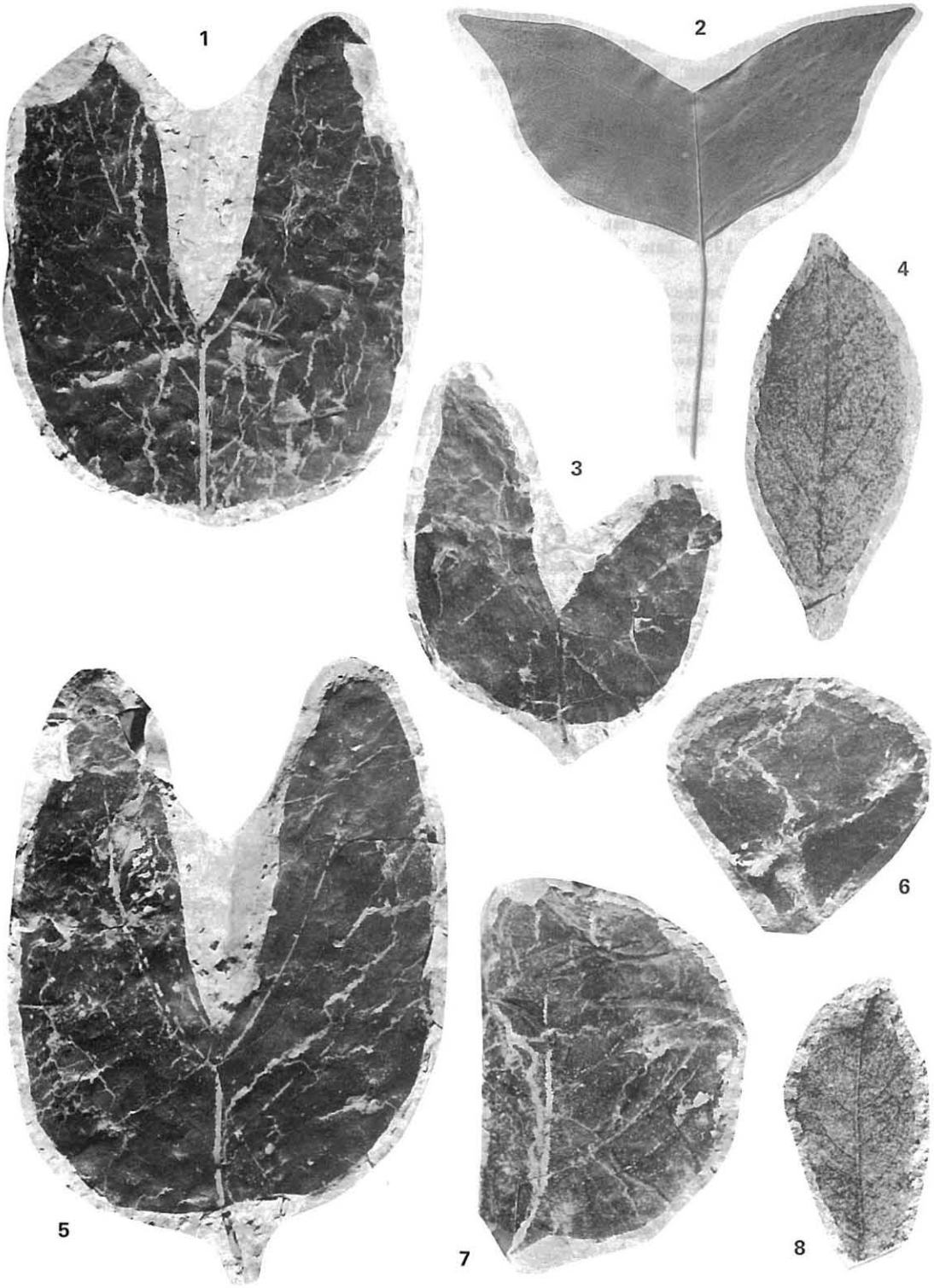
Figs. 1, 3 *Liriodendron iijimae* Tanai. Paratypes, H.U.M.P. nos. 26075, 26076 (Hikage).

Fig. 2 *Liriodendron tulipifera* Linn. A living leaf for comparison, collected at the Botanic Garden of Hokkaido University.

Fig. 4, 8 *Dryophyllum subfalcatum* Lesquereux. Hypotypes, H.U.M.P. nos. 26100, 26101 (Kadonosawa).

Fig. 5 *Liriodendron iijimae* Tanai. Holotype, H.U.M.P. no. 26074 (Hikage).

Fig. 6, 7 *Trochodendron kujiense* Tanai. x2 Holotype, H.U.M.P. no. 26095 (Minato), hypotype no. 26096 (Minato).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Formation, and they are doubtlessly referable monocotyledonous leaves. However, they are too fragmentary to assign their generic status.

Occurrence: Sawayama, Hikage, Hikagezawa, Oashi, Kadonosawa and Minato, Kuji City (Sawayama Formation).

Collection: H.U.M.P. nos. 26138, 26139, 26140.

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Explanation of Plate 11

(All natural size unless otherwise stated)

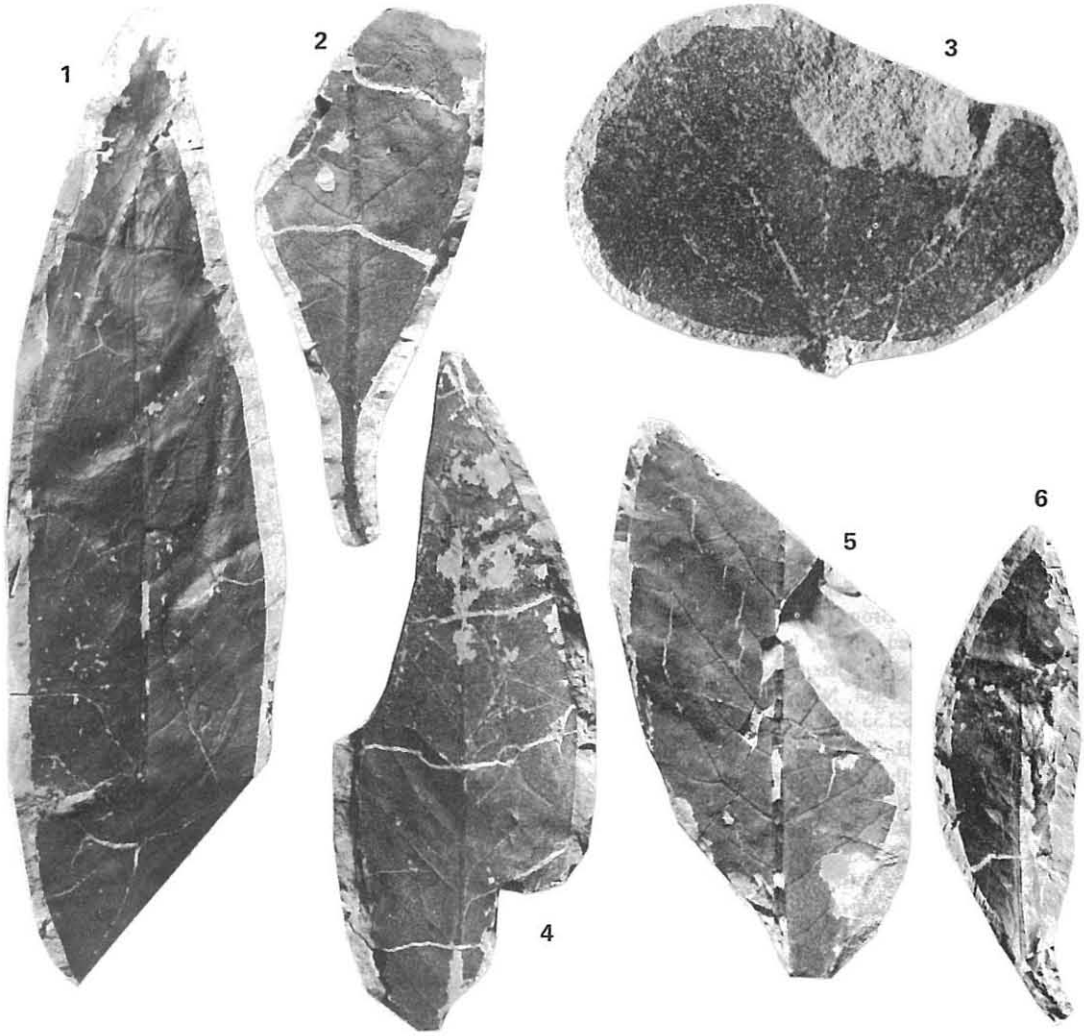
Fig. 1 *Laurophyllum kujianum* Tanai. Holotype, H.U.M.P. no. 26085 (Hikage).

Figs. 2, 4, 6 *Laurophyllum kujianum* Tanai. Paratypes, H.U.M.P. nos. 26086-26088 (Hikage).

Fig. 3 *Menispermites kujiensis* Tanai. Hypotype, H.U.M.P. no. 26093 (Kadonosawa).

Fig. 5 *Laurophyllum kujianum* Tanai. Hypotype, H.U.M.P. no. 26089 (Hikage).

Figs. 7, 8 *Laurophyllum kujianum* Tanai. ×250 (cuticle from the paratype no. 26087. Fig. 7 showing the epidermal cells and hair-base of the upper cuticle. Fig. 8 showing stomata, epidermal cells and cells on vein of the lower cuticle.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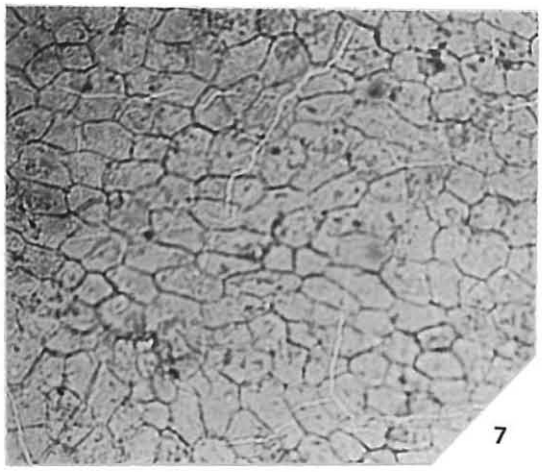
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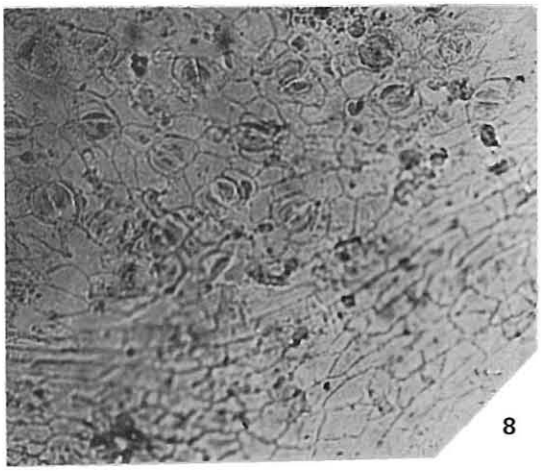
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Explanation of Plate 12

(All natural size unless otherwise stated)

Figs. 1, 2 *Menispermites kujiensis* Tanai. Holotype, H.U.M.P. no. 26092 (Oashi), hypotype no. 26094 (Kadonosawa).

Figs. 3, 5 *Hemitrapa angulata* (Newb.) Matsuo. x2 Hypotypes, H.U.M.P. nos. 26037b, 26123a (Kadonosawa).

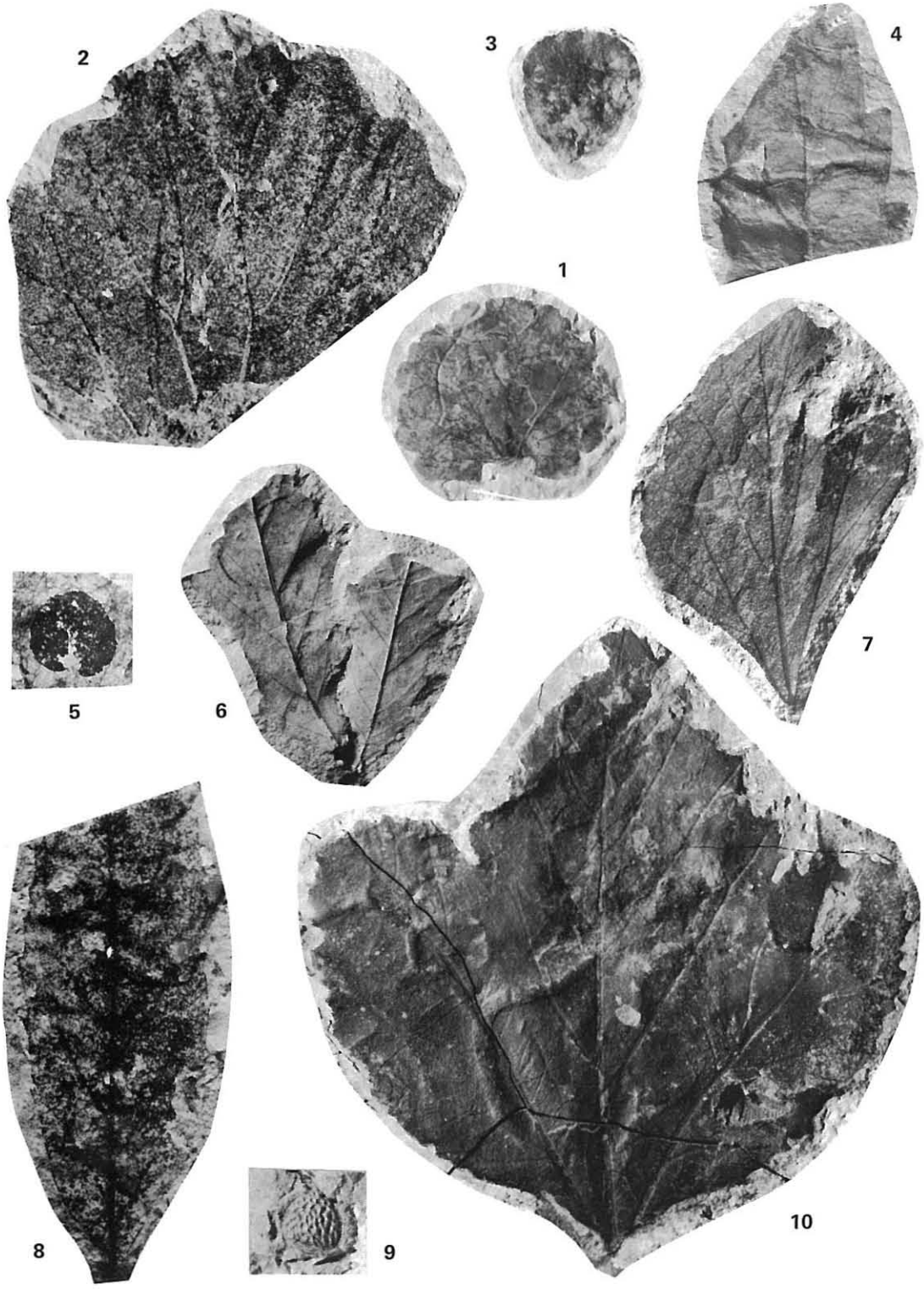
Figs. 4, 6 *Sapindophyllum quercifolium* (Hollick) Tanai. Hypotypes, H.U.M.P. nos. 26116, 26117 (Oashi). fig. 4 x2, fig. 6 x1.5.

Fig. 7 *Cissus marginata* (Lesq.) Brown. Hypotype, H.U.M.P. no. 26119 (Tamagawa).

Fig. 8 *Dryophyllum subfalcatum* Lesquereux. Hypotype, H.U.M.P. no. 26102 (Kadonosawa).

Fig. 9 *Carpolithes kujiensis* Tanai. x2 Holotype, H.U.M.P. no. 26126 (Hikage).

Fig. 10 *Platanus cuneifolia* (Bronn) Kryshtofovich. Hypotype, H.U.M.P. no. 26097 (Tamagawa).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Explanation of Plate 13

(All natural size unless otherwise stated)

Fig. 1 *Rogersia angustifolia* Fontaine. ×1.5 Hypotype, H.U.M.P. no. 26135 (Kunitan-B).
Fig. 2 *Dillenites lanceolatus* Tanai. ×1.5 Holotype, H.U.M.P. no. 26105 (Oashi).
Fig. 3 *Dillenites lanceolatus* Tanai. Paratype, H.U.M.P. no. 26106 (Oashi).
Fig. 4 *Salix lancensis* Berry. ×1.5 Hypotype, H.U.M.P. no. 26107 (Kadonosawa).
Fig. 5 *Cuplicarpus kujiensis* Tanai. ×2 Holotype, H.U.M.P. no. 26108 (Kadonosawa).
Fig. 6–8 *Salix lancensis* Berry. Hypotypes, H.U.M.P. nos. 26118-26120 (Kadonosawa).
Figs. 9, 10 *Platanus cuneifolia* (Bronn) Kryshtofovich. Hypotype, H.U.M.P. no. 26098 (Tamagawa). Fig. 10 showing the epidermal cells and a trichome base of the upper cuticle (×250).


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Explanation of Plate 14

(All natural size unless otherwise stated).

Fig. 1 *Sapindophyllum quercifolium* (Hollick) Tanai. x2 Hypotype, H.U.M.P. no. 26118 (Tamagawa).

Figs. 2, 3, 12 *Carpolithes arcticus* (Heer) Hickey. x2 Hypotypes, H.U.M.P. nos. 26123b (Kadonosawa), 26124 (Tamagawa) 26125 (Tamagawa).

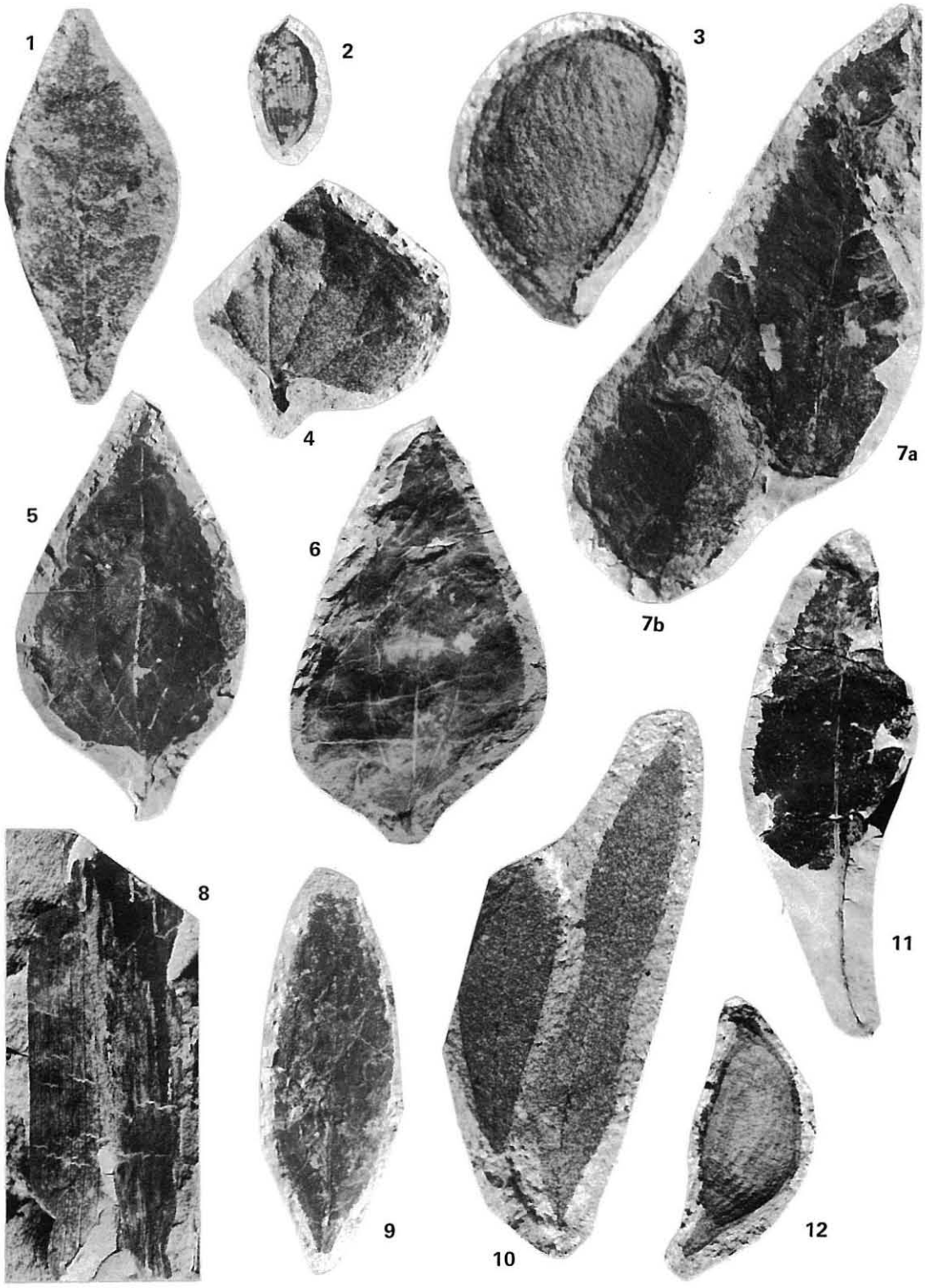
Fig. 4 *Trochodendroides arctica* (Heer) Berry. Hypotype, H.U.M.P. no. 26136 (Kadonosawa).

Figs. 5, 6 *Ziziphus kujiensis* Tanai. Holotype, H.U.M.P. no. 26120 (Hikage), paratype no. 26121 (Hikagezawa).

Figs. 7, 11 *Dicotylophyllum iwateanum* Tanai. Holotype (fig. 7a), H.U.M.P. no. 26131a, hypotypes nos. 26131b, 26132 (Oashi).

Fig. 8 *Monocotylophyllum* sp. H.U.M.P. no. 26138 (Hikage).

Figs. 9, 10 *Debeya tikhonovichii* (Krysht.) Krassilov. fig. 9 x1, fig. 10 x2. Hypotypes, H.U.M.P. nos. 26129 (Oashi), 26130 (Kadonosawa).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