92. *The Climatic Conditions of the Eocene Woodwardia Zone, Ishikari Coalfield, Hokkaido, with Description of Ficus eowightiana Endo, n. sp.*

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In the southern (Yubari) division of the Ishikari coalfield, the Palaeogene coal-bearing Ishikari Group¹⁾ consists of the following five formations, in descending order:

Poronai formation (Eocene)

— Unconformity —

1. Ikushunbetsu coal-bearing formation
2. Wakkanappe formation

— Unconformity? —

3. Yubari coal-bearing formation
2. Horokabetsu formation

1. Noborikawa coal-bearing formation

— Unconformity —

Hakobuchi formation (Upper Cretaceous)

Of them, the Ikushunbetsu formation, especially its lower part (*Woodwardia* zone) is very rich in plant fossils, and the writer could discriminate about 62 species listed below:

Table I. Fossil plants from the *Woodwardia* zone

<i>Equisetum ezoensis</i> Endo	<i>Cercidiphyllum arcticum</i> Brown
<i>Dennstaedtia americana</i> Knowlton	<i>Cercidiphyllum elongatum</i> Brown
<i>Onoclea hebraidica</i> Gardner	<i>Cercidiphyllum paleojaponicum</i> Endo
<i>Osmunda regalis</i> L. var. ?	<i>Cercis hokkaidoensis</i> Endo
<i>Woodwardia japonica</i> Sw. var.	<i>Celastrus typica</i> MacGinitie
<i>eocenica</i> Endo (new var.)	<i>Celastrus borealis</i> Heer
<i>Cephalotaxus yubariensis</i> Endo	<i>Corylus FASTERI</i> Ward
<i>Glyptostrobus europaeus</i> Heer	<i>Diospyros protokaki</i> Endo
<i>Sequoia disticha</i> Heer	<i>Dombeyopsis yubariensis</i> Endo
<i>Sequoia Langsdorfii</i> Brongniart	<i>Dryophyllum yubariensis</i> Endo
<i>Taxodium distichum miocenum</i> Heer	<i>Dryophyllum</i> sp.
<i>Geonimites yubariensis</i> Endo	<i>Fagus Antipofii</i> Abich
<i>Musophyllum complicatum</i> Lesquereux	<i>Fagus</i> sp.
<i>Acer Arcticum</i> Heer	<i>Ficus eowightiana</i> Endo
<i>Alnus Kefersteinii</i> (Goepfert)	<i>Ficus ezoensis</i> Endo
<i>Alnus paleojaponica</i> Endo	<i>Ficus columbioides</i> Endo
<i>Betula Brongniarti</i> Ettingshausen	<i>Ficus occidentalis</i> Lesquereux
<i>Betula paleomaximowicziana</i> Endo	<i>Ficus planicostata</i> Lesquereux
<i>Broussonetia Imai</i> Endo	<i>Ficus planifolioides</i> Endo
<i>Carpinus Shimokawarai</i> Endo	<i>Ficus tennesseensis</i> Lesquereux
<i>Carpinus Takaoi</i> Endo	<i>Ficus tiliacifolia</i> Heer

<i>Ficus yubariensis</i> Endo	<i>Ptelea eocenica</i> Endo
<i>Grewiopsis yubariensis</i> Endo	<i>Pyrus yubariensis</i> Endo
<i>Juglans denveriana</i> Knowlton	<i>Rhamnus protoutilis</i> Endo
<i>Koelreuteria eocenica</i> Endo	<i>Sassafras alaskanum</i> Hollick
<i>Liquidambar protoformosana</i> Endo	<i>Sassafras yubariensis</i> Endo
<i>Magnolia protokobus</i> Endo	<i>Styrax protobassia</i> Endo
<i>Magnolia</i> sp.	<i>Tilia eo-japonica</i> Endo
<i>Melastomites quinquinervis</i> Heer	<i>Ulmus nipponica</i> Endo
<i>Platanus aceroides</i> (Goepp.) Subspecies	<i>Viburnum Nordenskiöldi</i> Heer
<i>Yubariensis</i> Endo	<i>Viburnum paleowightii</i> Endo
<i>Populus grandifolia</i> Endo	<i>Viburnum protoerosum</i> Endo

The greater part of the plant remains are impressions of tree-leaves of the genera same with those now growing in the tropical, temperate and frigid zones of East Asia, and the present fossil flora bears an aspect in its constitution closely related to the recent one of central Kyushu.

In the southern part of the Kumamoto city, central Kyushu, there exist many beautiful forests of deciduous trees and ferns growing luxuriantly, and the recent flora of this tract has lately been studied by Kanjiro Mayehara in detail (Table II); it is somewhat similar to and reminds one strongly of the ancient flora of the *Woodwardia* zone.

Table II. Selected list of plants living in the southern tract of Kumamoto

<i>Dennstaedtia Wilfordii</i> Koidzumi	<i>Ficus Wightiana</i> Wall.
<i>Woodwardia japonica</i> Smith	<i>Ficus Thunbergii</i> Max.
<i>Woodwardia orientalis</i> Sw.	<i>Cercidiphyllum japonicum</i> S. et Z.
<i>Osmunda japonica</i> Thunb.	<i>Mallotus japonicus</i> Mull. Arg.
<i>Cephalotaxus Harringtonia</i> Koch	<i>Magnolia salicifolia</i> Max.
<i>Celtis jessoensis</i> Koidzumi	<i>Celastrus punctatus</i> Thunb.
<i>Fagus crenata</i> Bl.	<i>Ampelopsis heterophylla</i> S. et Z.
<i>Ulmus parvifolia</i> Jacq.	<i>Tilia japonica</i> Simk.
<i>Broussonetia Kaempferi</i> Sieb	<i>Hibiscus hamabo</i> S. et Z.
<i>Ficus Pumila</i> Linn.	<i>Camellia Japonica</i> Linn.
<i>Ficus erecta</i> Thunb.	<i>Marlea platanifolia</i> S. et Z.
<i>Ficus nipponica</i> Fr. et Sav.	<i>Cornus controversa</i> Hemsl.

(Besides, there are many species of the genera, *Salix*, *Carpinus*, *Quercus*, *prunus* and of the families, Lauraceae, Aceraceae, Caprifoliaceae, etc.)

The most conspicuous species of the fossil flora is *Woodwardia japonica* Sw. var. *eocenica* Endo, n. var.,¹⁾ since its remains are most abundant. It belongs to the group of *Woodwardia virginica* and is an ally of *W. japonica* Sw. now thriving only in the warm-temperate zone of southern Japan (Ryukyu Islands, Kyushu, southern Shikoku), beside Formosa. In general, *Woodwardia* is a member of warm temperate flora with a narrow geographical range. *W. orientalis* Sm. is another most common fern of southern, warm temperate zone of Japan; the northern limit of its distribution is the sea cliffs of

the Pacific coast at Iwama, near the town Ueda, southern Fukushima Prefecture. This locality is a rare warm place, exceptionally warm even in winter, and *W. orientalis* grows there luxuriantly in large colonies.

Broussonetia Imai is another characteristic species of the *Woodwardia* zone; it is very similar to *B. Kaempferi* Sieb. living in the warm temperate zone of Japan.

Ficus eowightiana Endo resembles so closely *F. wightiana* Wall. of the present day, particularly in the characteristic impression of its peduncular base, as if the former being the direct ancestor of the latter.

There are now about 700 species of the genus *Ficus* in the world, and a few of them are growing in southern Japan. A. G. Nathorst⁹⁾ once distinguished three climatic zones in Japan referring to the plant-distribution, namely, the *Ficus wightiana*-, *Pinus thunbergi*-, and *Fagus crenata* zones, the first occupying the southernmost part of the Japanese Islands, the second northern Kyushu, Shikoku and southern Honshu, and the third northern Honshu and southern Hokkaido. His *Ficus wightiana* zone just corresponds to the warm temperate zone. *Ficus eowightiana*, like *F. wightiana*, may serve as an indicator of the warm temperate climate under which the fossil flora of the *Woodwardia* zone once existed.

Next, the leaf margin of dicotyledonous trees seems to depend much on climatic conditions. In general, the percentage of the number of species of trees with entire leaf margin, to the total number of them increases rapidly from the frigid forest zone, through the temperate and warm temperate forest zones to the tropical forest zone, just in the opposite sense with the trees having duplicately serrate leaf margin. This percentage hardly amounts to 8 in northern Hokkaido of the frigid forest zone, while it attains 12 in southern Hokkaido and 46 in the southernmost Kyushu around Kagoshima of the warm temperate forest zone.

The annexed Table III shows the percentage of the species of dicotyledonous trees with entire and double-serrate leaf margin respectively to the total number of them at various districts in Japan

Table III

	Entire	Double-serrate
Micronesia ⁴⁾ and Philippines ¹³⁾	90%	0%
Ryugamitsu near Kagoshima city ⁸⁾	46	2
Southern Kumamoto Prefecture ⁷⁾	33	12
Sendai city, Miyagi Prefecture ¹²⁾	21	14
Near Sapporo city, Hokkaido ⁵⁾	12	27
Tokyo University forest, Chichibu, Kwanto Mts.	15	38

and those of the Micronesia and the Philippines for comparison.

The present writer could discriminate about 50 species of dicotyledonous plants in the abundant fossil leaves obtained from the *Woodwardia* zone, and noticed that 35% of them possessed leaves of entire margin and 14% leaves of double-serrate margin. The percentages approach closely those of the modern forests of southern Kumamoto.

Plant-growth much depends on climatological factors, especially temperature and humidity; the climate in the life-time of the fossil flora of the *Woodwardia* zone may approximately inferred from that of the Kumamoto district of the present day. The temperature and humidity, 1933-1950, recorded at Kumamoto, are quoted below from "Climate of Japan" 1958.¹⁰⁾

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Temperature(°C)	Mean	4.3	5.3	8.9	14.1	18.5	22.3	26.4	27.0	23.2	17.1	11.7	5.8	15.5
	Max.	9.9	11.1	15.1	20.7	24.9	27.6	31.3	32.6	28.9	23.8	18.3	12.7	21.4
	Min.	-0.7	0.1	2.9	7.7	12.7	17.5	22.5	22.7	18.6	11.3	5.8	1.4	10.2
Relat. Humidity (%)		75	73	71	73	75	78	81	78	79	76	77	77	76
Rainfall amount (mm)		49	74	114	148	161	321	312	165	174	91	75	73	1757

It is almost certain that the fossil flora of the *Woodwardia* zone enjoyed a warm temperate climate during life.

Description

Ficus eowightiana Endo, n. sp.

Figs. 1-3

Description: Leaves ovate lanceolate, $14\pm$ cm long, $6.5\pm$ cm wide. Midrib straight and stout, with two acrodromatic basal secondaries; other secondaries in $6\pm$ pairs, curving upwards and looping along near-margin, with veinlets between Tertiaries and quaternaries forming net-works with the others. Petiole long $4\pm$ cm. Branchlets with many characteristic impressions or concave peduncle-base, $0.4\pm$ mm in diameter, with trace of 7 or more vascular bundles. Texture thick and coriaceous.

Remarks: The fossil leaves are quite similar to those of existing *Ficus wightiana* Wall., which is the most characteristic species of Japan growing in the warm temperate region of southern Kyushu and southern Shikoku. The former are larger than the latter and have the secondary veins less in number. The branchlets have many impressions of peduncle-base, which are quite identical with those of the living species. *F. eowightiana* may be the remote ancestor of *F. wightiana*.

Fig. 1. *Ficus eowightiana* Endo $\times$ ca. 1. Fig. 2. *Ficus eowightiana* Endo $\times$ ca. 1. Restored from Fig. 1. Fig. 3. Peduncular base impression from *Ficus eowightiana* Endo $\times$ ca. 3.
Locality: Kakuda coal-field, Kuriyama-machi, Yubari-gori, Hokkaido.

Localities: Kakuda coal-mines, Kuriyama-machi, Yubari-gun, Hokkaido.

Geological occurrence: *Woodwardia* zone of the Ikushunbetsu formation, Ishikari Group; Eocene.

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