Bull. Natn. Sci. Mus., Ser. C (Geol.), 4 (3), Sept. 22, 1978

Early Cretaceous Plants from the Yuasa District and the Aridagawa Valley, Wakayama Prefecture, in the Outer Zone of Japan Part 1

By

Tatsuaki KIMURA

Tokyo Gakugei University, Koganei, Tokyo 184

and

Yoshiyuki KANSHA

Nippon Koei Co. Ltd., Sendai 980

Introductory Notes

Good development not only of the Lower Cretaceous strata but also of the Upper Cretaceous ones is found along the coast of the Yuasa district and its adjacent valley of the Aridagawa, Wakayama Prefecture in the Outer Zone of Japan. The area has much been investigated by many geologists and the fossils were described by many palaeontologists (for details, see MATSUMOTO *et al.*, 1953).

As to the Lower Cretaceous strata, the succession in descending order (depending mainly on MATSUMOTO, 1947) as shown in Table 1, is generally accepted.

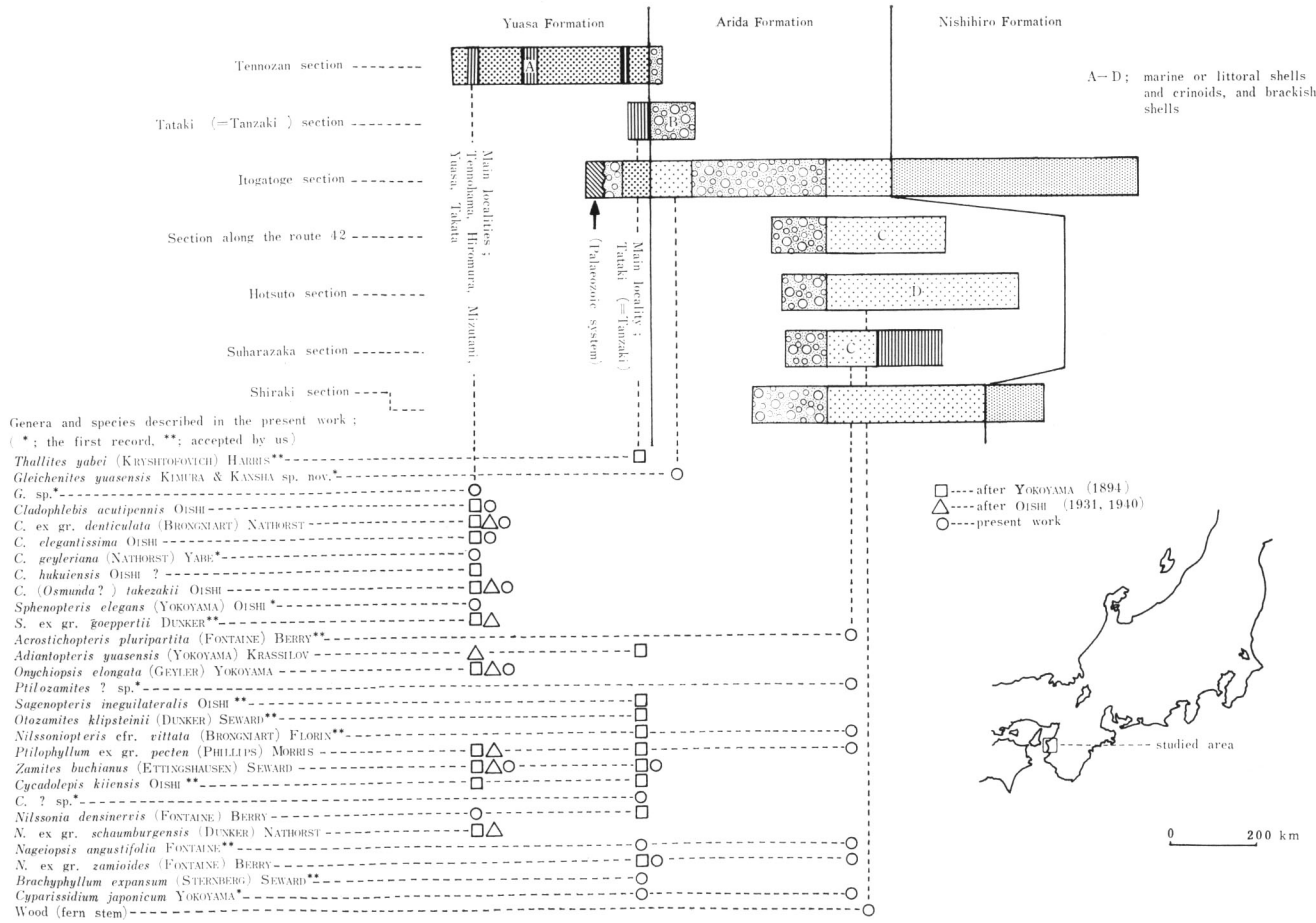
Depending on rich animal fossils contained, the Yuasa, the Arida and the Nishihiro Formations are dated as the early Neocomian (Berriasian—Valanginian), the late Neocomian (Hauterivian—Barremian) and the Aptian–Albian respectively.

Fairly rich plant fossils have long been known (YOKOYAMA, 1894; NAGAO, 1926; YABE, 1927; OISHI, 1931, 1940). In addition, some wood remains were described by

Table 1. The brief succession of the Lower Cretaceous in this area.

Upper Cretaceous System
——————fault——————
Nishihiro Formation (Izeki Formation in the southern part of this area);
Indeterminable plants; shallow sea or littoral shells, and brackish shells.
——————disconformity——————
Arida Formation; 200–300 m thick.
Plants; neritic echinoids and shells including ammonites indicating Barremian age; stromatopoda and *Cidaris* in a black leef-limestone intercalated.
Yuasa Formation; ca 100 m thick.
Plants; brackish, littoral and shallow sea shells; a fresh water ostracod.
——————unconformity——————
Palaeozoic System

Table 2. Stratigraphical sections in the Yuasa district and the Aridagawa valley, and the occurrence of fossil plants (KIMURA & KANSHA, 1978)



ENDO (1926) and OGURA (1927).

In 1972, one of us, KANSHA collected many specimens from various localities in this area and showed the stratigraphical position of these localities as shown in Table 2.

This paper deals with the description of the new material and with revision of previous works except wood remains.

Previous Works in Palaeobotany

In 1894, YOKOYAMA described the following species from Yuasa. This locality is now supposed to correspond to the lower plant-bed of the Yuasa Formation. (At the right are the revised plant names accepted in the present work).

Chladophlebis nathorsti YOKOYAMA	=*Cladophlebis* ex gr. *denticulata* (BRONGNIART) NATHORST
Pecopteris geyleriana NATHORST	=*C. geyleriana* (NATHORST) YABE
Pteris (?) sp.	=*C.* (*Osmunda* ?) *takezakii* OISHI
Sphenopteris tenuicula YOKOYAMA	=*Sphenopteris* ex gr. *goeppertii* DUNKER
Adiantites yuasensis YOKOYAMA	=*Adiantopteris yuasensis* (YOKOYAMA) KRASSILOV
Onychiopsis elongata (GEYLER) YOKOYAMA	
Zamiophyllum buchianum (ETTINGSHAUSEN) NATHORST	=*Zamites buchianus* (ETTINGSHAUSEN) SEWARD
Z. buchianum (ETTINGSHAUSEN) var. *angustifolia* FONTAINE	=Ditto
Z. naumanni NATHORST	=Ditto
Glossozamites parvifolius YOKOYAMA	=indeterminable
Nilssonia pterophylloides YOKOYAMA (non NATHORST)	=*Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS
N. schaumburgensis DUNKER	=*Nilssonia* ex gr. *schaumburgensis* (DUNKER) NATHORST
Torreya venuta YOKOYAMA	=indeterminable

In 1926, depending on OISHI's identification, NAGAO recorded the following species, without either illustration or description, from Takata. This locality may correspond to the lower plant-bed of the Yuasa Formation. They may be revised as shown at the right.

Cladophlebis browniana (DUNKER) SEWARD	=(pars) *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.
	=(pars) *Cladophlebis geyleriana* (NATHORST) YABE
Ruffordia goepperti (DUNKER) SEWARD	=*Sphenopteris* ex gr. *goeppertii* DUNKER
Acrostichopteris longipennis FONTAINE	=*Acrostichopteris pluripartita* (FONTAINE) BERRY
Onychiopsis mantelli (BRONGNIART)	=*Onychiopsis elongata* (GEYLER)

NATHORST YOKOYAMA

In 1927, depending also on OISHI's identification, YABE listed the following species from Tennohama, Mizutani and Takata. These localities may correspond to the lower plant-bed of the Yuasa Formation. These species except ones with asterisk cited by YABE after YOKOYAMA, may also be revised as shown at the right.

Cladophlebis browniana (DUNKER) SEWARD	=(pars) *Gleichenites yuasensis* KIMURA et KANSHA sp. nov. =(pars) *Cladophlebis geyleriana* (NATHORST) YABE
C. nathorsti YOKOYAMA	=*C.* ex gr. *denticulata* (BRONGNIART) NATHORST
Sphenopteris goepperti DUNKER	=*Sphenopteris* ex gr. *goeppertii* DUNKER
Adiantites yuasensis YOKOYAMA	=*Adiantopteris yuasensis* (YOKOYAMA) KRASSILOV
Acrostichopteris cfr. *longipennis* FONTAINE	=*Acrostichopteris pluripartita* (FONTAINE) BERRY
Onychiopsis elongata (GEYLER) YOKOYAMA	
O. psilotoides (STOKES et WEBB) WARD	=*Onychiopsis elongata* (GEYLER) YOKOYAMA
Hausmannia (?) sp.	=?
Zamiophyllum buchianum (ETTINGSHAUSEN) NATHORST	=*Zamites buchianus* (ETTINGSHAUSEN) SEWARD
Glossozamites parvifolius YOKOYAMA*	=indeterminable
Nilssonia 'pterophylloides' YOKOYAMA (non NATHORST)	=*Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS
Ptilophyllum pecten L. et H.	=Ditto
Nilssonia schaumburgensis (DUNKER) NATHORST	=*Nilssonia* ex gr. *schaumburgensis* (DUNKER) NATHORST
Podozamites lanceolatus L. et H.	=?
Torreya YOKOYAMA*	=indeterminable

On the same time, YABE illustrated *Ptilophyllum cutchense* FEISTMANTEL obtained from Yuasa (pl. 3, fig. 3). This specimen should now be included in our *Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS and its locality may correspond to the lower plant bed of the Yuasa Formation.

In 1931, OISHI described the following species from Takata, with the alteration of his previous identification in NAGAO (1926) and YABE (1927).

Equisetites sp.	
Cladophlebis browniana (DUNKER) SEWARD	=(pars) *Gleichenites yuasensis* KIMURA et KANSHA sp. nov. =(pars) *Cladophlebis geyleriana* (NATHORST) YABE
Cladophlebis ? sp.	
Sphenopteris goepperti DUNKER	=(pars) *Sphenopteris* ex gr. *goeppertii*

	DUNKER
	=(pars) *Acrostichopteris pluripartita* (FONTAINE) BERRY
Onychiopsis psilotoides (STOKES et WEBB) WARD	=*Onychiopsis elongata* (GEYLER) YOKOYAMA
Carpolithes sp.	

In his monograph regarding the Mesozoic floras of Japan, OISHI (1940) described the following species from various localities in this area. The stratigraphical position of these localities is shown in Table 2. (At the right are the revised names accepted in the present work).

Marchantites yabei KRYSHTOFOVICH	=*Thallites yabei* (KRYSHTOFOVICH) HARRIS
Cladophlebis acutipennis OISHI	
C. denticulata (BRONGNIART)	=*Cladophlebis* ex gr. *denticulata* (BRONGNIART) NATHORST
C. elegantissima OISHI	
C. exiliformis (GEYLER) OISHI	=(pars) *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.
	=(pars) *Cladophlebis geyleriana* (NATHORST) YABE
C. hukuiensis OISHI	=*C. hukuiensis* OISHI ?
C. takezakii OISHI	=*C.* (*Osmunda* ?) *takezakii* OISHI
Sphenopteris goepperti DUNKER	=(pars) *Sphenopteris* ex gr. *goeppertii* DUNKER
	=(pars) *Acrostichopteris pluripartita* (FONTAINE) BERRY
S. sp.	
Adiantites toyoraensis OISHI ?	=?
A. yuasensis YOKOYAMA	=*Adiantopteris yuasensis* (YOKOYAMA) KRASSILOV
Onychiopsis elongata (GEYLER) YOKOYAMA	
Sagenopteris ? *inequilateralis* OISHI	=*Sagenopteris inequilateralis* OISHI
Otozamites klipsteini (DUNKER) SEWARD	
Ptilophyllum pecten (PHILLIPS) MORRIS	=*Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS
Zamiophyllum buchianum (ETTINGSHAUSEN) NATHORST	=*Zamites buchianus* (ETTINGSHAUSEN) SEWARD
Cycadolepis kiiensis OISHI	
Nilssonia densinerve (FONTAINE) BERRY	=*Nilssonia densinervis* (FONTAINE) BERRY
N. orientalis HEER	=*Nilssoniopteris* cfr. *vittata* (BRONGNIART) FLORIN
N. schaumburgensis (DUNKER) NATHORST	=*Nilssonia* ex gr. *schaumburgensis* (DUNKER) NATHORST

Podozamites lanceolatus (LINDLEY et HUTTON)	=(probably) *Nageiopsis angustifolia* FONTAINE
Nageiopsis zamioides FONTAINE	=*N.* ex gr. *zamioides* (FONTAINE) BERRY

List of Species

The following is a list of species hitherto discriminated, based upon our new material (with one asterisk), together with those by the previous authors accepted by us in the present work (two asterisks).

Thallophyta; *Thallites yabei* (KRYSHTOFOVICH) HARRIS**

Filicales, Gleicheniaceae; *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.*, *G.* sp.*

Unclassified ferns; *Cladophlebis acutipennis* OISHI, *C.* ex gr. *denticulata* (BRONGNIART) NATHORST, *C. elegantissima* OISHI, *C. geyleriana* (NATHORST) YABE*, *C. hukuiensis* OISHI?, *C.* (*Osmunda?*) *takezakii* OISHI, *Sphenopteris elegans* (YOKOYAMA) OISHI*, *S.* ex gr. *goeppertii* DUNKER**, *Acrostichopteris pluripartita* (FONTAINE) BERRY*, *Adiantopteris yuasensis* (YOKOYAMA) KRASSILOV, *Onychiopsis elongata* (GEYLER) YOKOYAMA

Pteridospermales including Caytoniales; *Ptilozamites*? sp.*, *Sagenopteris inequilateralis* OISHI**

Bennettitales; *Otozamites klipsteinii* (DUNKER) SEWARD**, *Nilssoniopteris* cfr. *vittata* (BRONGNIART) FLORIN*, *Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS, *Zamites buchianus* (ETTINGSHAUSEN) SEWARD, *Cycadolepis kiiensis* OISHI**, *C.*? sp.*

Cycadales; *Nilssonia densinervis* (FONTAINE) BERRY, *N.* ex gr. *schaumburgensis* (DUNKER) NATHORST**

Unclassified conifers; *Nageiopsis angustifolia* FONTAINE*, *N.* ex gr. *zamioides* (FONTAINE) BERRY, *Brachyphyllum expansum* (STERNBERG) SEWARD*, *Cyparissidium japonicum* YOKOYAMA*

Characteristic of the Flora and Comparison with Other Floras

As shown in Table 2, it is now clear that YOKOYAMA's specimens were from the lower plant-bed of the Yuasa Formation and OISHI's specimens from both the lower and the upper plant-beds of the formation. In addition we found three plant-beds in the Arida Formation in which the lower and the upper ones yielded only *Gleichenites yuasensis* and fern stems respectively. The middle plant bed is fairly fossiliferous. Besides the above, in this area ENDO described *Tempskya* sp. and OGURA orignially described *Cyathocaulis naktongensis* and included ENDO's *Tempskya* sp. in it. Unfortunately we do not know their exact stratigraphical horizons.

We could not find the determinable plants from the Nishihiro Formation.

In our view, determinable fossil plants in this area are now restricted to the Yuasa and the Arida Formations.

It is clear that the plant assemblage in this area is quite similar in composition to that of the early Cretaceous flora of the 'Wealden' type in the Outer Zone of Japan (see KIMURA & HIRATA, 1975, p. 68, fig. 1). So far as the discriminated species in this area are concerned, it is difficult to see any significant difference in floral composition between the Yuasa and the Arida Formations, except that such unclassified ferns as *Cladophlebis* and *Sphenopteris* which are common in the Yuasa Formation, have not been found from the Arida Formation.

We thus conclude that no marked change of vegetation took place during the Neocomian age in this area. The same was mentioned in detail by KIMURA and HIRATA (1975) in the Lower Cretaceous sequence of Kochi Prefecture, the type sequence of the early Cretaceous flora in the Outer Zone of Japan.

As repeatedly mentioned by KIMURA (1961, 1975a, b), KIMURA and HIRATA (1975), KIMURA and ASAMA (1975), etc., the late Jurassic to the early Cretaceous flora in the Outer Zone of Japan differs in floral composition from the coeval floras in the Inner Zone of Japan. Actually among the species discriminated here in this area, only *Thallites yabei, Adiantopteris yuasensis* and *Onychiopsis elongata* are common between both floras. Although an unclassified fern regarded as *Cladophlebis* ex gr. *denticulata* has been known in both floras, its detailed feature is quite different from one another due to its locality.

As was already mentioned by KIMURA (1975a, b), during the late Jurassic and the early Cretaceous time, the Outer Zone of Japan corresponds to the East Asiatic Province in the Indo-European Palaeofloristic Area proposed by VAKHRAMEEV (1964, 1966, 1971), and the Inner Zone of Japan would represent the southern margin of his Siberian Palaeofloristic Area together with Northeastern China and South Korea.

Then the difference of the floras in composition between the Outer and the Inner Zone of Japan would be due to that of the edaphic condition between both zones or palaeofloristic areas.

Acknowledgements

We first express our sincere gratitude to Professor Emeritus Thomas M. HARRIS F.R.S., of the University of Reading for his very helpful suggestions and kindest reading over the present manuscript.

We are indebted to Dr. Kazuo ASAMA, Director of the Department of Geology, National Science Museum, Tokyo for giving us the facilities to publish this paper. We also give our thanks to Miss Tamiko OHANA, a graduate student of the Tokyo Gakugei University for her kind help in drawing the figures in this paper.

Systematic Description

Unfortunately no cuticle or organic material is preserved in the present material. The specimens here described are all deposited in the National Science Museum, Tokyo.

Thallophyta

Form-genus *Thallites* WALTON, 1925: 564

Thallites yabei (KRYSHTOFOVICH) HARRIS

Sagenopteris bilobata YABE var. *major* YABE; 1905, p. 41, pl. 3, fig. 6a (non figs. 6b, 6c) (Nagdong Group, Korea).

Marchantites yabei KRYSHTOFOVICH; 1929, p. 145, pl. 15, fig. 3 (Aptian Lypovetz Formation, Suifun Basin); OISHI, 1940, p. 183, pl. 1, fig. 1 (Kuwashima, Oguchi Formation).

Thallites yabei (KRYSHTOFOVICH) HARRIS, 1942 (nomenclature); LUNDBLAD, 1955, p. 31 (comparison); KRASSILOV, 1967, p. 97, pl. 4, fig. 4 (Lypovetz Formation).

Horizon: Yuasa Formation (Lower bed).

Occurrence: Probably rare.

Distribution: Lower Cretaceous of Southern Primorye, South Korea, Inner Zone of Japan and the Yuasa Formation.

Filicales

Gleicheniaceae

Genus *Gleichenites* GOEPPERT, 1836: 172

Gleichenites yuasensis KIMURA et KANSHA sp. nov.

Pl. 1, figs. 1–2; Pl. 2, fig. 1; Pl. 3, fig. 1; Pl. 4, fig. 1; Fig. 1a–e

Pecopteris geyleriana NATHORST (pars); 1890, p. 8, pl. 4, fig. 6; figs. 3–5 (fertile pinnae or pinnules?) (Kataji, Ryoseki Group).

Pecopteris exilis GEYLER or *P. geyleriana* NATHORST; 1890, p. 8, pl. 4, fig. 2 (Ditto).

Gleichenites nipponensis OISHI (pars); 1940, p. 202, pl. 3, fig. 2 (non figs. 3, 3a) (Kaisekiyama, Ryoseki Group).

Holotype; NSM–PP–7224.

Diagnosis: Sterile frond probably medium in size, at least tripinnate. Penultimate pinnae set closely, overlapping each other laterally. (whole shape and main rachis unknown). Ultimate pinnae set closely, elongated, nearly parallel-sided, flexible, abruptly narrowing to the acuminate apex, typically 4.5 cm long and 8 mm wide, and attached to the slender axis (2 mm across) at an angle of 55 degrees. Sterile pinnules set closely, katadromic in order, elongated or elongate-triangular or triangular in form, sometimes falcate, narrowing gradually towards the acutely or rarely bluntly pointed apex, attached by whole base to the slender pinna axis at an angle of 40–45 degrees, typically 5.5 mm long and 1.8 mm wide; midnerve persisting to the tip. (secondaries invisible).

Fertile frond at least tripinnate. (whole shape and main rachis unknown). Penultimate pinnae set closely, overlapping each other laterally and with rather thick axis, 2.5 mm across. Ultimate pinnae set closely, linear, often bending upwards, typically 4–4.5 cm long and 3.5 mm wide. Fertile pinnules set closely, semicircular, triangular or often rhomboidal in form, typically 2 mm in diameter, with acutely pointed

apex; sori ca 1 mm in diameter, with prominent placenta, one on the centre of each pinnule. (detail of sorus not known).

Description: According to our examination on many specimens obtained, fertile and sterile penultimate pinnae appear to be separated each other, but are always in close association in occurrence.

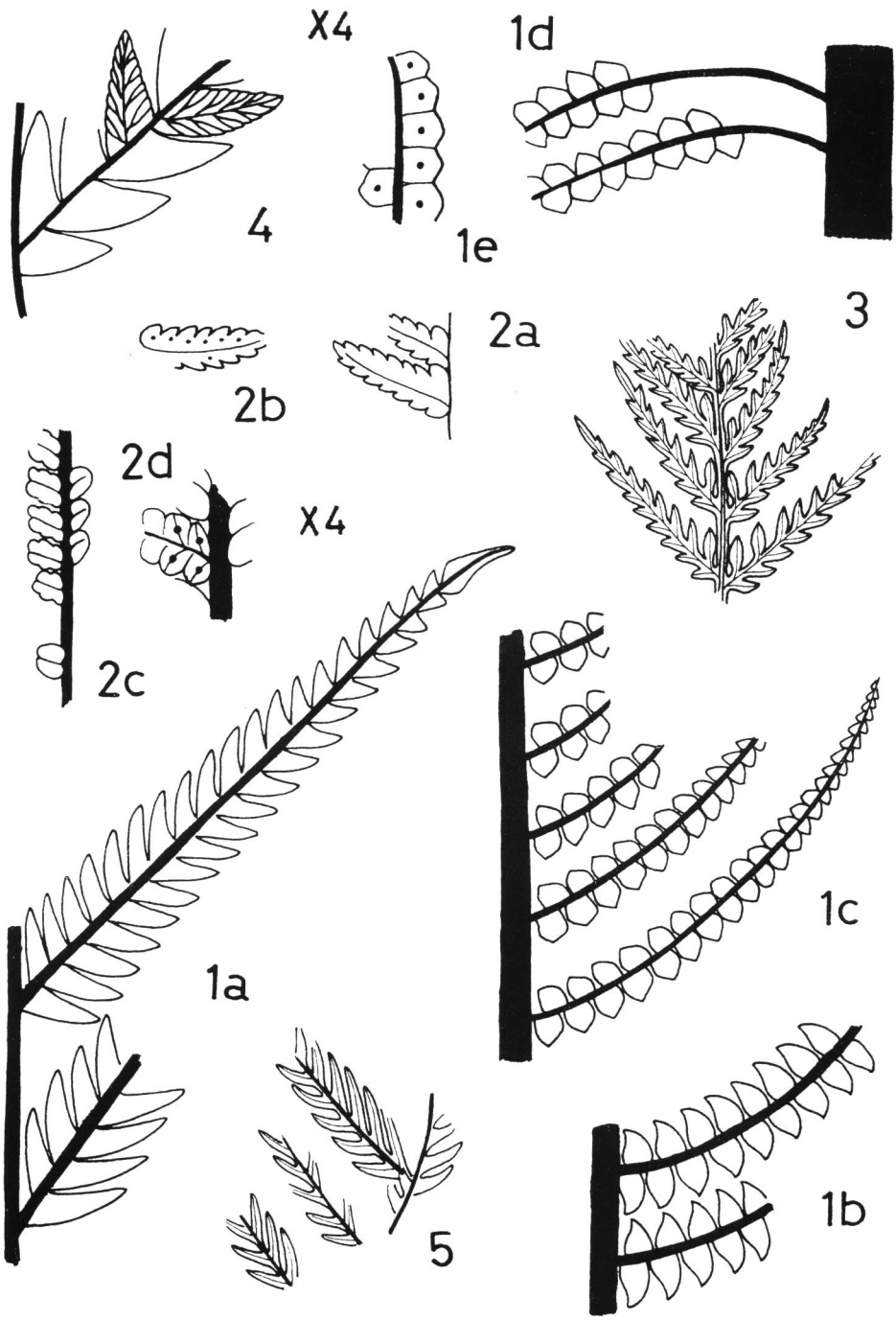
In the present material, both fertile and sterile pinnae are disposed in the same architecture except that the axes of fertile pinnae are more thicker than those of sterile. In other words, external difference between fertile and sterile pinnae is only that of the length of pinnules, that is, much reduced sterile pinnules in length would make the fertile ones.

Plate 1, figure 1 (holotype) shows a part of sterile penultimate pinna on which the above diagnosis of sterile leaves is mainly based, and a part of fertile one in close association. In the present species some sterile pinnules would remind us of *Gleichenites gieseckianus* in general outline as shown in Pl. 1, fig. 2 and Fig. 1b. But judging from their occurrence in close association with other normal ones, we feel sure that they represent the deformed or twisted sterile pinnules of *G. yuasensis*. Plate 2, figure 1 shows a part of sterile penultimate pinna with twisted pinnules in which a slender pinna axis is clearly seen. Plate 4, figure 1 shows a part of penultimate pinna enlarged partly from the paratype, clearly representing the same architecture as the sterile ones. In this specimen, fertile pinnae appear to be set remotely, but the pinna interval is similar to that of the sterile. Plate 3, figure 1 shows four fertile pinnae with rather thick axis, in which the trace of central placenta on each pinnule is clearly seen. Figure 1 (a–e) shows the outline of sterile and fertile pinnules in detail and the position of placentae.

Comparison and remarks: Judging from its general outline of fertile pinnules and its placentae around which imprints of sporangia are seen, we feel sure that this species belongs to Gleicheniaceae. But unfortunately we could not make out sporangial details in spite of our repeated trials of balsam transfers, because of ill-preservation.

This species resembles closely *Gleichenites nipponensis* known mainly from the Tetori Supergroup, in the Inner Zone of Japan and the Lo-tzu-kou Group, NE-China, but it is distinguishable from the latter in the following points;

1) In both species fertile pinnules are rather similar in outline, but the sterile pinnules are different from each other; in *Gleichenites nipponensis*, sterile pinnules are of typical *Pecopteris* type, quadrilateral or finger shaped in outline with broadly rounded apices, but in the present species they are elongate-triangular or triangular in outline with acutely pointed apices as shown in Fig. 1a–b. 2) In *G. nipponensis*, both fertile and sterile pinnules are often mixed on the same pinna (KIMURA & SEKIDO, MS), but not so in the present species. In the present species, both fertile and sterile pinnae appear to be separated independently, at least in the order of penultimate pinna. 3) In *G. nipponensis*, sori are commonly distributed as one on the centre of each first lateral nerve (KIMURA & SEKIDO, MS), but in the present species sori are


X4
1d
4
1e
3
2a
2b
2d
X4
2c
1a
1c
1b
5

unexceptionally located as one on the centre of each fertile pinnule. 4) In *G. nipponensis*, all axes including main rachis are always thick as shown in such specimens as described by OISHI (1941, p. 169, pl. 37, figs. 1, 2) from the Lower Cretaceous of Lo-tzu-kou, by KIMURA (1958, pl. 1, fig. 5 regarded at the time as *Cladophlebis exiliformis*) from the Kuzuryu Group and by KIMURA and SEKIDO (MS, many good specimens) from the Oguchi Formation. In these specimens, main rachis reaches 2 cm across and other ones follow it. But the present species is characterized by rather slender habit of axes, although its main rachis has not been known. Its penultimate pinna axes are less thick than those of *G. nipponensis*, even the maximum one does not exceed 4 mm across.

In the preserved specimens, most of fertile pinnules appear to be semi-circular because of their strongly reflexed distal margin, but they are in fact triangular or pentagonal in outline and with acutely pointed apex as shown in Fig. 1c–e.

So far as the outline of fertile pinnules is concerned, many allied species to the present one have been recorded from the Lower Cretaceous strata in Greenland, India, Patagonia, etc., but we don't identify them because their sterile leaves are unknown to us.

It is sure that a part of NATHORST's specimens regarded by him as *Pecopteris geyleriana* or as *P. exilis* and OISHI's specimens regarded as *Gleichenites nipponensis* both from the Ryoseki Group, Kochi Prefecture, belong to the present species.

Horizon: Arida Formation (Lower bed).

Occurrence: Abundant.

Specimens:

Holotype, NSM–PP 7224;

Paratypes, NSM–PP 7214, 7212, 7213, 7216, 7217, 7218, 7219, 7220, 7222, 7223, 7230, 7233, 7234, 7237, 7239, 7240, 7285.

Figs. 1–5. (All enlarged twice, unless otherwise stated)

1. *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.; 1a. typical sterile pinnae (Holotype, PP–7224), 1b. sterile pinnae with twisted pinnules (PP–7212), 1c. a part of fertile penultimate pinna (PP–7219), 1d. a part of fertile penultimate pinnae, with rather thick axis (PP–7233), 1e. several fertile pinnules, showing their outline and the position of placentae (PP–7230, balsam transfer).
2. *Gleichenites* sp.; 2a. showing the outline of fertile pinnules (PP–7297), 2b. showing the position of placentae (PP–7293), 2c. a part of fertile pinna with strongly reflexed pinnules (PP–7291), 2d. a part of fertile pinnule flattened from 2c, showing the outline of lobes, the venation and the position of placentae.
3. *Cladophlebis acutipennis* OISHI; a part of pinna (or penultimate pinna), showing deeply lobed pinnules (or ultimate pinnae) and the venation (PP–7235).
4. *Cladophlebis* ex gr. *denticulata* (BRONGNIART) NATHORST; a part of sterile pinna, showing the outline of pinnules and the venation (PP–7286).
5. *Cladophlebis elegantissima* OISHI; a part of penultimate pinna with four ultimate pinnae partly piled up, showing the outline of rather remotely set pinnules in which lateral nerves are not visible even by balsam transfer (PP–7262, balsam transfer).

Gleichenites sp.
Pl. 3, figs. 2–5; Fig. 2a–d

Description: Several detached fertile pinna fragments were obtained. Fertile pinnules are set closely, elongate-oblong or elongate-oval in outline, typically 0.9 cm long and 3.5 mm wide at base, slightly falcate, with highly constricted base and bluntly or roundly pointed apex. Laminae are divided into 7 pairs of shallow lobes. Each lobe is attached nearly perpendicularly to the midnerve, then bending forwards. The lobes of a first pair are usually larger in size than others. The tip of lobe is in fact acutely pointed, but in the preserved specimens it appears to be rounded, because of strongly reflexed distal margin of each lobe. Sori are circular in outline, about 1 mm in diameter with a prominent central placenta, one on the centre of each lobe as shown in Fig. 2b, d. Unfortunately, in spite of our repeated trials of balsam transfers, we could not make their structure clear, because of ill-preservation of material.

Plate 3, figures 2–4 show incompletely preserved pinna fragments and Plate 3, figure 5 shows an another fertile pinna fragment in which faintly preserved sori are seen. Figures 2a and 2c show the outline of pinnules.

Remarks: Judging from the faintly preserved sporangia around a prominent placenta on each lobe of pinnule, the present specimens belong to Gleicheniaceae.

The present specimens would be distinguishable from *Gleichenites yuasensis* here described and *G. nipponensis* in the outline of fertile pinnules, but a question whether the present specimens represent the distal part of penultimate pinnae of *G. yuasensis* or not, is raised. We, however, here provisionally regard the present specimens as *Gleichenites* sp., because the direct relation between the present specimens and *G. yuasensis* has not been found, and they occurred from the different horizon.

Horizon: Yuasa Formation (Lower bed).

Occurrence: Rare.

Specimens: NSM–PP 7283, 7288, 7290, 7293, 7297–7299.

Unclassified ferns
Form-genus *Cladophlebis* BRONGNIART, 1849: 105
Cladophlebis acutipennis OISHI
Pl. 2, fig. 2; Pl. 3, fig. 6; Fig. 3

Thyrsopteris sp.; YOKOYAMA, 1894, p. 213, pl. 23, fig. 3 (Fujikawa, Upper Monobegawa Group, Tokushima Prefecture).

Pecopteris cfr. *virginiensis* FONTAINE; YOKOYAMA, 1894, p. 220, pl. 24, fig. 1 (Ditto).

Cladophlebis acutipennis OISHI; 1940, p. 249, pl. 9, figs. 4–6 (Yuasa Formation; Masaki, Upper Monobegawa Group, Tokushima Prefecture); KIMURA, 1976, p. 190, text-fig. 3 (Yatsushiro Formation).

Description: Plate 3, figure 6 shows an ultimate pinna fragment with long and narrow pinnules, typically 2.7 cm long, sometimes flexuous, narrowing gradually towards the acuminated apex. Pinnules are deeply divided into 9–10 pairs of segments; each segment is broadly triangular and directed forwards. Figure 3 shows the outline

of this pinna in detail.

Plate 2, figure 2 shows three pinna fragments piled up one another, bearing long and narrow pinnules with lobes or segments which are deeply dissected and strongly directed forwards. In all specimens of this species obtained, nerves are invisible and fructification has not been found.

Remarks: Judging from their closely associated occurrence, the figured specimens might belong to a same plant and are referable to those originally described by OISHI from the same locality and also to those described by YOKOYAMA as *Thyrsopteris* sp. and *Pecopteris* cfr. *virginiensis* from the Upper Monobegawa Group. The detailed comparison on the present species was already dealt by OISHI (1940, p. 251).

Horizon: Yuasa Formation (Lower bed).

Occurrence: Common.

Distribution: Lower Cretaceous in the Outer Zone of Japan.

Specimens: NSM–PP 7226, 7231, 7235, 7243, 7246, 7250–7252.

Cladophlebis ex gr. *denticulata* (BRONGNIART) NATHORST

Pl. 4, fig. 2; Fig. 4

Cladophlebis sp.; NATHORST, 1890, p. 4, pl. 1, figs. 1–3 (Togodani, Ryoseki Group, Kochi Prefecture).
Cladophlebis nathorsti YOKOYAMA; 1894, p. 220, pl. 28, figs. 3, 4, 10, 11 (Kaisekiyama, Kataji and Ishiseki, Ryoseki Group; Yuasa, Yuasa Formation).

Remarks: Owing to the difficulty to distinguish the present specimens only in external form from those regarded as *Cladophlebis denticulata*, we regard unavoidably the *Cladophlebis* specimens showing the following features as *Cladophlebis* ex gr. *denticulata*; Frond bipinnate, sterile pinnules triangular or broadly deltoid in outline, medium to large in size, often falcate and with several pairs of once forking secondaries.

The present specimens (partly shown in Pl. 4, fig. 2; Fig. 4) agree well with those described by NATHORST and YOKOYAMA from the Lower Cretaceous in the Outer Zone of Japan, but are somewhat different in external form from those from other areas.

The Japanese specimens having regarded as *C. denticulata* are generally far smaller in size of pinnule than the original ones from the Yorkshire Jurassic, but as mentioned above, it is difficult to distinguish the Japanese specimens from those from Yorkshire, because both show the similar figure one another.

Horizon: Yuasa Formation (Lower bed).

Occurrence: Common.

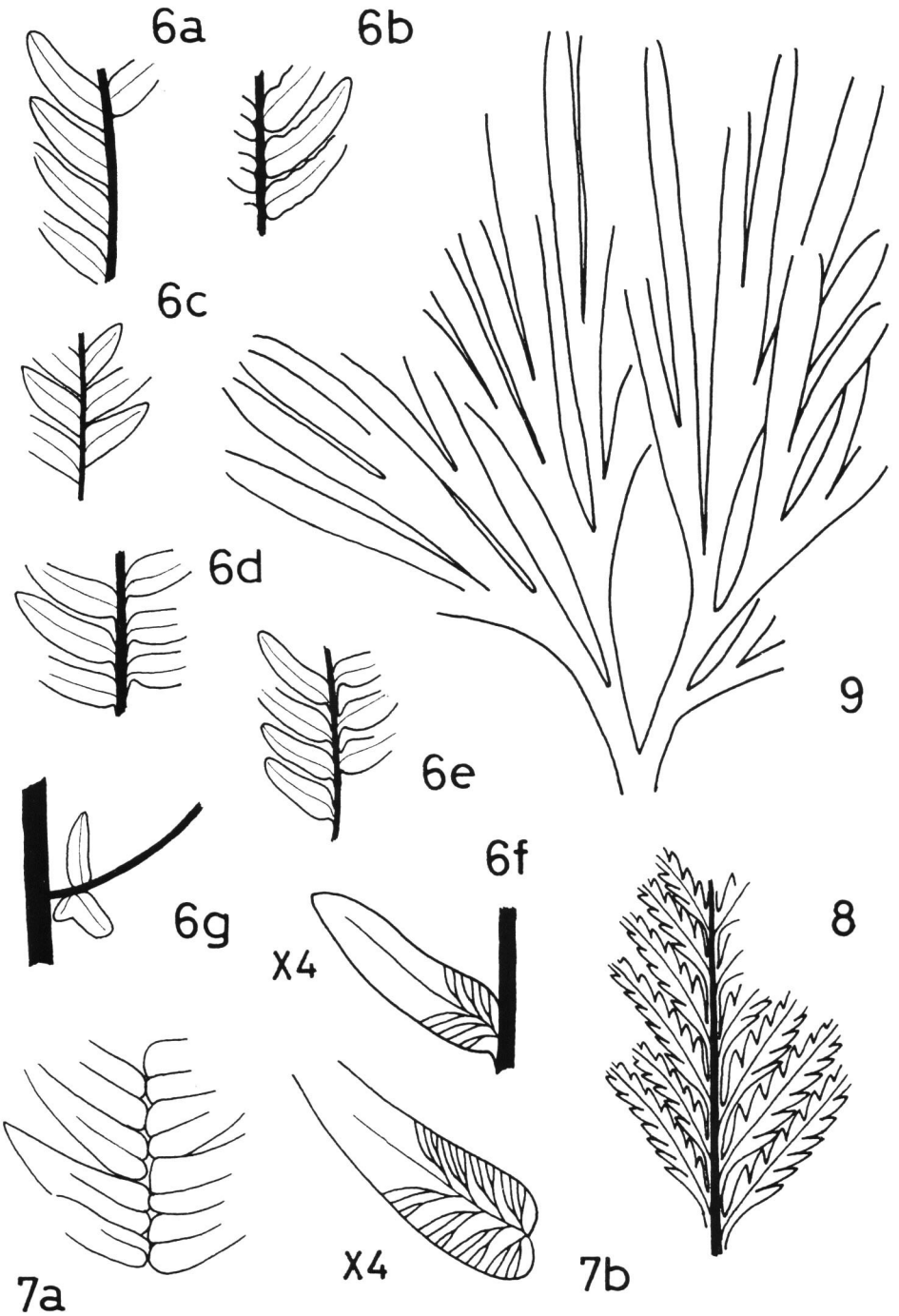
Distribution: Similar forms are common to the Lower Cretaceous in the Outer Zone of Japan.

Specimens: NSM–PP 7228, 7265, 7268, 7286, 7272.

Cladophlebis elegantissima OISHI

Pl. 2, fig. 3; Fig. 5

Cladophlebis elegantissima OISHI; 1940, p. 260, pl. 11, figs. 1, 1a, 1b (Hiromura, Yuasa Formation); KIMURA, 1976, p. 190, pl. 2, fig. 3; pl. 4, fig. 2; text-fig. 4a, b (Yatsushiro Formation).


6a
6b
6c
6d
6e
6f
6g
9
8
X4
X4
7a
7b

Remarks: The present specimens (partly shown in Pl. 2, fig. 3; Fig. 5), though incomplete pinna fragments, agree with the original ones described by OISHI from the same locality. The detailed description and comparison were already given by OISHI (1940) and KIMURA (1976).

The present species is characterized by its long and narrow or elongate-triangular pinnules, but in spite of our repeated trials of balsam transfers, we could not give an additional evidence to the preceding descriptions.

Horizon: Yuasa Formation (Lower bed).

Occurrence: Rather rare.

Distribution: Lower Cretaceous, sporadically in the Outer Zone of Japan.

Specimens: NSM–PP 7262, 7278, 7289.

Cladophlebis geyleriana (NATHORST) YABE

Pl. 2, fig. 4; Pl. 3, figs. 7–8; Fig. 6a–g

Pecopteris geyleriana NATHORST (pars); 1890, p. 8, pl. 4, fig. 1; pl. 6, fig. 1 (Kataji, Ryoseki Formation); YOKOYAMA, 1894, p. 219, pl. 21, fig. 12(?); pl. 23, figs. 1, 1a; pl. 28, fig. 5 (Yuasa, Yuasa Formation; Fujikawa, Upper Monobegawa Group; Kaisekiyama, Ryoseki Group).

Cladophlebis geyleriana (NATHORST) YABE; 1922, p. 7 (nomenclature); KIMURA, 1976, p. 192, pl. 5, fig. 2; pl. 6, fig. 4; text-fig. 5a, b (Yatsushiro Formation).

Cladophlebis exiliformis (GEYLER) OISHI (pars); 1940, p. 261, pl. 14, fig. 1 (Hiromura, Yuasa Formation).

Remarks: This species is characterized by the pinnules which have asymmetrically lobed basal margins, and more or less constricted base, and by broadly deltoid or distinctly bilobed basal basiscopic pinnules as shown in Fig. 6g. KIMURA (1976) recognised this a distinct species.

OISHI (1940) proposed a comprehensive species *Cladophlebis exiliformis* (GEYLER) including *Pecopteris exiliformis* (GEYLER, 1877), *Pecopteris exilis* (YOKOYAMA, 1889), *Pecopteris* (or *Cladophlebis*) *geyleriana, Pecopteris* (or *Cladophlebis*) *browniana, Cladophlebis dunkeri*, etc. However, as the recent results of the studies on a good number of their specimens collected from the Tetori Supergroup, and of their re-examination on OISHI's *Cladophlebis exiliformis*, KIMURA and SEKIDO (MS) showed that in the Tetori Supergroup, *Cladophlebis exiliformis*-type ferns were distinguished into sterile leaves of various ferns as follows; *Gleichenites hakusanensis* (KIMURA et SEKIDO) KIMURA et SEKIDO comb. nov., *G. ishikawaensis* KIMURA et SEKIDO sp. nov.,

Figs. 6–9. (All enlarged twice, unless otherwise stated)

6. *Cladophlebis geyleriana* (NATHORST) YABE; 6a–d. various forms of sterile pinnules on a same frond (PP–7236), 6e. a part of pinna, showing the outline of typical pinnules (PP–7263), 6f. showing the venation, enlarged from one of pinnules shown in 6e, 6g. the outline of bilobed first basiscopic pinnule (PP–7292).
7. *Cladophlebis* (*Osmunda*?) *takezakii* OISHI; 7a. a part of pinna, showing the outline of pinnules (PP–7254), 7b. showing the venation, enlarged from one of pinnules shown in 7a.
8. *Sphenopteris elegans* (YOKOYAMA) OISHI; showing the outline of pinnules with decurrent base (PP–7232).
9. *Acrostichopteris pluripartita* (FONTAINE) BERRY; showing the outline of a detached leaf (PP–7307).

G. nipponensis OISHI, *G. yamazakii* KIMURA et SEKIDO sp. nov., *Klukia okamigoensis* KIMURA et SEKIDO sp. nov., *Birisia alata* (PRYNADA) SAMYLINA and *B. onychioides* (VASSILEVSKAJA et KARA-MURSA) SAMYLINA.

Accordingly, so far as the ferns in the Tetori Supergroup are concerned, OISHI's *Cladophlebis exiliformis* would be invalid, then the same would be likely in the ferns regarded as *C. exiliformis* in the coeval floras of the Outer Zone of Japan, though they might be not common to those from the Tetori Supergroup.

The present specimens (partly shown in Pl. 2, fig. 4; Pl. 3, figs. 7–8; Fig. 6a–g) agree in general outline well with NATHORST's original ones (pl. 4, fig. 1 and pl. 6, fig. 1; but not others).

Horizon: Yuasa Formation (Lower bed).

Occurrence: Common.

Distribution: Lower Cretaceous in the Outer Zone of Japan.

Specimens: NSM–PP 7220, 7222, 7236, 7238, 7241, 7242, 7244, 7247, 7248, 7256, 7257, 7259, 7260, 7263, 7264, 7267, 7269, 7271, 7274, 7287, 7292.

Cladophlebis hukuiensis OISHI?

Comparable specimen:

Cladophlebis hukuiensis OISHI (pars); 1940, p. 267, pl. 16, figs. 1, 1a (Hiromura, Yuasa Formation).

Remarks: A single incomplete pinna fragment was obtained from OISHI's locality. The present specimen differs in general form from some of those described by OISHI (1940, pl. 16, figs. 2–4) and by KIMURA (1958, p. 23, pl. 1, fig. 4; pl. 2, fig. 1; text-fig. 4) from Mochiana, Upper Jurassic Kuzuryu Group and also from the fine specimen from the Mekkodani, Oguchi Formation (KIMURA and SEKIDO, MS).

Accordingly, the identity of the specimens from the present locality with others would be quite questionable. Then, we here provisionally regard the present specimen together with OISHI's one derived from the same locality as *Cladophlebis hukuiensis*?.

Horizon: Yuasa Formation (Lower bed).

Occurrence: Rare.

Specimen: NSM–PP 7336.

Cladophlebis (*Osmunda*?) *takezakii* OISHI

Pl. 3, fig. 9; Fig. 7a–b

Pteris? sp.; YOKOYAMA, 1894, p. 216, pl. 20, fig. 9; pl. 21, figs. 6–7 (Hachimanzawa, Sebayashi Formation; Yuasa, Yuasa Formation).

Cladophlebis takezakii OISHI; 1940, p. 288, pl. 21, figs. 4, 4a (Nishinotani, Lower Monobegawa Group).

Description: A single pinna fragment with several pinnules as shown in Plate 3, figure 9 (Fig. 7a–b in detail), was obtained. The present specimen is referable to those regarded by YOKOYAMA as *Pteris*? sp. from the same locality and later by OISHI as *Cladophlebis takezakii*.

The present pinnules are small-sized, but show strongly their constricted base,

and densely crowded and twice forking lateral nerves both characterizing the present species defined by OISHI.

Remarks: The outline of present pinnules, especially their strongly constricted base reminds us of its belonging to *Osmunda*. Very recently MATSUKAWA collected many good specimens of this species from the Sebayashi Formation (Aptian-Albian in age), Gumma Prefecture, in the Outer Zone of Japan. The detailed description with the emended diagnosis of this species will be given in the near future by KIMURA and MATSUKAWA.

Horizon: Yuasa Formation (Lower bed).

Occurrence: Rare.

Distribution: Lower Cretaceous, sporadically in the Outer Zone of Japan.

Specimen: NSM–PP 7254.

Part II to be continued

Explanation of Plates

Plate 1

Figs. 1–2. *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.; 1. Sterile and fertile (by the arrow) penultimate pinnae in close association (Holotype, PP–7224), ×2. 2. Sterile penultimate pinnae with twisted pinnules (PP–7212), ×2.

Fig. 3. *Acrostichopteris pluripartita* (FONTAINE) BERRY; a detached leaf (PP–7307), ×2.

Fig. 4. *Ptilozamites*? sp.; a part of long and narrow leaf (PP–7276), ×1.

Figs. 5–7. *Nilssoniopteris* cfr. *vittata* (BRONGNIART) FLORIN; 5. An apical part of ribbon-like leaf (PP–7305), ×1. 6. A middle portion of leaf (PP–7313), ×1. 7. Rounded base of lamina and petiole (PP–7331), ×2.

Plate 2

Fig. 1. *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.; a part of penultimate pinna with twisted pinnules (PP–7213), ×2.

Fig. 2. *Cladophlebis acutipennis* OISHI; showing long and narrow pinnules with lobes directed forwards (PP–7226), ×2.

Fig. 3. *Cladophlebis elegantissima* OISHI; a part of penultimate pinna, with tiny pinnules rather set remotely (PP–7262, balsam transfer), ×2.

Fig. 4. *Cladophlebis geyleriana* (NATHORST) YABE; a part of sterile frond torn in pieces and piled up one another, with various pinnules in form (PP–7236), ×1.

Fig. 5. *Sphenopteris elegans* (YOKOYAMA) OISHI; a part of pinna with elongate-oval pinnules with decurrent base (PP–7232), ×2.

Fig. 6. *Nilssonia densinervis* (FONTAINE) BERRY; a tiny leaf-fragment (PP–7280), ×1.

Fig. 7. *Nageiopsis* ex gr. *zamioides* (FONTAINE) BERRY; (PP–7304), ×2.

Plate 3

Fig. 1. *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.; a part of fertile penultimate pinna with rather thick axis (PP–7233), ×2.

Figs. 2–5. *Gleichenites* sp.; all showing fertile pinna fragments (2; PP–7283, 3; PP–7293, 4; PP–7297, 5; PP–7291), ×2.

Fig. 6. *Cladophlebis acutipennis* OISHI; a part of pinna (or penultimate pinna), showing deeply lobed pinnules (or ultimate pinnae) (PP–7235), ×2.

Figs. 7–8. *Cladophlebis geyleriana* (NATHORST) YABE; both showing the fragments of sterile fronds (7; PP–7292, 8; PP–7263), ×2.

Fig. 9. *Cladophlebis* (*Osmunda*?) *takezakii* OISHI; showing a part of pinna with rather small-sized pinnules (PP–7254), ×2.

Plate 4

Fig. 1. *Gleichenites yuasensis* KIMURA et KANSHA sp. nov.; showing a part of typical fertile penultimate pinna enlarged from the paratype (PP–7219), ×2.

Fig. 2. *Cladophlebis* ex gr. *denticulata* (BRONGNIART) NATHORST; a part of sterile frond (PP–7286), ×2.

Figs. 3–4. *Ptilophyllum* ex gr. *pecten* (PHILLIPS) MORRIS; fragments of rather small-sized leaves (3; PP–7270, 4; PP–7275), ×2.

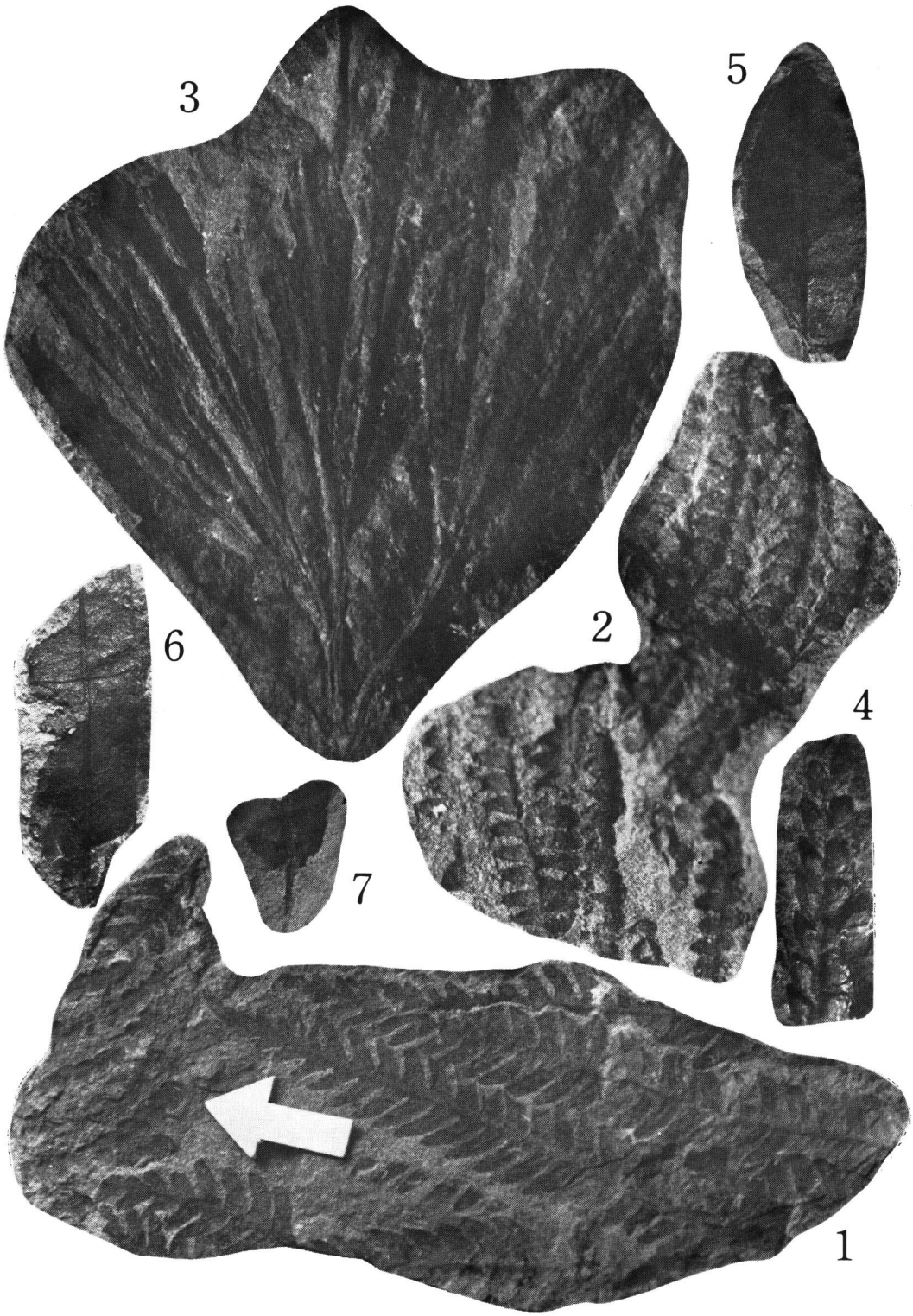
Fig. 5. *Nilssoniopteris* cfr. *vittata* (BRONGNIART) FLORIN; *Ptilozamites*? sp. (pointed by the arrow); (PP–7340), ×1.

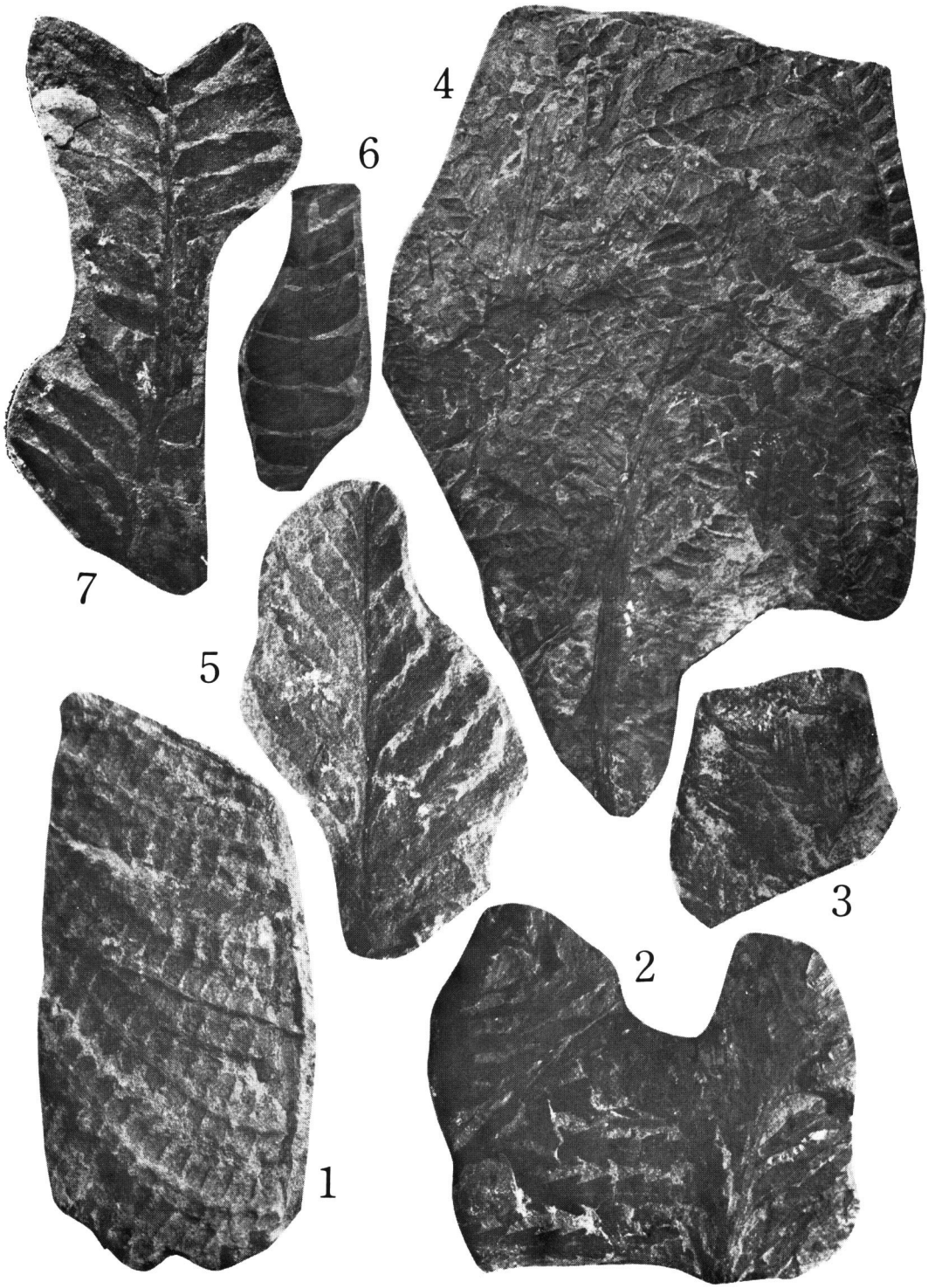
Fig. 6. *Cycadolepis*? sp.; (PP–7303), ×2.

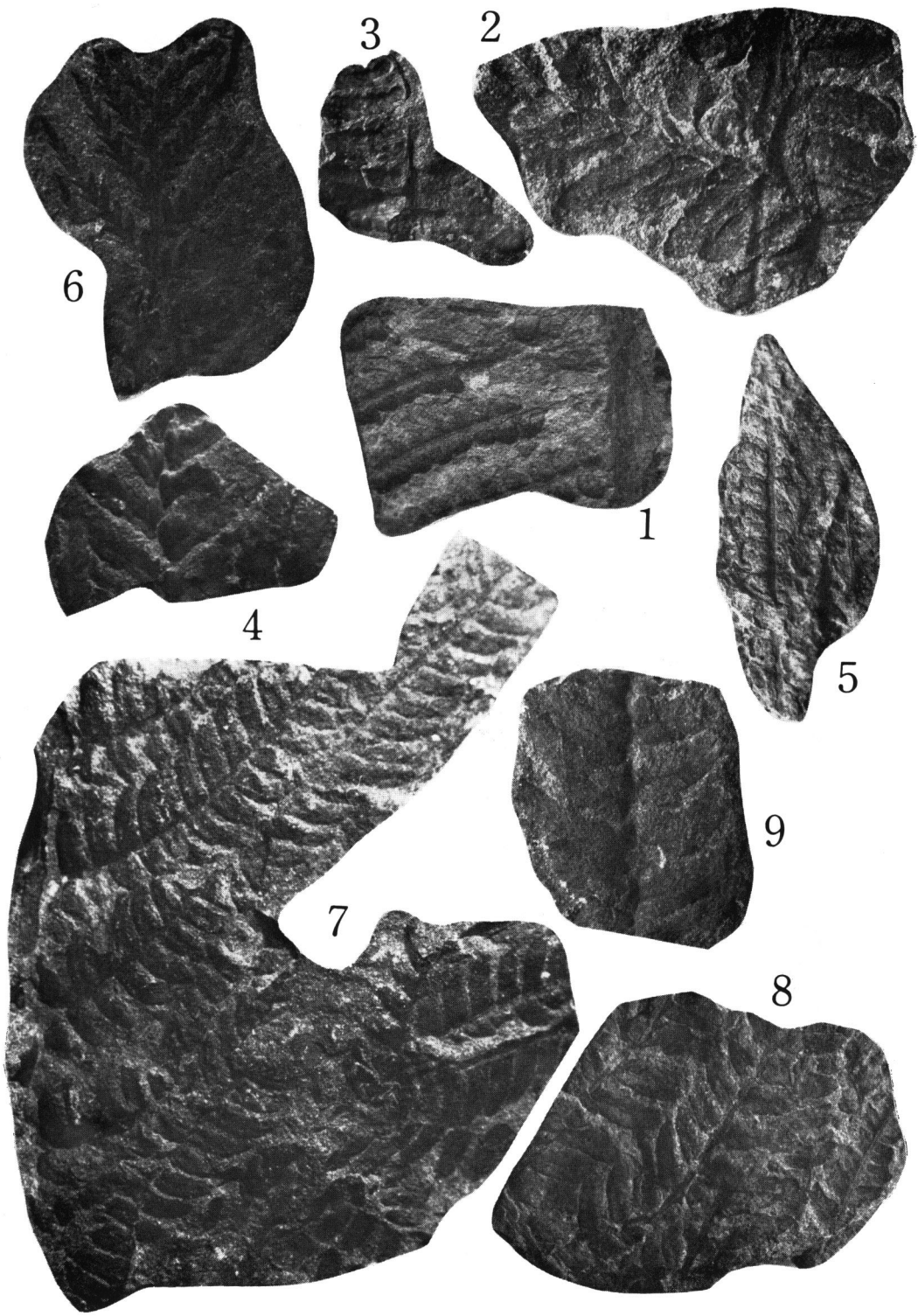
Fig. 7. 7A. *Brachyphyllum expansum* (STERNBERG) SEWARD; a fragment of pinnate leafy-shoot. 7B. *Nageiopsis angustifolia* FONTAINE; detached leaves (PP–7344), ×2.

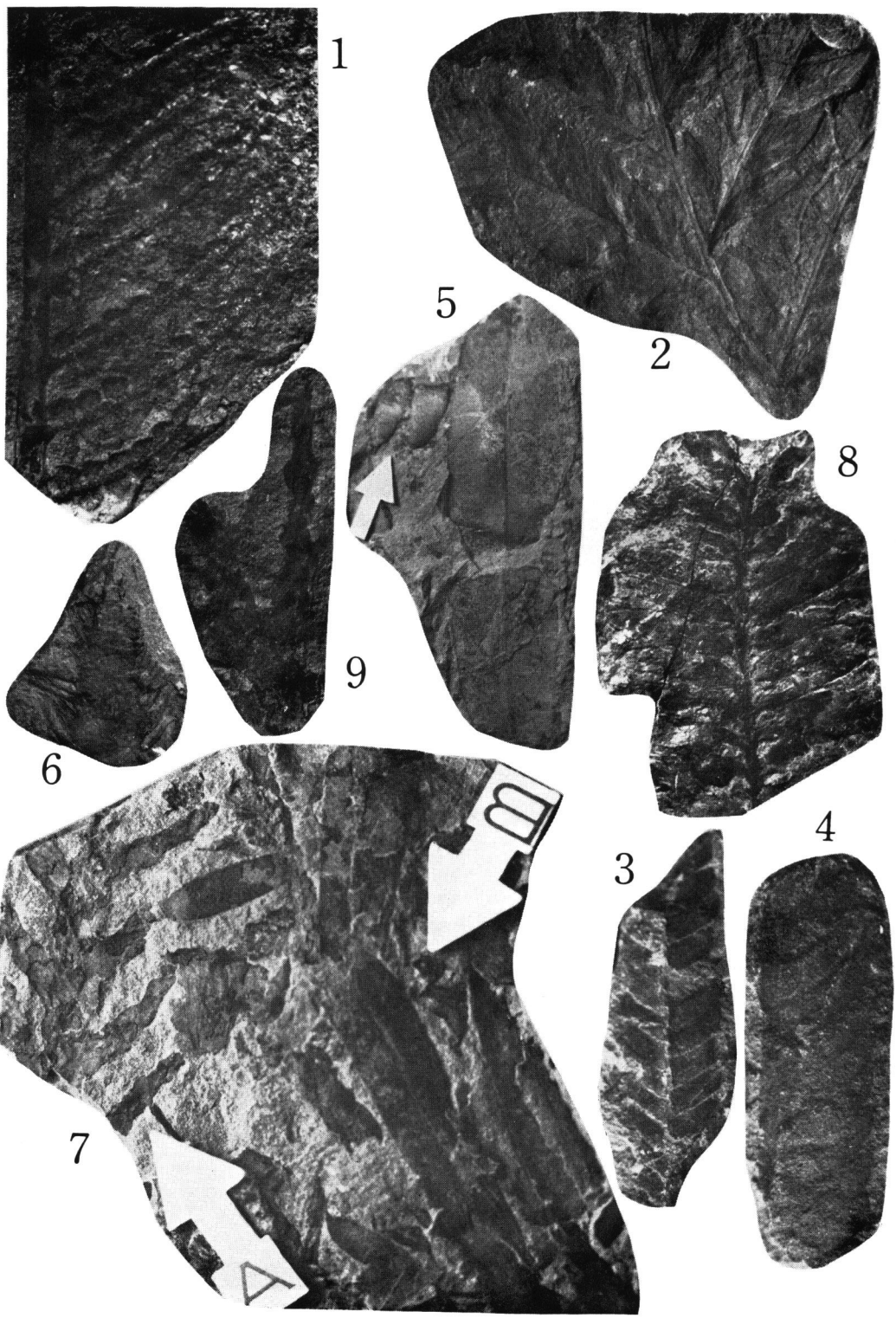
Fig. 8. *Nageiopsis* ex gr. *zamioides* (FONTAINE) BERRY; (PP–7274), ×2.

Fig. 9. *Cyparissidium japonicum* YOKOYAMA; a part of leafy-shoot (PP–7304), ×2.


3
5
2
6
4
7
1


4
6
7
5
3
2
1


3
2
6
1
5
4
9
7
8


1
2
3
4
5
6
7
8
9
A
B