Bull. Natn. Sci. Mus., Tokyo, Ser. C, **14** (3), pp. 103–133, September 22, 1988

Late Jurassic Plants from the Tochikubo Formation (Oxfordian), Somanakamura Group, in the Outer Zone of Northeast Japan*. I

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(Communicated by Ikuwo OBATA)

Abstract This paper deals with the systematic description of fossil plants from the Oxfordian Tochikubo Formation of the Somanakamura Group (Middle to Late Jurassic), which is mostly of marine origin and is distributed in the eastern part of Fukushima Prefecture, in the Outer Zone of Northeast Japan. We described 32 taxa consisting of 10 ferns, 10 bennettitaleans including 5 forms of *Ptilophyllum*, 7 cycadaleans, 1 unclassified cycadophyte, 3 conifers and 1 unclassified reproductive organ (seed). This plant-assemblage is characterized by the abundant occurrence of *Zamites*, *Ptilophyllum* and *Nilssonia*. While no ginkgoalean, czekanowskialean and *Podozamites* have been found.

This plant-assemblage is obviously of the Ryoseki-type in floristic composition and holds important stratigraphic and phytogeographic position along the Circum Pacific regions.

Foreword

Fossil plants are quite abundant in the Tochikubo Formation of the Somanakamura Group mostly of marine origin, exposed in the eastern part of Fukushima Prefecture (Fig. 1A). The geology and biostratigraphy of the Somanakamura Group were studied in detail by MORI (1963) (Table 1).

The following fossil plants were first described by OISHI (1940) from the Somanakamura Group (*; accepted in this work. **; revised in this work and revised names are shown at the right respectively):

Sphenopteris elegans (YOKOYAMA) OISHI* (Zusahara=Jisahara; pl. 8, figs. 2–3)
S. goepperti DUNKER (Horisakabashi and Zusahara)
S. pinnatifida (FONTAINE) OISHI (Zusahara; pl. 9, fig. 1)
Cladophlebis denticulata (BRONGNIART)** (Zusahara)=possibly *C.* sp. cf. *C. virginiensis* FONTAINE
C. distans (HEER) YABE** (Horisakabashi)=?
C. exiliformis (GEYLER) OISHI** (Kayanokibashi)=?

* Supported by the Grant-in-Aids for Scientific Research from the Ministry of Education, Science and Culture (no. 59540499).

C. lobifolia (PHILLIPS) BRONGNIART** (Zusahara; pl. 18, fig. 4)=*Eboracia microlobifolia* KIMURA et OHANA

Onychiopsis elongata (GEYLER) YOKOYAMA** (Shidasawa and Ishigami-mura)= possibly *O. yokoyamai* (YABE) KIMURA et AIBA

Ptilophyllum pecten (PHILLIPS) MORRIS** (Zusahara, Shidasawa, Ishigami-mura and Kami-mano-mura; pl. 35, fig. 3)=*P. jurassicum* KIMURA et OHANA sp. nov.

Cf. *Zamites feneonis* BRONGNIART** (Kayanokibashi; pl. 38, fig. 1)=*Z. nipponicus* KIMURA et OHANA sp. nov.

Zamiophyllum buchianum (ETTINGSHAUSEN) NATHORST (Ishigami-mura)=?

Pseudoctenis brevipennis OISHI* (Zusahara; pl. 28, figs. 6–7 and Ishigami-mura; pl. 28, fig. 5)

Nilssonia orientalis HEER** (Zusahara and Shidasawa)=*N.* sp. cf. *N. canadensis* BELL.

N. schaumburgensis (DUNKER) NATHORST** (Horisakabashi; pl. 27, fig. 9, Zusahara and Shidasawa)=*N.* ex. gr. *schaumburgensis* (DUNKER) NATHORST

Elatocladus obtusifolia OISHI (Kami-mano-mura; pl. 41, fig. 1, 1a)**=*Pagiophyllum* sp.

Nageiopsis zamioides FONTAINE** (Zusahara)=possibly *Parasequoia* sp. cf. *P. cretacea* KRASSILOV

Podozamites lanceolatus (LINDLEY et HUTTON)** (Zusahara)=?

'Geonoma' trinerve OISHI* (Zusahara; pl. 45, fig. 7; pl. 47, figs. 9–10)

In addition, ENDO (1952) described *Klukia exilis* (PHILLIPS) RACIBORSKI from Shidasawa and Zusahara and gave the list of fossil plants (p. 166). Besides, MASATANI and TAMURA (1959) also made the list of fossil plants of the group.

During from 1980 to 1984, K. IKEHARA, H. TAKIMOTO and other graduate and undergraduate students of the Tokyo Gakugei University collected a number of specimens of fossil plants from the Tochikubo Formation at the following localities (from north to south; Fig. 1B):

Soma City: Umenokizawa and Karasuzawa (UK).

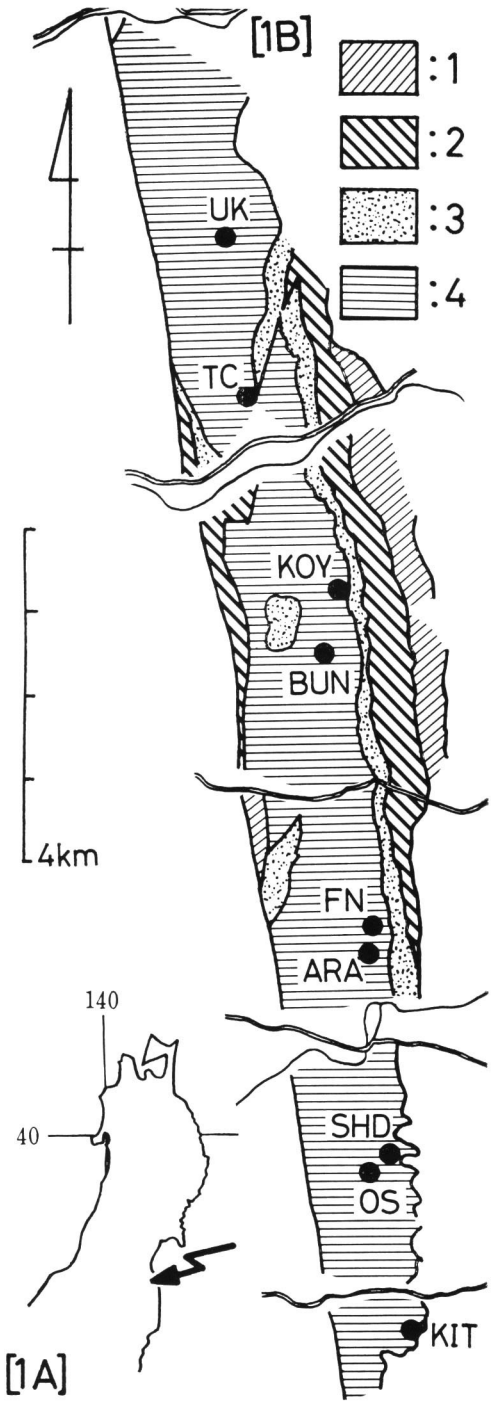
Kashima-machi, Soma-gun: Koyamada-Rindo (KOY) and Bunasaka (or Funasaka) (BUN)

Haranomachi City: Fukanonakayama-Rindo (FN), Aratozawa (ARA), Shidasawa (SHD), Oku-Shidasawa (OS) and Kitayachi (KIT).

Of these, the Bunasaka-locality is fairly extensive and the plant-bearing beds are exposed along the path successively for about 750 m.

This paper deals with the systematic description of fossil plants newly obtained from the Tochikubo Formation and mentions the characteristic feature of this plant-assemblage.

Detailed comparison of this plant-assemblage with coeval floras in East Asia and other regions will be made by us after the descriptions of fossil plants from the coeval or nearly coeval Oginohama Formation of the Oshika Group mostly of marine origin and Moné and Kogoshio Formations of the Shishiori Group of marine origin distributed in the Outer Zone of Northeast Japan.



Figs. 1A–B. 1A. Location of the studied area indicated by an arrow. 1B. Brief geological map of the studied area [after MORI (1963)] and the main fossil plant-sites. Fossil plants are rare in occurrence at TC (Kitanoirisawa) locality.

1. Koyamada Formation, 2. Tomizawa Formation, 3. Nakanosawa Formation, and 4. Tochikubo Formation.

Table 1. Stratigraphy of the Somanakamura Group [after MORI (1963)].

	Formation	Thickness (m)	age
Somanakamura Group	Koyamada F.*	180	Tithonio-Berriasian
	Tomizawa F.	400	(Kimmeridgio-Tithonian)
	Nakanosawa F.*	50-165	Oxfordio-Kimmeridgian
	Tochikubo F.	350+	(Oxfordian)
	①		
	Yamagami F.*	150-200	Callovian
	②		
	Awazu F.*	200	Bajocio-Bathonian
	③		
	Kitazawa F.*	ca.250	(Bajocian)
	④		

* ; of marine origin yielding such index fossils as ammonites, bivalves, corals and brachiopods. ① and ④; fault, ②; disconformity, ③; slight unconformity, ( ); presumed age.

List of fossil plants discriminated from the Tochikubo Formation

Unfortunately all the reproductive organs of ferns were destroyed and the cuticles of gymnosperm-leaves were not preserved because of the subsequent igneous intrusions and geological disturbances taken place in this area. Therefore our identifications of fossil plants were unavoidably based only on the external morphology of their imprints.

Among our vast collection, we discriminated the following plant-taxa (Occurrence: LVA; locally very abundant, LA; locally abundant, LC; locally common, RR; rather rare, R; rare, VR; very rare):

Ferns:

Gleichenites? sp. A (R)
Matonidium ex gr. *goepperti* (ETTINGSHAUSEN) SCHENK (LC)
Eboracia microlobifolia KIMURA et OHANA (LA)
Sphenopteris elegans (YOKOYAMA) OISHI (LC)
Cladophlebis acutipennis OISHI (RR)
C. sp. cf. *C. matonioides* OISHI (RR)
C. sp. cf. *C. virginiensis* FONTAINE (LA)
C. sp. A (LC)
C. sp. B (RR)
Acrostichopteris? sp. (VR)

Bennettitaleans:

Otozamites sp. cf. *O. kondoi* OISHI (VR)
Zamites sp. cf. *Z. megaphyllus* (PHILLIPS) SEWARD (LC)
Z. nipponicus KIMURA et OHANA sp. nov. (LVA)
Z. sp. A (VR)
Z. sp. B (VR)
Nipponoptilophyllum bipinnatum KIMURA et TSUJII (LC)
Ptilophyllum jurassicum KIMURA et OHANA sp. nov. (LA)
P. sp. F (R)
P. sp. G (VR)
P. sp. H (R)

Cycadaleans:
Pseudoctenis brevipennis OISHI (R)
P. sp. A (VR)
Nilssonia sp. cf. *N. canadensis* BELL (LC)
N. sp. cf. *N. densinervis* (FONTAINE) BERRY (LC)
N. longipinnata KIMURA et OHANA sp. nov. (LC)
N. oblique-truncata KIMURA et OHANA sp. nov. (LC)
N. ex gr. *schaumburgensis* (DUNKER) NATHORST (LA)

Unclassified cycadophyte:
Cycadites sp. (LC)

Conifers:
Elatocladus sp. A (VR)
Pagiophyllum sp. (LC)
Parasequoia sp. cf. *P. cretacea* KRASSILOV (LC)

Unclassified seed:
Carpolithus sp. A (LC)

Characteristic features of the plant-assemblage

The following are the characteristic features of this plant-assemblage from the Tochikubo Formation:

1) Ferns with known botanical affinities are narrowly represented each by a single species belonging to the Gleicheniaceae, Matoniaceae and Dicksoniaceae. Of these, the first one is incompletely represented and the last one is only a single representative of Dicksoniaceae in the Late Jurassic-Early Cretaceous floras in the Outer Zone of Northeast Japan. On the other hand, dicksoniaceous ferns are varied and abundant in the coeval floras in the Inner Zone of Japan. No matoniaceous fern has been recorded in the coeval floras in the Inner Zone of Japan.

Other ferns are all represented by the sterile leaves.

2) Bennettitaleans are characterized by the abundant occurrence of new types of *Zamites* and *Ptilophyllum*. Both genera are characteristic elements of the Late Jurassic-Early Cretaceous Ryoseki-type floras in the Outer Zone of Japan, and have

not been recorded in the coeval floras in the Inner Zone of Japan.

3) *Nilssonia* leaves are varied and abundant. *Nilssonia schaumburgensis*-type leaves have only been known in the Ryoseki-type floras.

4) It is worth mentioning that no ginkgoalean, czekanowskialean and *Podozamites* leafy-shoot which are common in occurrence in the Late Jurassic-Early Cretaceous floras in the Inner Zone of Japan, have not been found in our collection from the Tochikubo Formation as well as from the coeval plant-beds in the Outer Zone of Japan.

5) Conifers are rather rare, but the presence of *Parasequoia* established by KRASSILOV (1967) from the Lower Cretaceous of Southern Primorye is distinctive. No coniferous shoot with long needle-like leaves has been found.

Accordingly it is evident that this plant-assemblage is of the Ryoseki-type (KIMURA, 1984, 1987) in its floristic composition.

Systematic description

Class Pteropsida
Order Filicales
Family Gleicheniaceae
Gleichenites? sp. A

(Pl. 1, fig. 1; Pl. 4, fig. 1; Pl. 5, fig. 1; Figs. 2a–b)

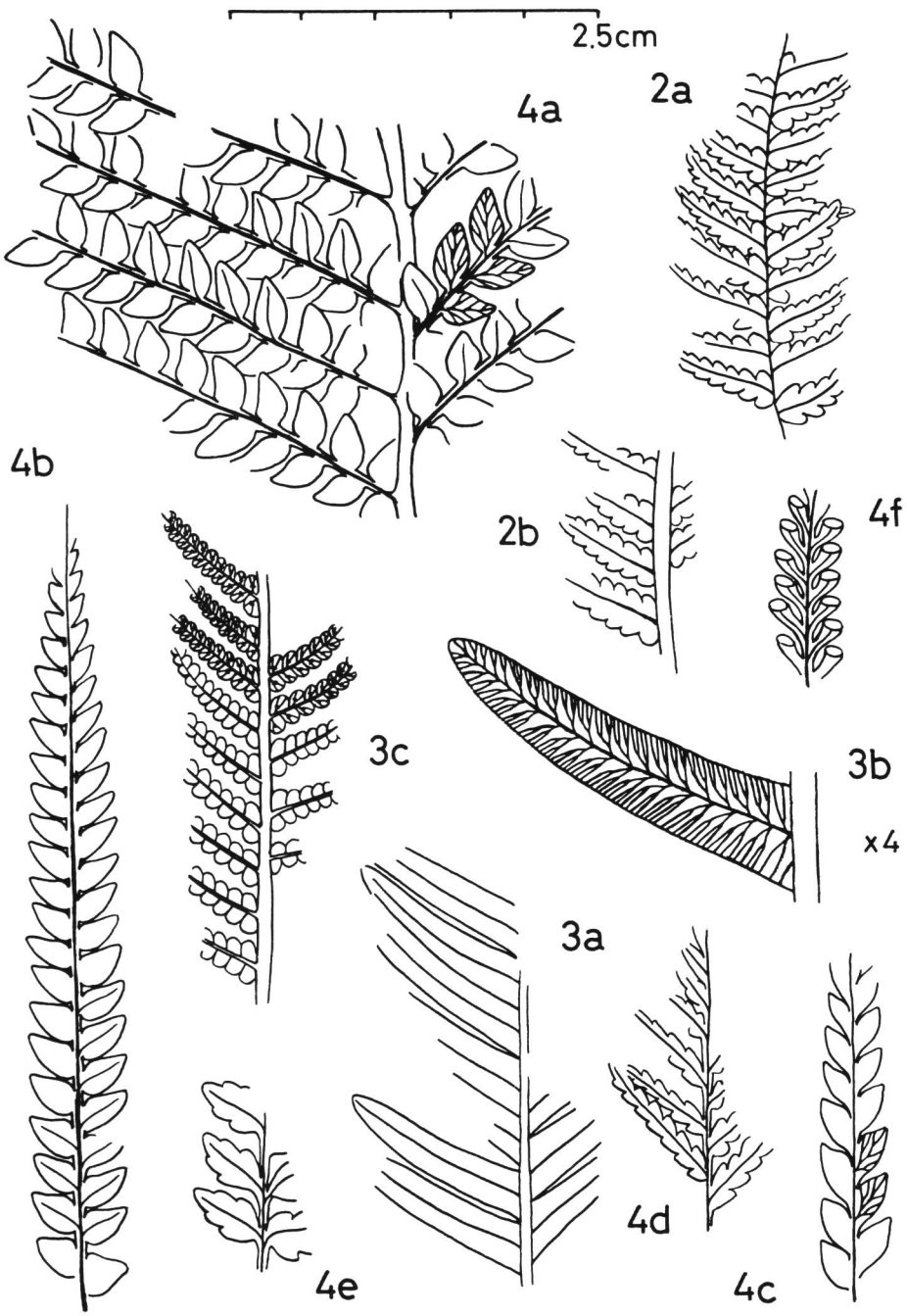
Material: NSM PP-8142～8150 (Shidasawa), 8151～8157 (Bunasaka).

Occurrence: Rare.

Description: Leaf is at least tripinnate, but its whole shape is uncertain. Ultimate pinnae are set closely, and attached alternately to the rather thick pinna axis, 2 mm wide at an angle of 45–50 degrees. Pinnules are also set closely, elongate-triangular in form, typically 8 mm long and 2 mm wide at middle, attached katadromically to the pinna axis at an angle of 80–90 degrees, and sometimes falcate. Margins are divided into up to 7 pairs of shallow lobes; each lobe is rather directed forwards, and with rounded or obtusely pointed apex. The lobes of the first pair are larger in size, twice as large as others. Venation is obscure; midnerve persists to the tip but lateral veins are invisible. Sori (?) are faintly preserved, 0.5–1 mm in diameter, each occurring on the centre of a lobe of basal 1–3 pairs, but details of soral characters are uncertain.

Figs. 2–4 (Enlarged twice, unless otherwise indicated).

2. *Gleichenites*? sp. A. 2a (NSM PP-8149), 2b (NSM PP-8148). Loc. Shidasawa.
3. *Matonidium* ex gr. *goepperti* (ETTINGSHAUSEN) SCHENK. 3a (NSM PP-8165, drawn partly from Pl. 2, fig. 3). 3b (NSM PP-8165, showing the venation enlarged). 3c (NSM PP-8164, showing the finely divided and small-sized pinnules).
4. *Eboracia microlobifolia* KIMURA et OHANA. 4a (NSM PP-8188, drawn from Pl. 3, fig. 2). 4b (NSM PP-8170, drawn from Pl. 1, fig. 2). 4c (NSM PP-8190). 4e (NSM PP-8184, drawn from Pl. 3, fig. 8). 4f. (NSM PP-8173, drawn from Pl. 3, fig. 9). Loc. Aratozawa. 4d (NSM PP-8180). Loc. Bunasaka.


2.5cm
4a
2a
4b
2b
4f
3c
3b
x4
3a
4d
4e
4c

Remarks: *Gleichenites*? sp. A is characterized by its tripinnate leaf bearing markedly lobed pinnules. In external form of pinnules, *Gleichenites*? sp. A is most close to *Sphenopteris* (*Gleichenites*?) *erecta* originally described by BELL (1956) from the Aptian Luscar and Albian Blairmore Formations, Western Canada. But we could not make detailed comparison of our leaves with the Canadian ones because of ill-preservation of both materials.

Family Matoniaceae

Genus *Matonidium* SCHENK, 1871: 219

Matonidium ex gr. *goepperti* (ETTINGSHAUSEN) SCHENK

(Pl. 1, fig. 6; Pl. 2, figs. 1–4; Figs. 3a–c)

Comparable specimens:

Alethopteris goepperti ETTINGSHAUSEN: ETTINGSHAUSEN, 1852, p. 16, pl. 5, figs. 1–7 (Lower Cretaceous of North Germany).

Matonidium goepperti (ETTINGSHAUSEN) SCHENK: SCHENK, 1871, p. 219, pl. 27, fig. 5; pl. 28, figs. 1–2; pl. 30, fig. 3; pl. 42, fig. 1 (ditto); HARRIS, 1961, p. 112, text-figs. 37–38 (Middle Jurassic of Yorkshire); KRASSILOV, 1967, p. 112, pl. 12, fig. 4 (Lower Cretaceous of Southern Primorye).

Material: NSM PP-8158 (Aratozawa), 8159～8169 (Shidasawa) and 31 other specimens. *Occurrence*: Locally common at Shidasawa, but very rare at Bunasaka and Aratozawa.

Description: Obtained are all broken pinna fragments including only two basal arms (Pl. 2, fig. 1). The pinnae are long and slender, up to 2.2 cm wide, but their whole length is unknown. The pinna axis is smooth, projecting more below than above, slender, 1 mm wide at base and 0.5 mm wide above, and sends off closely set pinnules at an angle of 60–90 degrees to the pinna axis. The pinnules on the middle portion of pinna are typically 2–3 mm wide near base and 2 cm long, narrowing gradually towards the obtusely pointed apex and often falcate; those on the basal apical regions of pinna are smaller in size, and their bases are expanded and connected with each other by a web of lamina about 0.5 mm wide. Margins are mostly entire, often strongly reflexed especially when fertile. The midnerve is marked on the underside of pinnule; in large-sized sterile pinnules, the midnerve sends off about 20 pairs of mostly twice forked lateral veins (Pl. 2, fig. 3; Fig. 3b), but in small-sized sterile pinnules, the lateral veins are mostly once forked. In fertile pinnules, the midnerve sends off about 10 paris of mostly once forked lateral veins.

In the fertile pinnules, the midnerve sends off about 10 pairs of mostly once forked lateral veins. The sori are superficial, about 0.5 mm in diameter, each just on the branching-point of lateral vein; in some cases sori become square in surface view because of pushing laterally one another and the surface of lamina is usually bulging above each sorus (Fig. 3c). The placenta is prominent, ending in a persistent indusium,

about 0.25 mm in diameter. The details of sporangia are uncertain.

Remarks: It is evident that our leaves are with matoniaceous affinity because of the presence of the basal pedate arms and the soral features. It is highly probable that our leaves belong to *Matonidium* and is closely comparable to *M. goepperti* known widely from the Middle Jurassic of Yorkshire and Lower Cretaceous floras of the Wealden-type. But we reserve to make full identity of our leaves with *Matonidium goepperti* redescribed in detail by HARRIS (1961), because of the uncertainty of our sporangial features.

Sterile pinnules of *Cladophlebis matonioides* originally described by OISHI (1940) and of *C.* sp. cf. *C. matonioides* described in this paper are close in form to the present pinnules, but both are distinguished fundamentally from *Matonidium* ex gr. *goepperti* by their tripinnate leaves instead of pedate ones in *M.* ex gr. *goepperti.*

Matonidium goepperti recorded by YABE (1927, p. 51) from the Moné or Kogoshio Formation was, according to OISHI (1940), said to be his *Cladophlebis matonioides.*

KRASSILOV (1967) described *Matonidium goepperti* from the Lower Cretaceous of Southern Primorye on the basis of pinna fragments. Its pinnules are shorter in length and correspond in form to basal ones of our pinnae.

The occurrence of *Matonidium* is the first record in the Japanese Mesozoic.

Family Dicksoniaceae

Genus *Eboracia* THOMAS, 1911: 387

Eboracia microlobifolia KIMURA et OHANA

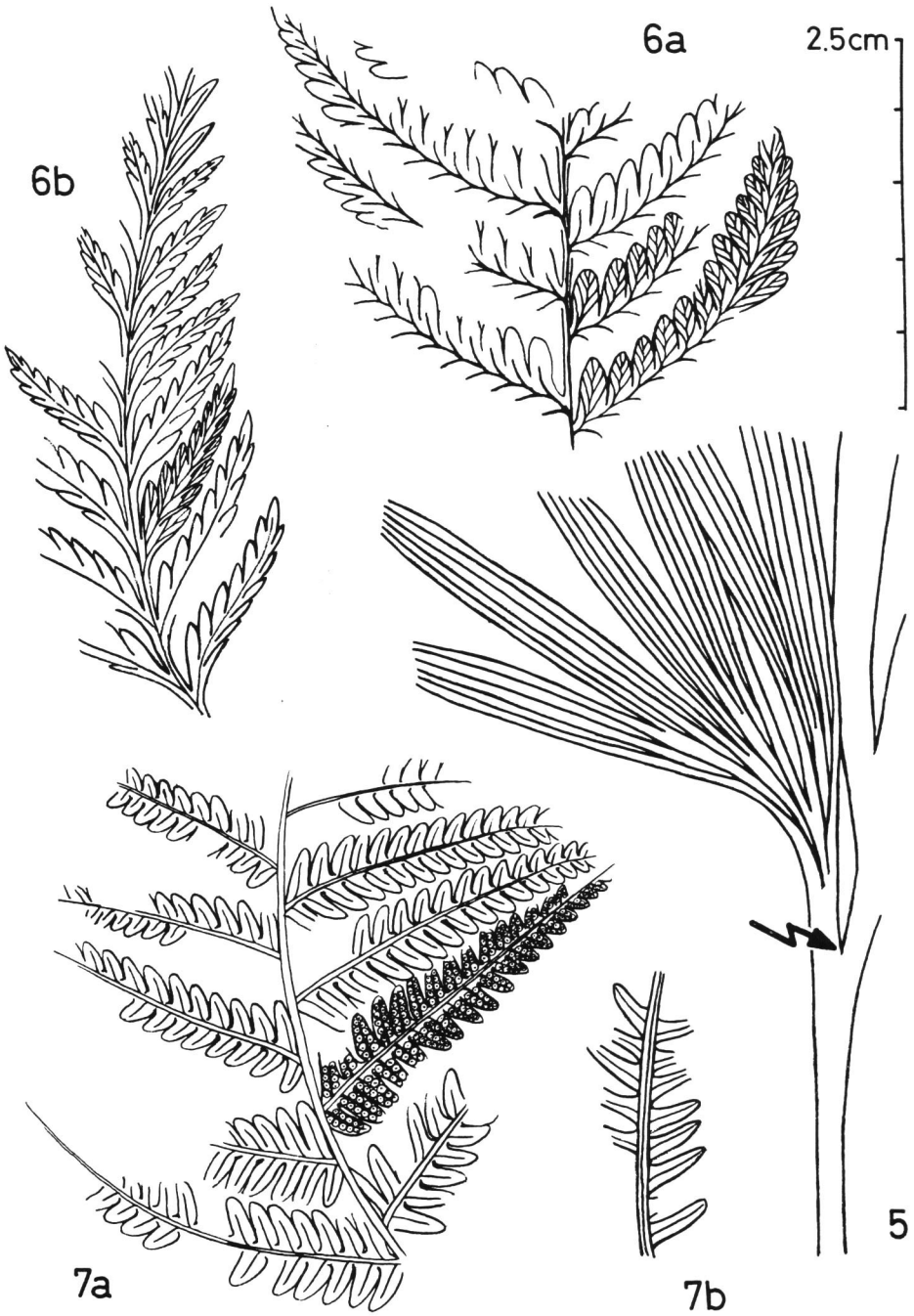
(Pl. 1, fig. 2; Pl. 3, figs. 1–9; Figs. 4a–f)

Cladophlebis (*Eboracia*?) *lobifolia* (PHILLIPS) BRONGNIART: OISHI, 1940, p. 273 (pars), pl. 18, fig. 4 (Zusahara).

Eboracia microlobifolia KIMURA et OHANA: KIMURA and OHANA, 1987a, pl. 16, pl. 1, figs. 1–4; text-figs. 2a–h (Ayukawa Formation).

Material: NSM PP-8170～8174, 8183～8190 (Aratozawa), 8175～8182 (Bunasaka) and 505 other specimens. *Occurrence*: Locally abundant at Aratozawa and Bunasaka, but rare at Shidasawa.

Description: Leaf is small- or medium-sized, at least bipinnate, elongate elliptic in form, more than 13.5 cm long and 6 cm wide, and with slender rachis (1 mm wide) with a median groove above, but its whole length is still unknown. Sterile pinnae are closely set, long and narrow, typically 5 cm long or more and up to 7 mm wide at base, gradually narrowing to the acutely pointed or acuminated apex, attached to the rachis at an angle of 65 degrees, and bearing 24–30 pairs of pinnules typically. Pinnules are closely set, katadromic in order, rhomboidal or deltoid in outline, with contracted base, typically 3 mm long and 1.2 mm wide and with entire margins; larger pinnules are sometimes divided shallowly into 2 pairs of lobes; each pinnule or lobe is with obtusely pointed apex. Basal pinnules are not specialized. Veins are of *Sphenopteris* (or *Eboracia*)-type, symposially disposed; the midnerve sends off 3–4 alternate pairs


6a
2.5cm
6b
5
7a
7b

of lateral veins; sometimes lateral veins of the basal pair are twice forked, but the others are once forked or simple. Fertile pinnae are also long and narrow, as long as sterile ones, bearing closely set fertile pinnules, but basal several pairs are sterile. Lamina of the fertile pinnule is reduced and each bears a single sorus at the tip or acroscopic side. Indusium is cylindrical, but sporangia are indistinct.

Remarks: This species is first described by KIMURA and OHANA (1987a) on the basis of a number of sterile and fertile leaf-fragments obtained from the Kiyosaki Sandstone Member (late Tithonian-Berriasian?), Ayukawa Formation, Oshika Group.

The present leaves are fully referable to those of *Eboracia microlobifolia*. In this paper we made some additional description to the original one such as of lobed sterile pinnules. Comparison of *Eboracia microlobifolia* with *E. lobifolia* (PHILLIPS) THOMAS and *Cladophlebis novopokrovskii* PRYNADA was already made in our previous paper (KIMURA and OHANA, 1987a).

From the Lower Cretaceous Oguchi Formation of the Tetori Supergroup in the Inner Zone of Japan, three *Eboracia* species, *E. ishikawaensis* KIMURA et SEKIDO (MS), *E. nipponica* KIMURA et SEKIDO (MS) and *E. tetoriensis* KIMURA et SEKIDO (MS) have been recognized. But they are all distinguished from *Eboracia microlobifolia* by the position of sori and the size and venation of pinnules.

In the Ryoseki-type floras, the dicksoniaceous ferns have not been recognized in the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. On the other hand, only two dicksoniaceous genera each with a single species including the present *Eboracia microlobifolia* have been found in the Upper Jurassic plant-beds in the Outer Zone of Northeast Japan.

Unclassified ferns

Form-genus *Acrostichopteris* FONTAINE, 1889, em. BERRY, 1911: 220

Acrostichopteris? sp.

(Pl. 2, fig. 12; Fig. 5)

Material: NSM PP-8240, 8241 (Bunasaka). *Occurrence*: Very rare.

Description: Pl. 2, fig. 12 (Fig. 5) shows a single broken pinna with a long stalk, 2 cm long. Lamina is divided possibly into two parts by a deep sinus reaching at the top of stalk. A part of the lamina is further divided into six ribbon-like lobes up to 3.5 mm wide; apices of lobes are all missing. Veins are 1 or 2 at the base of a part, forking dichotomously 3 or 4 times; each lobe receives 4 parallel veins.

Remarks: Our specimen is quite incomplete, but we are of the opinion that it

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Figs. 5–7 (Enlarged twice).

5. *Acrostichopteris*? sp. (NSM PP-8240, drawn from Pl. 2, fig. 12; an arrow, see text).
6. *Cladophlebis acutipennis* OISHI. 6a (NSM PP-8202). Loc. Aratozawa. 6b (NSM PP-8204, drawn from Pl. 2, fig. 6). Loc. Bunasaka.
7. *Cladophlebis* sp. cf. *C. matonioides* OISHI. 7a (NSM PP-8211, drawn from Pl. 2, fig. 8). 7b (NSM PP-8209). Loc. Aratozawa.

was originally a stalked pinna with semicircular lamina divided into two nearly equal parts by a deep sinus. If our above-mentioned supposition is true, a point indicated by an arrow in Fig. 5 shows the bottom of the median sinus of lamina and the right half of lamina is mostly missing.

Our specimens reminds us of a stalked pinna of such plant as a non-committal genus *Acrostichopteris*. But its incompleteness led us to regard it as *Acrostichopteris*? sp.

It is worth mentioning that such pinnae as our present specimen are often encountered in the Ryoseki-type floras. They have often been confused with ginkgoalean leaves.

Form-genus *Cladophlebis* BRONGNIART, 1849: 105
Cladophlebis acutipennis OISHI

(Pl. 2, figs. 5–7; Figs. 6a–b)

Cladophlebis acutipennis OISHI: OISHI, 1940, p. 249, pl. 9, figs. 4–6 (Lower Cretaceous Yuasa Formation and Upper Monobegawa Group): KIMURA, 1976, p. 190, text-fig. 3 (Lower Cretaceous Yatsushiro Formation): KIMURA and KANSHA, 1978a, p. 110, pl. 2, fig. 2; pl. 3, fig. 6; text-fig. 3 (Yuasa Formation): KIMURA and MATSUKAWA, 1979, p. 94, pl. 1, fig. 3; text-fig. 3 (Lower Cretaceous Sebayashi Formation).

Tyrsopteris sp.: YOKOYAMA, 1894, p. 213, pl. 23, fig. 3 (Upper Monobegawa Group).

Pecopteris cf. *virginiensis* FONTAINE: YOKOYAMA, 1894, p. 220, pl. 24, fig. 1 (ditto).

Material: NSM PP-8201, 8202 (Aratozawa), 8203～8206 (Bunasaka) and 20 other specimens. *Occurrence*: Rather rare.

Remarks: Sterile fern leaves referable to this species have been known from the Lower Cretaceous plant-beds in the Outer Zone of Japan. At this time similar sterile leaves are found from the Tochikubo Formation as illustrated here. No sterile fern leaves referable to this species have not been found from the Upper Jurassic and Lower Cretaceous plant-beds in the Inner Zone of Japan.

Cladophlebis sp. cf. *C. matonioides* OISHI

(Pl. 2, fig. 8; Pl. 5, figs. 2–3; Figs. 7a–b)

Material: NSM PP-8207 (Shidasawa), 8208～8211 (Aratozawa) and 4 other specimens. *Occurrence*: Rather rare.

Description: The leaf is at least tripinnate. Main rachis is 2.5 mm wide, sending off closely set first branches at an angle of 70 degrees; the first branch, up to 3 cm wide, but its whole shape unknown. The second branch is long and narrow, typically 2.5 cm long and 4 mm wide, often falcate and sends off 18 pairs of small-sized pinnules katadromically. The pinnules are deltoid to rectangular in form, with obtusely pointed or rounded apex and attached to the wide angle with the expanded base;

rectangular pinnule is 4 mm long and 0.5–1 mm wide. The midnerve is distinct, persisting to the tip, but lateral veins are invisible. Three-five pairs of circular reproductive organs (sori ?), 0.4 mm in diameter, are disposed superficially on both sides of the midnerve, but their details are uncertain.

Remarks: Our pinnules resemble closely in form those of *Cladophlebis matonioides* originally described by OISHI (1940) possibly from the Oginohama and Moné Formations on the basis of sterile leaves. However, as our pinnules are far smaller than those of *Cladophlebis matonioides*, we at present regard our leaves as *C.* sp. cf. *C. matonioides*.

Our pinna fragments resemble those of *Matonidium* ex gr. *goepperti* described in this paper, but our leaves are distinguished from those of the latter by their obviously tripinnate habit instead of pedate leaves of the latter.

Cladophlebis sp. cf. *C. virginiensis* FONTAINE

(Pl. 1, fig. 7; Pl. 3, fig. 10; Pl. 4, figs. 2–5; Figs. 8a–d)

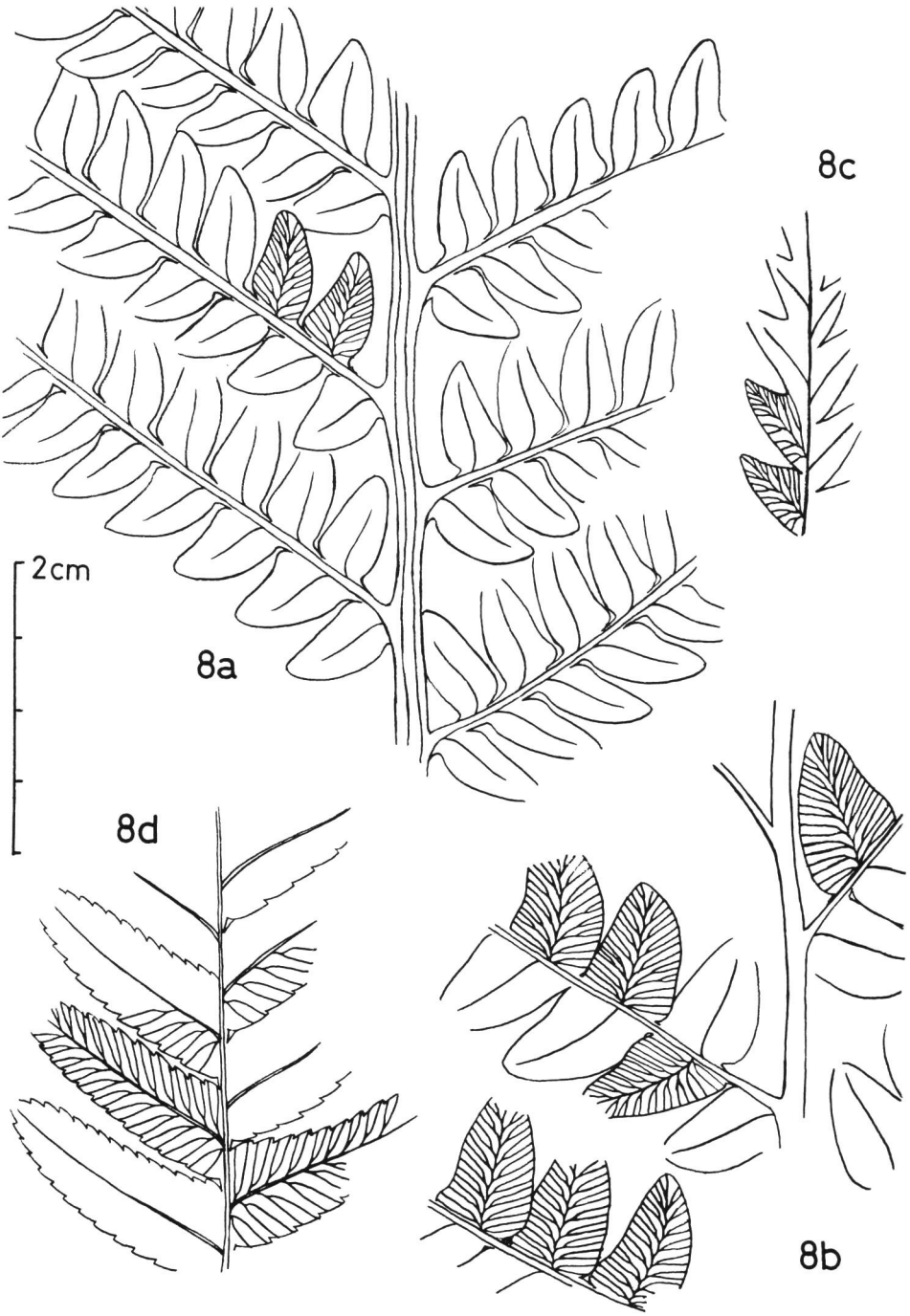
Material: NSM PP-8212 (Bunasaka), 8213～8229 (Aratozawa) and 99 other specimens. *Occurrence*: Locally abundant at Aratozawa.

Description: Obtained are all sterile bipinnate leaf-fragments. Of these, a leaf shown in Pl. 4, fig. 2 is the largest fragment. Rachis is rather thick, 3 mm wide below with a median furrow on its upper surface, sending off katadromically long, narrow and nearly parallel-sided pinnae typically at an angle of 50 degrees, 9.5 cm long and 1.6 cm wide at the middle, and bearing 18–20 pairs of pinnules at a wide angle to the pinna axis. Pinnules are closely set and variable in form according to the position on a leaf; deltoid in form on the distal half of a leaf and elongated-deltoid on the proximal half of a leaf. In deltoid pinnules, margins are entire; acroscopic basal margin is rather markedly constricted and basiscopic basal margin slightly constricted, then decurrent; midnerve is distinct, persisting to the obtusely pointed apex and sends off 7 pairs of mostly once forked lateral veins obliquely. Elongate-deltoid pinnules are attached to the pinna axis by the whole base; margins are shallowly serrate, with obtusely pointed apex; midnerve sends off 11–12 pairs of once forked lateral veins obliquely; each serration receives a set of lateral vein.

Remarks: Our leaves resemble closely those of *Cladophlebis virginiensis* FONTAINE and its allied species (see BERRY, 1911, pp. 248–249; BELL, 1956, p. 50) known from the Lower Cretaceous of North America in form and venation of pinnules.

In some leaves of *Cladophlebis virginiensis* (e.g. *C. virginiensis* forma *acuta*, by BELL, 1956), basiscopic basal pinnules are broader and bilobed (BELL's pl. 5, fig. 1). No such specialized pinnules have been found in our collection. Therefore, we reserve to identify our leaves fully with those of *Cladophlebis virginiensis*.

In all specimens examined, pinnules appear to be coriaceous and their upper surface is mostly convex and their margins are sometimes reflexed.


8c
2cm
8a
8d
8b

Cladophlebis sp. A

(Pl. 2, fig. 9; Pl. 5, figs. 4–6; Fig. 9)

Material: NSM PP-8230~8234 (Aratozawa) and other 21 specimens.

Occurrence: Locally common at Aratozawa.

Description: Obtained leaves are all sterile, tripinnate and medium-sized, but their whole shape and size are unknown. Ultimate pinnae are set rather closely, at least 5 cm long and 0.7 cm wide, attached nearly perpendicularly to the comparatively thick penultimate pinna axis (4 mm wide basally) and send off katadromically 23–25 pairs of pinnules. Pinnules are small-sized, rectangular in form with obtusely pointed apex and expanded base, attached by their whole base to the pinna axis at a wide angle, but angle is reduced distally, typically 5 mm long and up to 1.5 mm wide and with obtusely pointed apex; margins are entire. The pinnules of basal pair often longer than the rest. Midnerve is rather distinct, persisting to the tip and sends off 7 pairs of once forked lateral veins.

Remarks: Our leaves are characterized by having small-sized pinnules which are rectangular in form with obtusely pointed apex and with once forked lateral veins.

Our leaves are most close to those illustrated by YOKOYAMA (1894) as *Pecopteris browniana* DUNKER from the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. But YOKOYAMA's leaves seem to be different from our leaves in their pinnules, according to YOKOYAMA (1894), sometimes with twice to thrice forked lateral veins.

The sterile pinnules of *Polypodites verestchaginii* originally described by KRASSILOV (1967) from the Lower Cretaceous of Southern Primorye resemble those of ours in form, size and venation.

Cladophlebis sp. B

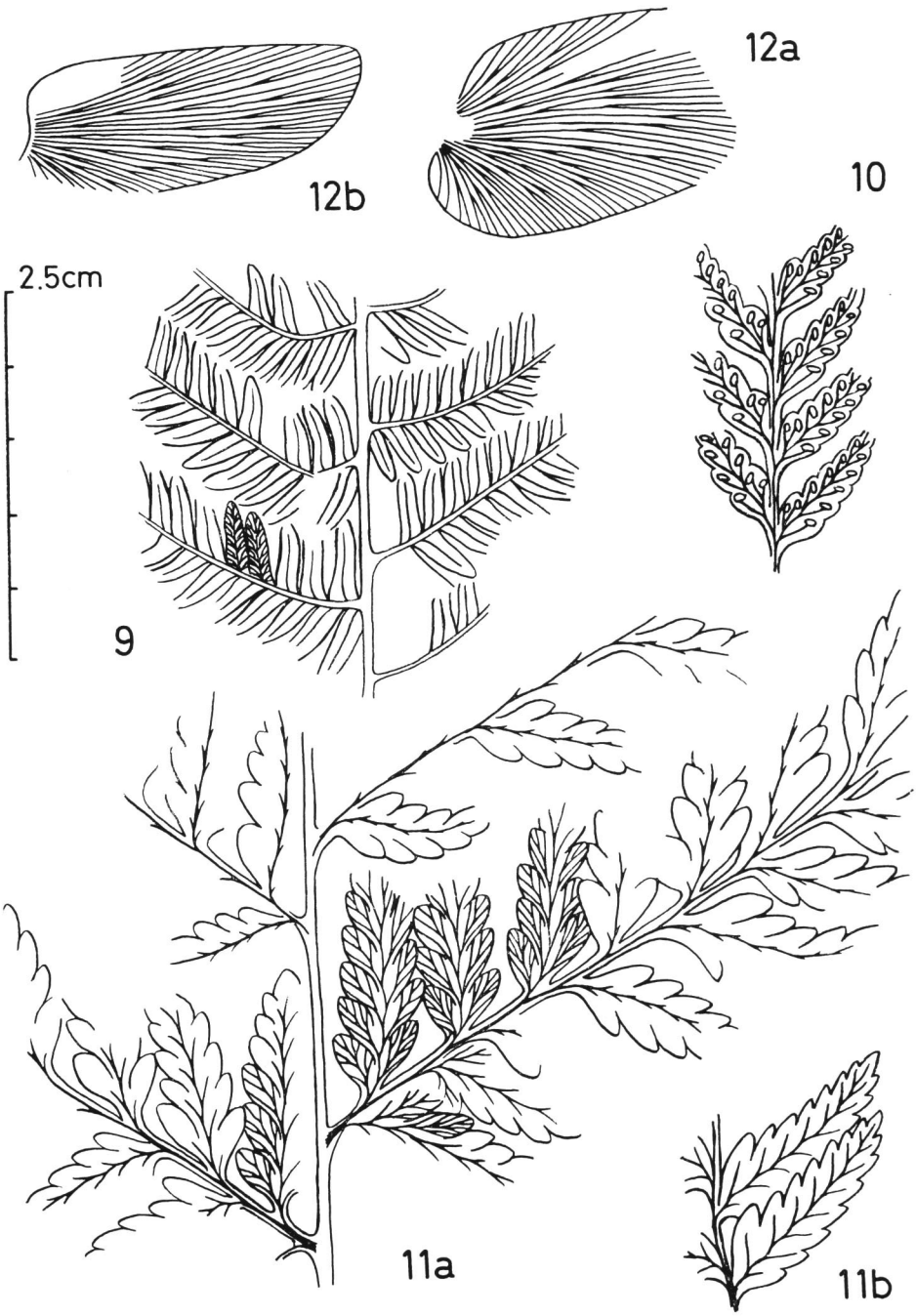
(Pl. 2, figs. 10–11; Pl. 5, fig. 7; Fig. 10)

Material: NSM PP-8235~8239 (Bunasaka). *Occurrence*: Rather rare.

Description: Obtained are only five fertile pinna fragments of which pinnules are rectangular in form, 1 cm long and 3 mm wide, with obtusely ponted apex and decurrent base, attached to the slender pinna axis at an angle of 60 degrees, and divided katadromically into 6–7 pairs of shallow lobes. Midnerve is distinct, not straight but zigzag in course, persiting to the tip, and sends off single or once forked lateral veins; each lobe receives a set of lateral vein, but the lateral veins do not reach the tip of each lobe. Fructification is semi-circular in surface view, up to 1 mm in diameter, superficial, and each terminating the lateral veins; details of the fructification are not known.

Figs. 8a–d (Enlarged twice).

Cladophlebis sp. cf. *C. virginiensis* FONTAINE. 8a (NSM PP-8228, drawn partly from Pl. 4, fig. 2). 8b (NSM PP-8221, drawn partly from Pl. 3, fig. 10). 8c (NSM PP-8224). 8d (NSM PP-8219, drawn from Pl. 4, fig. 4). Loc. Aratozawa.


12a
12b
10
2.5cm
9
11a
11b

Remarks: Owing to the uncertainty of our fructification, it is difficult to ascertain the taxonomic position of our leaves. Therefore, unavoidably we at present regard our leaves as *Cladophlebis* sp. B.

Externally our pinnules resemble those of *Polypodites polysorus* PRYNADA described by KRASSILOV (1967) from the Lower Cretaceous of Southern Primorye.

The pinnules of *Cladophlebis* sp. B also resemble those of *Dicksoniopteris naumanni* originally described by NATHORST (1890) and later by YOKOYAMA (1894) from the Lower Cretaceous plant-beds in the Outer Zone of Southwest Japan. OISHI (1939, 1940) regarded NATHORST's and YOKOYAMA's leaves as *Klukia yokoyamae*.

Form-genus *Sphenopteris* STERNBERG, 1825: 15
Sphenopteris elegans (YOKOYAMA) OISHI

(Pl. 1, figs. 3–5; Figs. 11a–b)

Onychiopsis elegans YOKOYAMA: YOKOYAMA, 1894, p. 215, pl. 28, fig. 7, 7a (Kaisekiyama; Lower Cretaceous Ryoseki Formation).

Sphenopteris elegans (YOKOYAMA) OISHI: OISHI, 1940, p. 236, pl. 8, fig. 1 (Otani; ditto), figs. 2–3 (Zusahara; possibly Tochikubo Formation).

Material: NSM PP-8191 (Aratozawa), 8192～8200 (Bunasaka) and 13 other specimens. *Occurrence*: Locally common at Aratozawa and Bunasaka.

Emended diagnosis: Leaf sterile and bipinnate. Rachis slender, 1 mm wide with a median furrow above, sending off pinnae at an angle of 60 degrees katadromically (Whole leaf unknown.). Pinnae set closely, overlapping each other laterally, elongate-triangular, 10 cm long or more and 3 cm wide at the middle portion of a leaf, with acuminated apex, and bearing 16 pairs of katadromically ordered pinnules. Pinnules ovate or elongate-ovate in form, medium-sized, typically 1.5 cm long and up to 0.5 cm wide, with obtusely pointed apex, divided shallowly into 5–7 pairs of lobes, but occasionally with entire margins, markedly contracted near the base, then sometimes decurrent, and attached to the very slender pinna axis at an angle of 60 degrees, but the angle increased towards the pinna base. Pinnules on the proximal region of a leaf sometimes longer with deeply divided lobes looking like small-sized pinnules with entire margins. Midnerve distinct, persisting to the tip, and sending off sympodially disposed lateral veins; each lateral vein further sending off simple secondary lateral vein, but basal ones sometimes once forked; each lobe receiving a set of lateral vein.

Remarks: *Sphenopteris elegans* was originally described by YOKOYAMA (1894)

Figs. 9–12 (Enlarged twice).

9. *Cladophlebis* sp. A (NSM PP-8232, drawn partly from Pl. 5, fig. 6). Loc. Aratozawa.
10. *Cladophlebis* sp. B (NSM PP-8236, drawn partly from Pl. 5, fig. 7). Loc. Bunasaka.
11. *Sphenopteris elegans* OISHI. 11a (NSM PP-8192, 8196, drawn partly from Pl. 1, fig. 4). 11b (ditto, showing the sympodial venation). Loc. Bunasaka.
12. *Otozamites* sp. cf. *O. kondoi* OISHI. 12a (NSM PP-8243). Loc. Fukanonakayama. 12b (NSM PP-8242). Loc. Upper course of the Shidasawa.

as *Onychiopsis elegans* on the basis of a single sterile pinna fragment from the Ryoseki Formation, and later revised by OISHI (1940) as *Sphenopteris elegans* on the basis of his additional ill-preserved material both from the Ryoseki and possibly from the Tochikubo Formations.

As our leaves were preserved rather well, they led us to give the above-mentioned emended diagnosis of this species.

YOKOYAMA (1894) mentioned that the pinnules were with entire margins in the proximal half and with corsely toothed margins in the apical half, and with obtusely pointed apex. But in our leaves, they show the pinnules divided into shallow lobes throughout as well as those of OISHI's specimens.

Sphenopteris elegans is characterized by its shallowly lobed pinnules with a marked midnerve sending off sympodially disposed lateral veins.

As a number of fern or fern-like leaves with similarly looked sterile pinnules have been recorded from the Upper Palaeozoic and Mesozoic plant-beds under the non-committal generic name *Sphenopteris*, it is fairly difficult to make the precise comparison of the present species with those *Sphenopteris* species.

The pinnules of *Sphenopteris elegans* resemble some sterile pinnules of *Coniopteris burejensis* (ZALESSKY) SEWARD, but in the latter species, pinnules and their lobes are much directed forwards.

Class Cycadopsida
Order Bennettitales
Genus *Otozamites* F. W. BRAUN, 1842
Otozamites sp. cf. *O. kondoi* OISHI

(Figs. 12a–b)

Material: NSM PP-8242 (Fukanonakayama), 8243 (upper course of Shidasawa), 8244 (Aratozawa). *Occurrence*: Very rare.

Description: Obtained are only four small-sized detached pinnae. The pinnae are oblong in outline, 2.3 cm long and 0.9–1.3 cm wide, with rather rounded asymmetrical base, but not auriculated; veins are originated from the central area of pinna base, then radiating, forking dichotomously at all levels, and mostly ending at lateral margins; density is 24 per cm at the distal part of pinna.

Remarks: Our pinnae are characterized by being not conspicuously auriculated ones and thus are close to those of *Otozamites kondoi* originally described by OISHI (1940) from the Upper Jurassic Shishiori Group. But at present we reserve to make full identity of our pinnae with those of OISHI's species because our pinnae are represented only by four detached pinnae.

Genus *Zamites* BRONGNIART, 1828

Zamites sp. cf. *Z. megaphyllus* (PHILLIPS) SEWARD

(Pl. 6, fig. 1; Pl. 7, figs. 1–2)

Cf. *Zamites megaphyllus* (PHILLIPS): OISHI, 1940, p. 356, pl. 34, fig. 5 (Shishiori Group; exact horizon uncertain): OYAMA, 1954, p. 105, pl. 4, fig. 5 (Samenoura, Oginohama Formation).

Material: NSM PP-8419～8423 (Aratozawa) and many other leaf-fragments.

Occurrence: Locally common at Aratozawa.

Description: Obtained are all large-sized pinna (or leaf) fragments. Pl. 7, fig. 1 shows a portion of pinna, 16 cm long and up to 3.2 cm wide. Surface of pinna is strongly convex and the margins are markedly reflexed. Veins are parallel, not converging at the distal end, 28 per cm in density.

Remarks: The pinna shown in Pl. 7, fig. 1 resembles externally those described by SEWARD (1904) as *Zamites megaphyllus* (PHILLIPS) from Yorkshire.

So far as we know, no such large-sized pinnae have been recorded from the Mesozoic of East Asia except for an isolated pinna described by OISHI (1940) as Cf. *Zamites megaphyllus* (PHILLIPS) from the Upper Jurassic Shishiori Group (his Oshima Plant-Bed).

Under the circumstances, we provisionally regard our large-sized pinnae (or leaves) as *Zamites* sp. cf. *Z. megaphyllus* (PHILLIPS).

Three broader pinna fragments illustrated by OYAMA (1954) as Cf. *Zamites megaphyllus* from the Oginohama Formation might be identical with our *Z.* sp. cf. *Z. megaphyllus*.

Zamites nipponicus KIMURA et OHANA sp. nov.

(Pl. 6, figs. 2–3; Pl. 7, fig. 3; Figs. 13a–c)

Cf. *Zamites feneonis* BRONGNIART: OISHI, 1940, p. 355 (pars), pl. 38, fig. 1 (possibly from the Tochikubo Formation) (non pl. 36, fig. 1).

Glossozamites cf. *hoheneggeri* (SCHENK): OYAMA, 1954, p. 106, pl. 5, fig. 8 (Upper Jurassic Oginohama Formation).

Material: Holotype; NSM PP-8245 (Bunasaka). Paratypes; NSM PP-8246, 8252, 8253, 8254 (ditto). Examined specimens; NSM PP-8247～8251 and 120 other specimens. *Stratum typicum*: Tochikubo Formation. *Locus typicus*: Bunasaka. *Occurrence*: Locally very abundant at Bunasaka and rather rare at Aratozawa and Fukanonakayama. *Derivatio nominis*: After Nippon (meaning 'Japan' in Japanese).

Diagnosis: Leaf medium-sized, elongate-oblanceolate in outline, presumably 40–50 cm long and up to 14.5 cm wide with rather slender rachis, 3.5 mm wide below. (Petiole unknown.) Pinnae long and narrow, elongate-lanceolate in outline, but the length varying according to the position of a leaf. Pinnae alternate, set rather remotely, attached to the upper sides of rachis at an angle of 60 degrees at the middle portion of

a leaf, but angle reduced at both ends, asymmetrically contracted and rounded at base, sometimes acroscopic base markedly contracted and rounded, and gradually narrowing to the acuminate apex; the longest pinna 9 cm long and up to 7.5 mm wide and the shortest one 1.3 cm long and up to 3 mm wide. Veins numerous, originating at narrow base, dichotomously forking near the base, then running parallel and ending at the margins of apical half of pinna, not converging at apex; typically 11 in number at base and 18–20 in number (25 per cm in density) at the middle.

Comparison and *discussion*: Our leaves belong undoubtedly to *Zamites*, because of our pinnae with asymmetrically contracted and rounded base attached to the upper sides of rachis.

Zamites nipponicus is characterized by its medium-sized elongate-oblanceolate leaf bearing elongate-lanceolate pinnae with acuminate apex and crowded veins.

This species was first described by OISHI (1940) possibly from the Tochikubo Formation as Cf. *Zamites feneonis* BRONGNIART. In fact *Zamites nipponicus* resembles most closely *Z. feneonis* (BRONGNIART) UNGER illustrated by ETTINGSHAUSEN (1852), SCHIMPER (1872) and other authors mainly from the Upper Jurassic-Lower Cretaceous of Europe. But *Zamites feneonis* is barely distinguished by its pinnae attached to the rachis at a wide angle, with symmetrically contracted base and with less crowded veins.

Zamites nipponicus also resembles in pinna form the following *Zamites* species:

Zamites hoheneggeri (SCHENK) LI: SZE *et al.*, 1963; formerly regarded as *Podozamites hoheneggeri* SCHENK (SCHENK, 1869) and as *Glossozamites hoheneggeri* (SCHENK) (YOKOYAMA, 1906): Middle-Upper Jurassic of Sichuan, China.

Z. corrugatus PRYNADA described by STANISLAVSKY (1971): Upper Triassic of Donbass.

Z. ivanovii KRYSHTOFOVICH et PRYNADA (SAMYLINA, 1961) or *Zamiophyllum ivanovii* (KRYSHTOFOVICH et PRYNADA) (KRASSILOV, 1967): Lower Cretaceous of Southern Primorye.

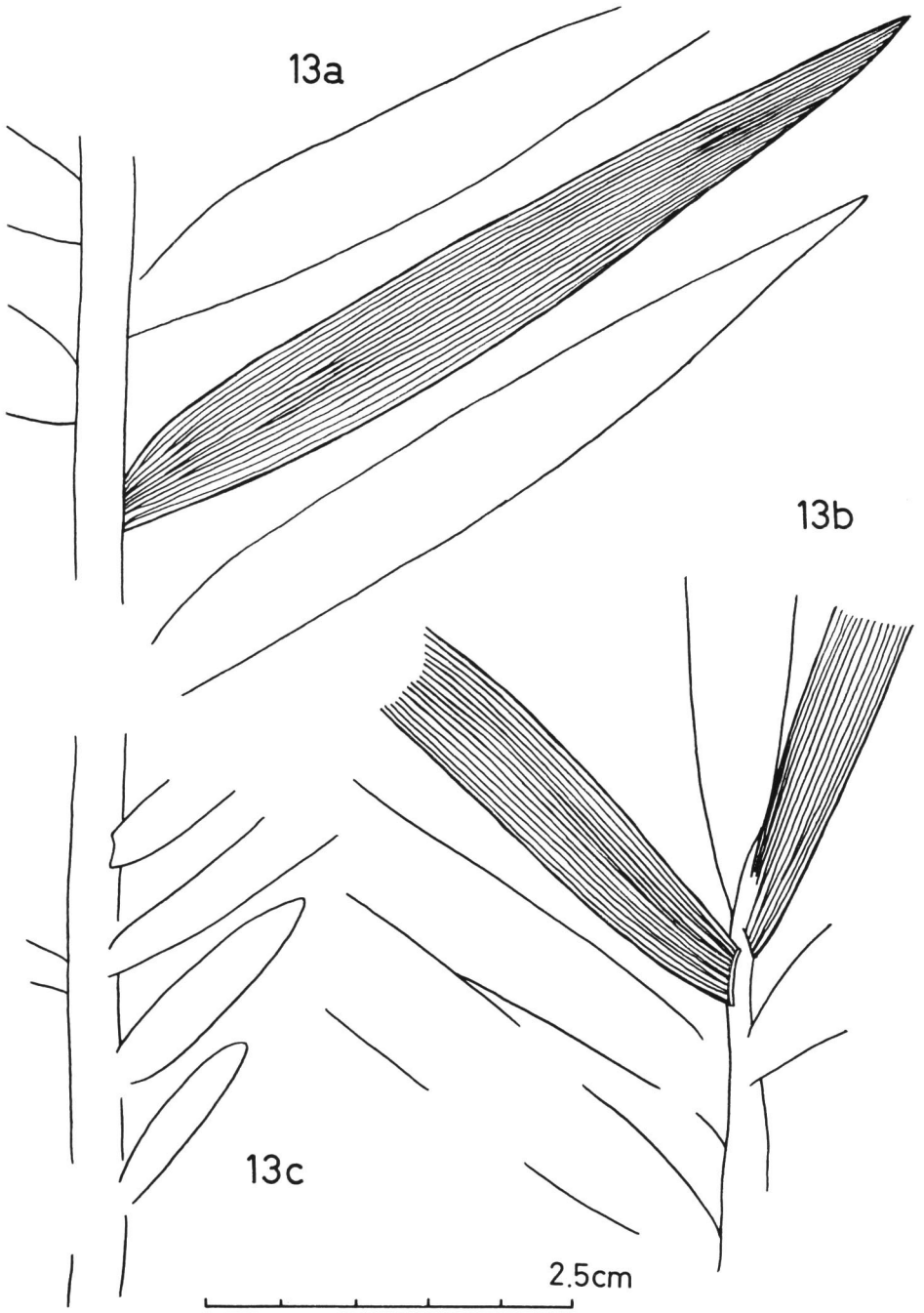
Z. vachrameevii DOLUDENKO: DOLUDENKO and SVANIDGE (1969): Upper Jurassic of Georgia.

Z. recta (TATE) SEWARD: Redescribed by ANDERSON and ANDERSON (1985): Lower Cretaceous of South Africa.

However, *Zamites hoheneggeri* is distinguished by its pinnae attached to the rachis at right angle, with markedly contracted base and with small number of veins (15 in each pinna), *Z. corrugatus* by its broader and shorter pinnae, *Z. ivanovii* by its closely set and rather broader pinnae with suddenly narrowed distal end, *Z. vachrameevii* by its narrower pinnae with not so contracted base and *Z. recta* by its far longer pinnae (nearly twice as long as those of *Z. nipponicus*).

Figs. 13a–c (Enlarged twice).

Zamites nipponicus KIMURA et OHANA sp. nov. 13a [NSM PP-8245, drawn partly from Pl. 6, fig. 3 (holotype)]. 13b (NSM PP-8247). 13c (NSM PP-8254; paratype). Loc. Bunasaka.


13a
13b
13c
2.5cm

The leaves of *Zamites varius* recently described by KIMURA and OHANA (1987b) from the Middle Jurassic Utano Formation, Japan also resemble in pinna form those of *Z. nipponicus*, but in the former species the pinnae are shorter and thick and with small number of veins (10 per cm in density).

A broken leaf regarded by OYAMA (1954) as *Glossozamites* cf. *hoheneggeri* from the Upper Jurassic Oginohama Formation may belong to *Zamites nipponicus*.

Zamites sp. A

(Pl. 7, figs. 4–5)

Material: NSM PP-8255 (Aratozawa). *Occurrence*: Very rare.

Description: Obtained are two detached pinnae on a slab, which are wedge-shaped, asymmetrical at base, 5.7–7 cm long and up to 1.7 cm wide; an apical half is narrowing to the obtusely pointed apex and the acroscopic base is rounded, but not forming an auricle. Veins are indistinct.

Remarks: Judging from these detached pinnae with asymmetrically rounded base, it is highly probable that our pinnae belong to those of unknown *Zamites* species.

Zamites sp. B

(Fig. 14)

Material: NSM PP-8256 (Aratozawa). *Occurrence*: Very rare.

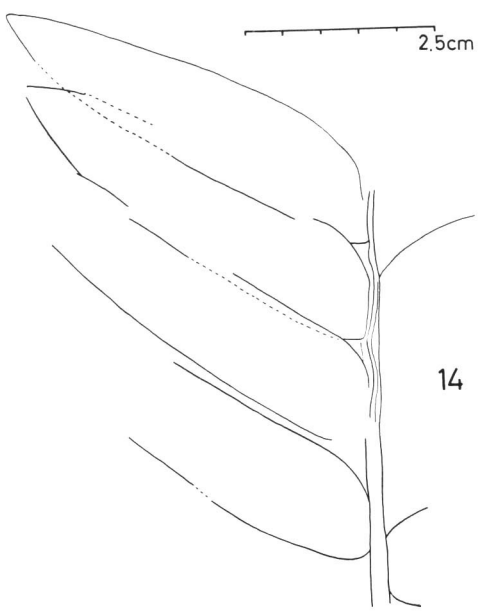


Fig. 14 (Natural size).
Zamites sp. B (NSM PP-8256). Loc. Aratozawa.

Description: A single broken leaf with oblong pinnae is obtained. Pinnae are set closely, imbricated, 5.5 cm long and up to 1.3 cm wide, abruptly narrowing to the obtusely pointed apex and with rounded base. Veins are invisible.

Remarks: Our leaf is characterized by its large-sized oblong pinnae and is different in pinna form from those of *Zamites nipponicus* and *Z.* sp. A described in this paper.

Our pinnae also resemble in form those of *Pseudoctenis brevipennis* OISHI described in next paper, but it is difficult to make the comparison of our leaf with those of the latter species because of ill-preservation of our leaf. Unavoidably we provisionally regard our leaf as *Zamites* sp. B.

Explanation of Plates

Plate 1 (All natural size):

Fig. 1. *Gleichenites*? sp. A (NSM PP-8147). Loc. Shidasawa.
Fig. 2. *Eboracia microlobifolia* KIMURA et OHANA (NSM PP-8170). Loc. Aratozawa.
Figs. 3–5. *Sphenopteris elegans* (YOKOYAMA) OISHI. 3 (NSM PP-8194), 4 (NSM PP-8192), 5 (NSM PP-8199). Loc. Bunasaka.
Fig. 6. *Matonidium* ex gr. *goepperti* (ETTINGSHAUSEN) SCHENK (NSM PP-8159). Loc. Shidasawa.
Fig. 7. *Cladophlebis* sp. cf. *C. virginiensis* FONTAINE (NSM PP-8220). Loc. Aratozawa.

Plate 2 (All natural size):

Figs. 1–4. *Matonidium* ex gr. *goepperti* (ETTINGSHAUSEN) SCHENK. 1 (NSM PP-8161; A-B show the basal arms), 2 (NSM PP-8159), 3 (NSM PP-8165), 4 (NSM PP-8163). Loc. Shidasawa.
Figs. 5–7. *Cladophlebis acutipennis* OISHI. 5 (NSM PP-8203), 6 (NSM PP-8204). Loc. Bunasaka. 7 (NSM PP-8201). Loc. Aratozawa.
Fig. 8. *Cladophlebis* sp. cf. *C. matonioides* OISHI (NSM PP-8211). Loc. Aratozawa.
Fig. 9. *Cladophlebis* sp. A (NSM PP-8230). Loc. Aratozawa.
Figs. 10–11. *Cladophlebis* sp. B. 10 (NSM PP-8238), 11 (NSM PP-8237). Loc. Bunasaka.
Fig. 12. *Acrostichopteris*? sp. (NSM PP-8240). Loc. Bunasaka.

Plate 3 (All natural size):

Figs. 1–9. *Eboracia microlobifolia* KIMURA et OHANA. 1–3: Sterile leaf-fragments. 1 (NSM PP-8189), 2 (NSM PP-8188), 3 (NSM PP-8171). 4–9: Leaf fragments each with both sterile and fertile parts. 4 (NSM PP-8174), 5 (NSM PP-8184), 7 (NSM PP-8172), 8 (NSM PP-8184), 9 (NSM PP-8173). Loc. Aratozawa. 6 (NSM PP-8175). Loc. Bunasaka.
Fig. 10. *Cladophlebis* sp. cf. *C. virginiensis* FONTAINE (NSM PP-8221). Loc. Aratozawa.

Plate 4 (All natural size):

Fig. 1. *Gleichenites*? sp. A (NSM PP-8150). Loc. Shidasawa.
Figs. 2–5. *Cladophlebis* sp. cf. *C. virginiensis* FONTAINE. 2 (NSM PP-8228), 3 (NSM PP-8214), 4 (NSM PP-8216), 5 (NSM PP-8219). Loc. Aratozawa.

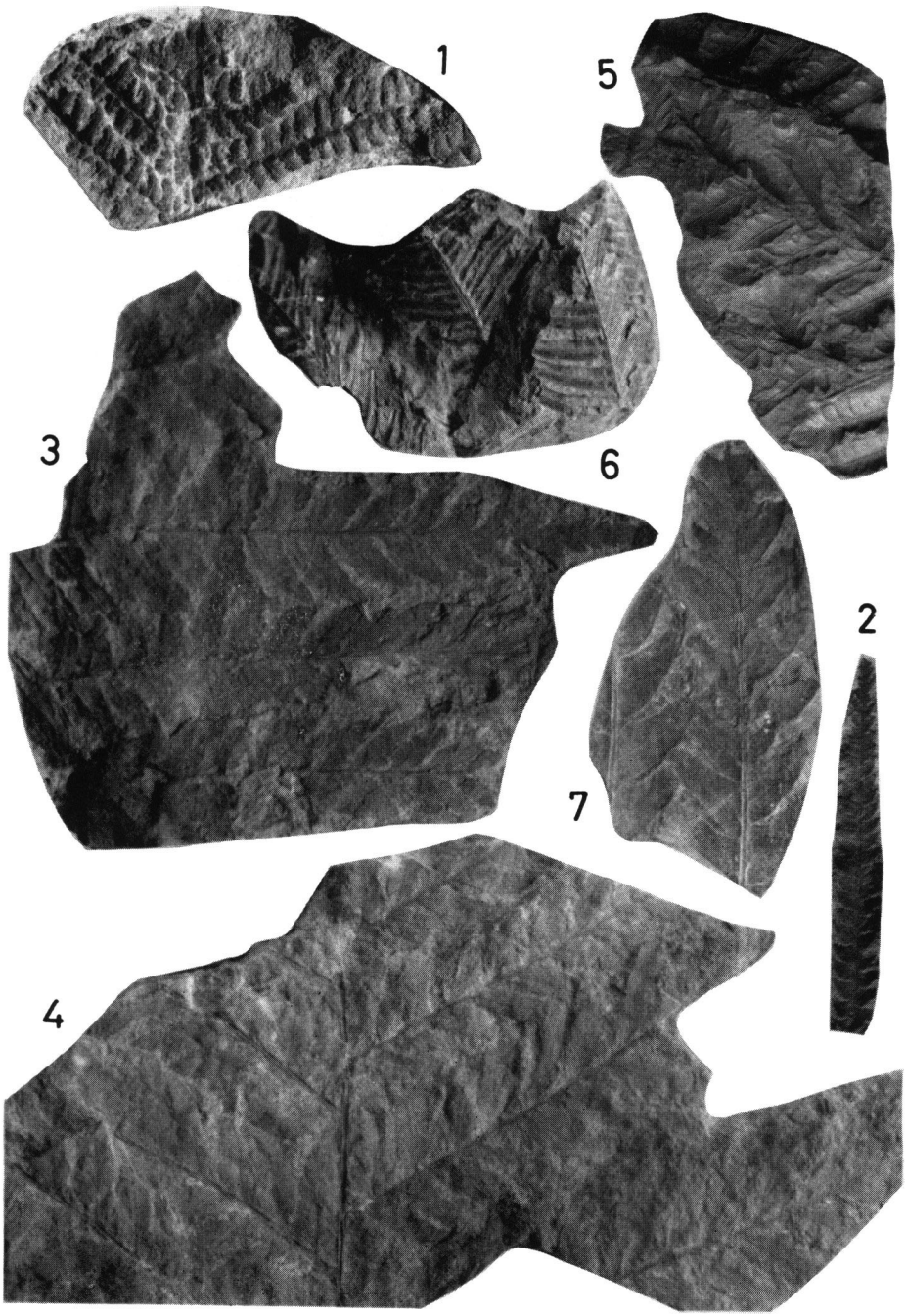
Plate 5 (All natural size):

Fig. 1. *Gleichenites*? sp. A (NSM PP-8148). Loc. Shidasawa.
Figs. 2–3. *Cladophlebis* sp. cf *C. matonioides* OISHI. 2 (NSM PP-8208). Loc. Aratozawa. 3 (NSM PP-8207). Loc. Shidasawa.

Figs. 4–6. *Cladophlebis* sp. A. 4 (NSM PP-8233), 5 (NSM PP-8231), 6 (NSM PP-8232). Loc. Aratozawa.
Fig. 7. *Cladophlebis* sp. B (NSM PP-8236). Loc. Bunasaka.

Plate 6 (All natural size):
Fig. 1. *Zamites* sp. cf. *Z. megaphyllus* (PHILLIPS) SEWARD. (NSM PP-8420). Loc. Aratozawa.
Figs. 2–3. *Zamites nipponicus* KIMURA et OHANA sp. nov. 2 (NSM PP-8246; paratype), 3 (NSM PP-8245; holotype). Loc. Bunasaka.

Plate 7 (All natural size):
Figs. 1–2. *Zamites* sp. cf. *Z. megaphyllus* (PHILLIPS) SEWARD. 1 (NSM PP-8419), 2 (NSM PP-8421). Loc. Aratozawa.
Figs. 3. *Zamites nipponicus* KIMURA et OHANA sp. nov. (NSM PP-8251). Loc. Bunasaka.
Figs. 4–5. *Zamites* sp. A (NSM PP-8255). Loc. Aratozawa.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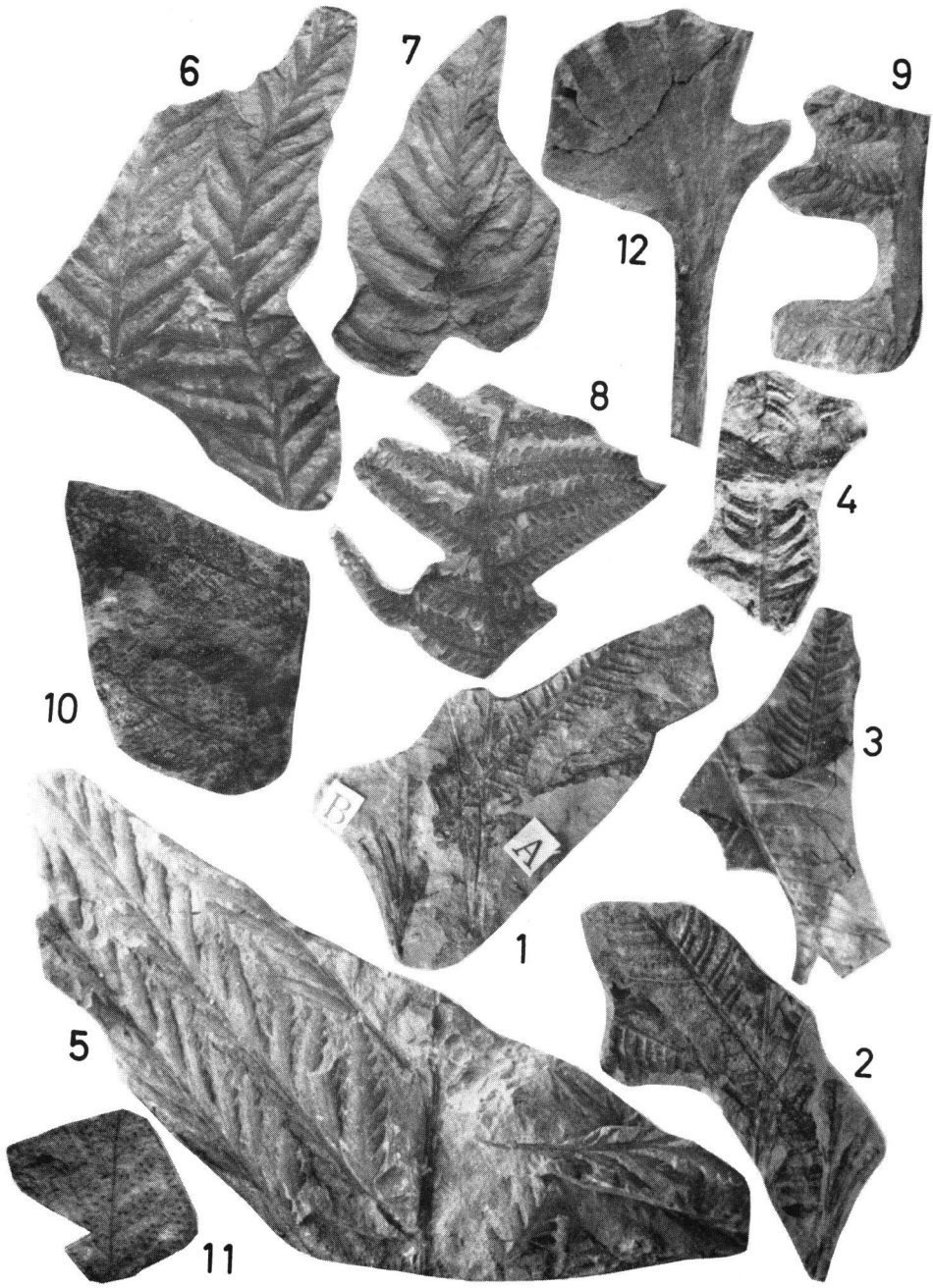
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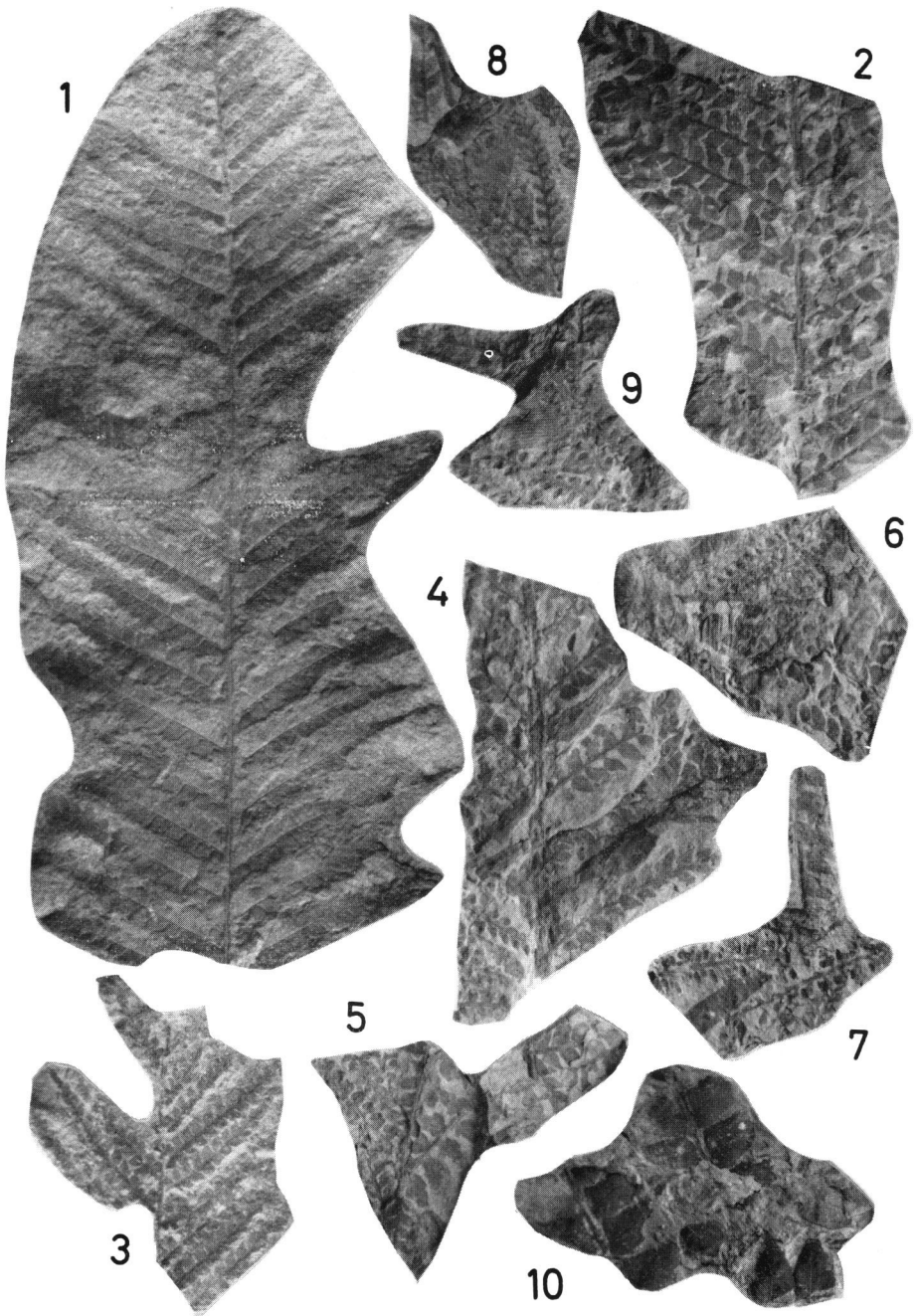
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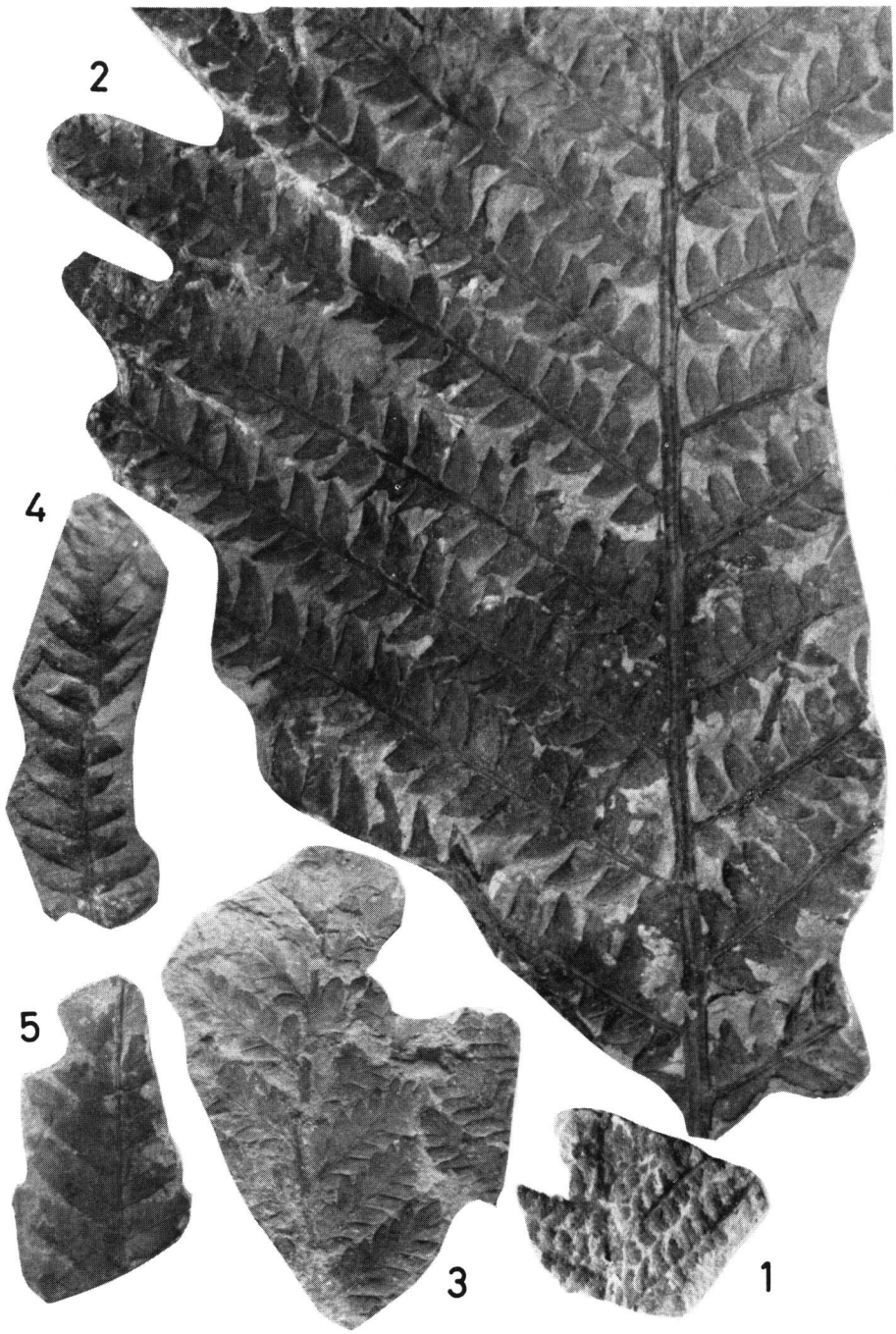
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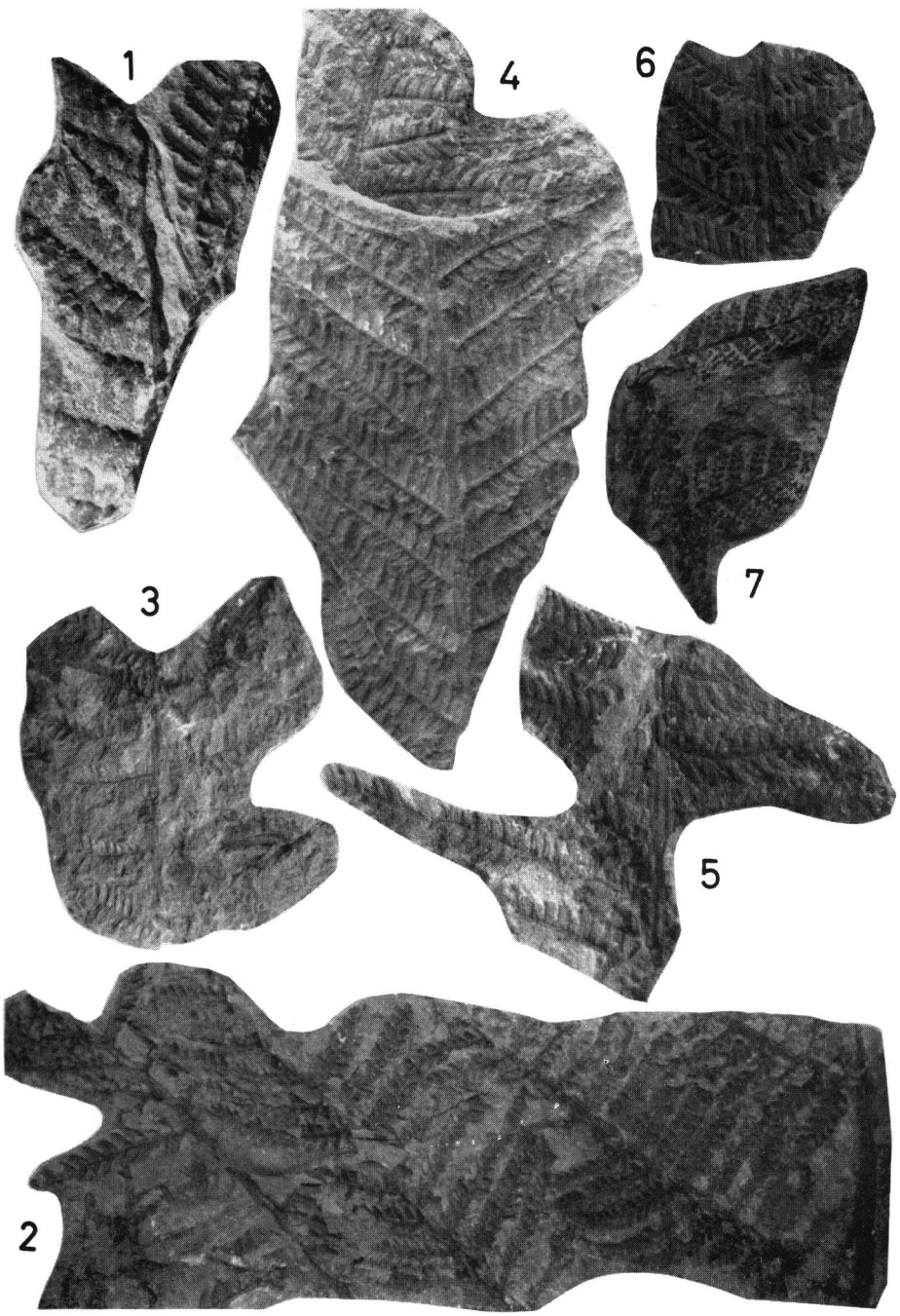
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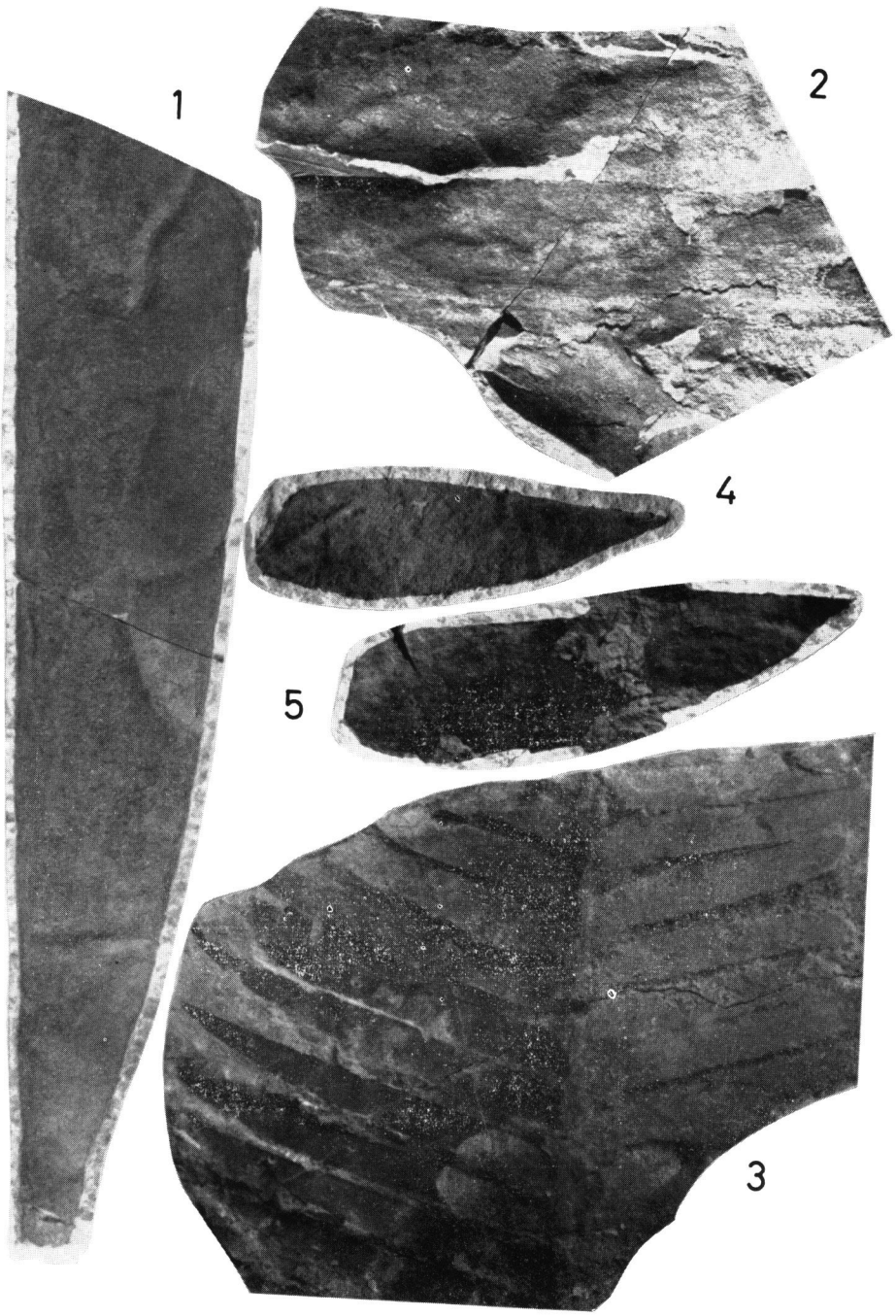
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