

Permian Plants from Maiya, Japan 2. *Taeniopteris*

by

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Introduction

A large number of fossil plants have been described from many localities and many horizons of Mesozoic and Cenozoic formations in Japan, but the localities of Upper Paleozoic plants are very few. In this respect, the abundant occurrence of fossil plants at Maiya is an exceptional case. The fossil plant bed at Maiya was discovered by F. UEDA in 1954, who kindly donated his collection to the National Science Museum. Since 1954 the writer has visited Maiya several times and collected numerous fossil plants and described some of them (ASAMA, 1967, 1970). This paper contains the description of specimens belonging to the genus *Taeniopteris* which is the most dominant plants in Maiya flora.

The writer takes this opportunity to express his sincere gratitude to Dr. Fusao UEDA for rendering every convenience and offering the valuable collection for this study. Particular appreciation is due to Messrs. Giichi ARAKAWA and Kyo ARAKAWA who helped in collecting fossils. The writer is indebted to Mr. Toru OISHI who collected and donated the holotype of *Taeniopteris oishii* and other specimens. Thanks are also due to Dr. Teruya UYENO of National Science Museum, Tokyo, for the reading of this manuscript.

Previous Work and Horizon of Plant Bed

The writer (1967) described specimens of the genus *Cathaysiopteris* and *Psygmophyllum* of Maiya flora as follows:

Cathaysiopteris whitei (HALLE) KOIDZUMI

Psygmophyllum flabellatum (LINDLEY et HUTTON) SCHIMPER

Psygmophyllum maiyaense ASAMA

Psygmophyllum sp.

Three years later (1970) the writer discussed about the evolution and classification of Sphenophyllales in Cathaysia Land, and described following four species of Sphenophyllales from Maiya:

Parasphenophyllum thonii var. *minor* (STERZEL) ASAMA

Trizygia oblongifolia (GERM. et KAULF.) ASAMA

Paratrizygia maiyaensis ASAMA

Paratrizygia uedae ASAMA

In this paper the writer describes 14 species of *Taeniopteris* from Maiya as follows:

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|---|-----------------------------------|
| 1. <i>Taeniopteris</i> cf. <i>T. schenkii</i> STERZEL | 8. <i>T. laciniata</i> KAWASAKI |
| 2. <i>T. paradensissima</i> n. sp. | 9. <i>T. arakawae</i> n. sp. |
| 3. <i>T. thailandica</i> ASAMA | 10. <i>T. oishii</i> n. sp. |
| 4. <i>T. latecostata</i> HALLE | 11. <i>T. linearifolia</i> n. sp. |
| 5. <i>T. nystroemii</i> HALLE | 12. <i>T.</i> sp. A |
| 6. <i>T. maiyaensis</i> n. sp. | 13. <i>T.</i> sp. B |
| 7. <i>T. setamaiensis</i> ASAMA et MURATA | 14. <i>T.</i> sp. C |

These fossils were all collected from the upper part of the Nishikôri Formation which contains two plant beds, A and B. The bed A yielded most of the fossils. Fossil Zones and lithological characters of Nishikôri Formation are as follows in descending order (by UEDA, 1963):

Tome Group (Upper Permian)

Toyoma Formation

Yamazaki Formation (*Yabeina* Zone)

Maiya Group (Upper and Lower Permian)

Tenjinnoki Formation (*Neoschwagerina* Zone)

Nishikôri Formation (*Parafusulina* and *Pseudoschwagerina* Zones)

Upper	{	Grey to black phyllite intercalated with thick limestone.
		Plant bed A in black shale, marine fossils, <i>Parafusulina</i> and <i>Michellinia</i> Zone.
		Plant bed B in laminated sandstone.
		Bivalve (<i>Aviculopecten</i> , etc.) in black sandy shale.
Lower	{	Brachiopoda rich (<i>Rhynchonella</i> , Trilobite, etc.) Zone.
		<i>Pseudoschwagerina</i> Zone.
		Conglomeratic sandy phyllite with Nautiloids, etc.

The greater part of the black shale of the Nishikôri Formation has altered to phyllite, which is used for roofing, so that occurrence of fossil plants is not expected. Only the layer yielding fossil plants has been left as a shale, which was not altered to phyllite. This condition is an exceptional phenomenon.

Locality of plant beds: Furudate, Maiya, Tôwa-cho, Tome-gun, Miyagi Prefecture

Geological horizon: *Parafusulina* Zone (Lower Permian).

Depositary: National Science Museum, Tokyo (NSM).

Description of Species

Genus *Taeniopteris* BRONGNIART

Taeniopteris cf. *T. schenkii* STERZEL

Plate 1, figs. 1–3; pl. 2, fig. 2; pl. 13, fig. 6

Taeniopteris cf. *schenkii*, HALLE, 1927, pp. 151–153; pl. 40, figs. 5–7.

Taeniopteris sp. cf. *T. schenkii*, KAWASAKI, 1931, pl. 67, fig. 187; 1934, pp. 161–162.

Description: Frond very large, at least 32.5 cm long, 7.5 cm wide on the impression, entire, very gradually narrowing to the base. Rachis attaining a maximum breadth of 8 mm at the base of frond on the impression, traversed by longitudinal striations. Lamina attached on the upper side of the rachis. Secondary veins give off at an acute angle, gradually bending outwards and then running straightly to the margin at an angle of 60°, slightly bending upwards near the margin, bifurcating once or twice near the rachis, numbering 13–16 per centimetre at the middle part between rachis and margin.

Remarks: Pl. 1, fig. 1 shows about a whole frond, though the complete apex and base are not preserved. Rachis is stout in the specimen shown in Pl. 1, fig. 1 and 8 mm wide, but it is very slender and 2 mm wide in the specimen of Pl. 2, fig. 2 which is the basal part of the frond. The apex of the frond is not preserved in any specimens, but the curvature of the margin of the upper part of the frond shown in both Pl. 1, figs. 1 and 3 suggests that they may have the rounded or blunt apex.

The venation is very characteristic. Secondary veins give off at an acute angle, bending outward and curving upwards near the margin. These venations are well shown in Pl. 1, figs. 2, 3 and Pl. 13, fig. 6.

HALLE (1927) reported *Taeniopteris* cf. *schenkii* STERZEL from the Lower Shihhotse Series of Central Shansi. HALLE showed 3 specimens in his Plate 40, of which two specimens are upper parts and the other is a lower part of the frond. Specimens from Maiya are identical with those of Shansi in the characteristic venation and the attachment of lamina on the upper side of the rachis.

The specimen figured (Pl. 67, fig. 187) by KAWASAKI (1931) under the name of *Taeniopteris* sp. cf. *T. schenkii* STERZEL from Jido Series of Korea is only one large frond which attains 22 cm long and 4–5 cm wide, and lacking the apical and basal parts. This Korean specimen resembles the present specimens described above in the characteristic venation.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotype, NSM-PP5489 (Pl. 1, fig. 1), PP5491 (Pl. 1, fig. 3), PP5490 (Pl. 2, fig. 2), PP5686 (Pl. 13, fig. 6).

Taeniopteris paradensissima ASAMA, n. sp.

Plate 2, fig. 1; pl. 3, figs. 3–4

Description: Frond linear, at least 30 cm long, attaining a breadth of 8 cm, rapidly contracted and rounded at the apex, base unknown.

Rachis moderately thick, attaining a maximum breadth of 8 mm at the lower part of the large frond in the impression. Lamina attached to the upper side of the rachis. Secondary veins fine, not decurrent, arising at an angle of 80°–90° to the rachis on the lower part and 70° on the upper part of the frond, not dividing, pursuing a straight course, numbering about 40 per centimetre in the middle part of the frond.

Only one specimen belonging to this species was found in Maiya which was shown in Pl. 2, fig. 1. This is very large frond attaining more than 30 cm in length and

the rachis was covered by the lamina which reaches the middle of the rachis (Plate 3, figs. 3–4, counterpart of Plate 2, fig. 1) at the upper and middle parts of the frond; and the secondary veins are not divided, pursuing straightly to the rachis. Therefore this species resembles *Nilssonia* in the venation and lamina covering the rachis.

The specimens described as *Taeniopteris densissima* by HALLE (1927, pp. 156–157, pl. 41, figs. 5–7) and by JONGMANS and GOTHAN (1935, p. 151, pl. 48, fig. 7; pl. 49, figs. 2–3, not fig. 4) very closely resemble the specimen described here in the shape and venation, but it is larger than *Taeniopteris densissima* in size.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Holotype, NSM-PP5493 (Pl. 2, fig. 1).

Taeniopteris thailandica ASAMA

Plate 3, fig. 1

Taeniopteris thailandica ASAMA, 1966, pp. 198–199; pl. 3, figs. 1–2; pl. 2, fig. 4a.

Description: Frond large, attaining a length of 17 cm, probably much more and breadth of 12 cm, narrowing gradually toward apex, apex and base unknown, margin entire. Rachis rather slender, 1 mm in width at the upper part, 3 mm at the middle part. Lamina attached to the upper side of the rachis. Secondary veins arising at low angles, very gradually bending outward and assuming a straight course to the margin at an angle of about 50°–60°, dividing once near rachis, numbering 16–20 per centimetre.

Remarks: In its form, size and venation, the present specimen (Pl. 3, fig. 1) is referable to *Taeniopteris thailandica* (ASAMA, 1966) from the Upper Permian of Thailand. In the size and the number of secondary veins, this species resembles *T. latecostata* (HALLE, 1927) reported from the Lower Shihhotse Series of Shansi (pp. 145–148, pl. 38, figs. 1–6). But the former has the secondary veins arising from the rachis with a low angle and curving near the rachis, and the latter has those straight and nearly perpendicular to the rachis.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotype, NSM-PP5673 (Pl. 3, fig. 1).

Taeniopteris latecostata HALLE

Plate 3, fig. 2; pl. 4, figs. 5–6; pl. 5, fig. 1; pl. 10, fig. 4

Taeniopteris latecostata HALLE, 1927, pp. 145–148; pl. 38, figs. 1–6.

Taeniopteris latecostata, KAWASAKI, 1931, pl. 62, fig. 163; 1934, p. 162.

Taeniopteris latecostata, JONGMANS und GOTHAN, 1935, p. 152; pl. 52, fig. 1; pl. 53, fig. 2; pl. 54, figs. 1–2.

Taeniopteris latecostata, GU and ZHI, 1974, p. 135; pl. 107, figs. 1–4.

Remarks: Many specimens belonging to this species are collected from Maiya, but there is no complete specimen. The specimen shown in Pl. 3, fig. 2 is the lower part of the frond, whose rachis measures 7 cm long and 10 mm wide. Secondary veins

give off at an acute angle in the left side of lamina, perpendicular to the rachis in the right side of the lamina respectively, and simple or bifurcating once near the rachis, numbering about 15 per centimetre in the middle part between the rachis and the margin. Pl. 4, fig. 5 shows the middle part of the frond and in this specimen the secondary veins are simple, straight and perpendicular to the rachis on both sides. The secondary veins symmetrically arranged on the both sides of the rachis (Pl. 4, fig. 5) indicate the natural venation, and the nonsymmetrical venations (Pl. 3, fig. 2, Pl. 4, fig. 6, Pl. 5, fig. 1 and Pl. 10, fig. 4) are not true venations but the false ones caused by deformation.

The best specimen is shown in Pl. 4, fig. 6, with the large frond, attaining a width of 10 cm. The apex and base are unknown. The lamina attaches to the upper side of the rachis. Secondary veins which are perpendicular to the rachis run straightly to the margin. Sometimes they bifurcate once near the rachis.

The number of veins are 15 per centimetre in Pl. 3, fig. 2, 17–19 in Pl. 4, figs. 6, 15 in Pl. 5, fig. 1, and 14 in Pl. 10, fig. 4 in the middle part between the rachis and margin.

From the characters mentioned above these specimens are referable to *Taeniopteris latecostata* HALLE (1927, pl. 38, figs. 1–6).

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotypes, NSM-PP1291b (Pl. 3, fig. 2), PP5498 (Pl. 4, fig. 5), PP5494 (Pl. 4, fig. 6), PP1291a (Pl. 5, fig. 1), PP5499 (Pl. 10, fig. 4).

Taeniopteris nystroemii HALLE

Plate 5, fig. 2; pl. 6, figs. 1–3; pl. 10, fig. 1; pl. 12, figs. 4–5.

Taeniopteris nystroemii HALLE, 1927, pp. 148–151; pl. 39, figs. 1–5.

Taeniopteris nystroemii, JONGMANS und GOTHAN, 1935, pp. 149–150; pl. 52, fig. 2; pl. 53, fig. 1.

Taeniopteris nystroemii, STOCKMANS et MATHIEU, 1939, p. 86; pl. 19, fig. 1.

Taeniopteris nystroemii, LEE, 1963, p. 157; pl. 41, figs. 1–2.

Remarks: There are many specimens similar to *Taeniopteris latecostata* HALLE in the large size; the attachment of lamina; and the venation; but different in having the denser veins and the low angle of the insertion of secondary veins.

The specimen shown in Pl. 5, fig. 2 is the best one, in which the frond is rather smaller, 18 cm long and 7 cm wide. The apex and base are not preserved. The rachis is slender, 1 mm wide at the upper part and 2 mm at the lower part. The lamina attaches on the upper side of the frond. Secondary veins form angles of 40°, 55° and 45° with the rachis at upper, middle and lower parts of the left side of the frond, respectively. On the right side of the frond, those angles are more obtuse, 70°, 85° and 90°. Veins are not decurrent to the rachis, running straightly to the margin, numbering about 19 per centimetre at the middle part between the rachis and margin.

The specimen shown in Pl. 6, fig. 1 is the upper part of the frond, reaching the width of 7 cm. The rachis is moderately thick, 2 mm wide. Secondary veins give off at an angle of 55°, running straightly to the margin, not dividing, numbering 20–22 per centimetre. In Pl. 6, fig. 2 the rachis attains a width of 6 mm, and the cover of

the lamina reaches to the middle of the rachis. Secondary veins give off at an angle of 80° , running straightly to the margin, numbering 20–26 per centimetre. In the specimen shown in Pl. 6, fig. 3, the rachis is very stout, attaining a width of 15 mm. In the specimens shown in Pl. 10, fig. 1, Pl. 12, figs. 4 and 5, secondary veins give off at an angle of about 60° , numbering 20–23 per centimetre. The specimens described above all have common characteristics; the straight secondary veins, the number of secondary veins (20–26) per centimetre, and the angle of the insertion of secondary veins and the rachis (about 60° at the middle part of the frond). From the above characteristics, these specimens are identified with *Taeniopteris nystroemii* HALLE.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotypes, NSM-PP1290 (Pl. 5, fig. 2), PP5506 (Pl. 6, fig. 2), PP5509 (Pl. 6, fig. 3), PP5511 (Pl. 10, fig. 1), PP5512 (Pl. 12, fig. 4), PP5513 (Pl. 12, fig. 5).

Horizon: Plant bed B (*Parafusulina* Zone).

Depository: Hypotype, NSM-PP5504 (Pl. 6, fig. 1).

Taeniopteris maiyaensis ASAMA n. sp.

Plate 7, figs. 4–5; pl. 8, fig. 1.

Description: Frond large, probably oblanceolate-linear, more than 13 cm long, 7 cm wide, tapering gradually in the upper part. Apex and base unknown. Rachis very thick in proportion to the width of frond, attaining a breadth of 6 mm at the upper part, 15 mm at the middle part of frond, striated longitudinally on the impression. Lamina attached to the upper side of the rachis. Secondary veins arising from rachis at acute angle, bifurcating once or twice near rachis, gradually bending outwards, then pursuing almost straight course at an angle of 45° to rachis at the middle part of the frond, more acute angle at the upper part. The number of secondary veins about 15 per centimetre at the middle between rachis and margin.

Remarks: The specimens shown in Pl. 7, figs. 4 and 5 are the upper and the middle parts of the frond respectively. In these specimens the most conspicuous characteristic is very stout rachis attaining 6 mm at the upper part (Pl. 7, fig. 4) and 15 mm at the middle part (Pl. 7, fig. 5) of the frond.

The venation on the left side and the right side of the rachis is not symmetrical, and this was caused by the deformation of the lamina, which is shown in the left side laminae of Pl. 7, fig. 4 and Pl. 8, fig. 1, the right side laminae do not indicate the true venation.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Holotype, NSM-PP5517 (Pl. 7, fig. 5). Paratypes, NSM-PP5514 (Pl. 7, fig. 4), PP5516 (Pl. 8, fig. 1).

Taeniopteris setamaiensis ASAMA et MURATA

Plate 9, figs. 4–5

Taeniopteris setamaiensis ASAMA and MURATA, 1974, p. 254: pl. 1, figs. 1a, 2; pl. 2,

figs. 1, 2a.

Remarks: Pl. 9, fig.4 shows the middle part of the frond, which is very large attaining a length of more than 26 cm, a breadth of 9 cm. The apex and base are not known. The rachis moderately thick attaining a breadth of 4.5 mm at the middle part of the frond.

The lamina does not cover the rachis. Secondary veins arise at 70°–80° from the rachis, simple or sometimes bifurcating once near the rachis, and run straightly to the margin. The number of veins at the middle part between the rachis and the margin of the frond is about 20 per centimetre.

This specimen is similar to *Taeniopteris setamaiensis* described by ASAMA and MURATA (1974, p. 254, pl. 1, figs. 1a and 2; pl. 2, figs. 1 and 2a) from the Lower Permian Motoiwazawa Sandstone Member, Setamai, Iwate Prefecture, in the very long linear frond, the high angle of insertion of secondary veins, and the number of veins.

The rachis of the lower part of the frond in the Setamai specimens is very stout attaining a breadth of 10 mm but 6 mm at middle part and this width is about the same in the present specimen. The rachis of the basal part of the frond of the present specimen is not known.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotype, NSM-PP5496 (Pl. 9, fig. 4).

Taeniopteris arakawae ASAMA, n. sp.

Plate 2, fig. 3; pl. 4, fig. 7; pl. 6, fig. 5; pl. 7, figs. 1–3;
pl. 8, figs. 2–3; pl. 9, figs. 1–2; pl. 11, figs. 1–4; pl. 12, figs. 1–2.

Description: Frond of unknown length (over 11 cm), attaining a maximum breadth of 2.5 cm, generally 1.5–1.7 cm, tapering gradually narrowing towards the base, more gradually towards the upper part. Apex and base unknown. Rachis slender, the width not exceeding 2–3 mm near the base in the broadest frond preserved, generally 1 mm at the middle part of the frond. Lamina inserted on the flanks of the rachis. Secondary veins form a very acute angle, then bending abruptly to a direction of almost perpendicular or high angle to rachis, dividing once or twice near rachis, numbering 20–25 per centimetre at middle part between the rachis and the margin.

Remarks: Most specimens collected were fragmentary, and the apex and the base are not preserved. A relatively good specimen shown in Pl. 9, fig. 1, is 11 cm long and 1.5 cm wide. Rachis is slender, 1 mm wide in the middle part of the specimen. In this specimen the width of the frond is same in the upper-most and the lowest parts of the frond and this may mean that the frond of this species is very long. In the specimen of Pl. 11, fig. 3 the frond is tapering gradually towards the lower part, but the very base was not preserved.

In the specimen of Pl. 6, fig. 5 the secondary veins are symmetrically arranged on both sides of the frond, giving off at acute angle, then bending outwards with an angle of 60° to the rachis, pursuing to the margin. In most specimens the secondary veins

are not symmetrically arranged, and the asymmetrical arrangement of secondary veins might have been caused by the deformation. Therefore the venation shown in Pl. 6, fig. 5 mentioned above is the true venation.

This species resembles *Taeniopteris tingii* HALLE (1927, pp. 158–160, pl. 42, figs. 3–8) from the Upper Shihhotse Series of Shansi, in the very long frond and venation, but the latter has the very stout rachis, measuring 4–5 mm wide at the base and 3 mm wide at the middle part of the frond. *Taeniopteris arakawae* has the slender rachis, measuring 1 mm in the middle part of frond.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Holotype, NSM-PP5538 (Pl. 6, fig. 5). Paratypes, NSM-PP5542 (Pl. 2, fig. 3), PP5554 (Pl. 4, fig. 7), PP5678 (Pl. 7, fig. 1), PP5553 (Pl. 7, fig. 2), PP5551 (Pl. 7, fig. 3), PP5545 (Pl. 8, fig. 2), PP5540 (Pl. 8, fig. 3), PP5536 (Pl. 9, fig. 1), PP5537 (Pl. 9, fig. 2), PP5550 (Pl. 11, fig. 1), PP5541 (Pl. 11, fig. 2), PP5560 (Pl. 11, fig. 3), PP5539 (Pl. 11, fig. 4), PP5557 (Pl. 12, fig. 1), PP5561 (Pl. 12, fig. 2).

Taeniopteris linearifolia ASAMA, n. sp.

Plate 6, fig. 4; pl. 9, fig. 3; pl. 10, fig. 2; pl. 11,
figs. 5–8; pl. 13, figs. 1–2.

Description: Frond linear to linear-lanceolate, attaining a length of at least 17 cm and a maximum breadth of 1.2 cm, tapering very gradually towards apex and base. Rachis slender, 1 mm wide at the middle and lower parts of the frond and very base unknown. Lamina inserted on the flanks of the rachis. Secondary veins usually simple, sometimes bifurcating once near the rachis, giving off from rachis with about 80°–90° through all parts of the frond, and pursuing a straight course to the margin. Number of veins at margin 25–30 per centimetre in middle part of frond.

Remarks: The species is characterized by the long and linear frond, and slender rachis, and simple or once forked secondary veins which are perpendicular to the rachis. Many specimens belonging to this species were collected but no complete one. The specimen shown in Pl. 11, fig. 7 is the longest one attaining a length of at least 17 cm from base to uppermost point. The upper parts of the frond were shown in Pl. 10, fig. 2, Pl. 11, fig. 8 and Pl. 13, fig. 1, in which they are tapering very gradually towards the upper part, ending with the blunt apex. In the specimen shown in Pl. 10, fig. 2 the secondary veins form an angle of 60° with the rachis in all parts of this frond. This condition is an exceptional case, for most specimens have the secondary veins forming blunt angle with the rachis as shown clearly in Pl. 13, fig. 2.

This species resembles *Taeniopteris szei* CHOW (1962, pp. 411–414, pl. 1, figs. 1A, 2, 2a, 3, 3a, 4) from the Upper Shihhotse Series of Fengfeng, Southern Hopei, in general habit of the frond, but *T. szei* has dotted rachis which is the characteristic of *Taeniopteris szei*. The present species resembles *Taeniopteris tingii* HALLE (1927, pp. 158–160, pl. 42, figs. 1–2) from the Upper Shihhotse Series of Shansi in the linear frond and venation of the secondary veins, but different from *T. tingii* in the slender rachis.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Holotype, NSM-PP5573 (Pl. 11, fig. 8). Paratypes, NSM-PP5574 (Pl. 6, fig. 4), PP5679 (Pl. 9, fig. 3), PP5571 (Pl. 10, fig. 2), PP5582 (Pl. 11, fig. 5), PP5576 (Pl. 11, fig. 6), PP5572 (Pl. 11, fig. 7), PP5682 (Pl. 13, fig. 1), PP5683, fig. 2).

Taeniopteris oishii ASAMA, n. sp.

Plate 4, figs. 1–4; pl. 5, fig. 5; pl. 13, figs. 3–5

Description: Frond small, linear, attaining a length of at least 7 cm and a maximum width of 7 mm, tapering gradually to the blunt apex, more gradually to the base. Rachis slender, 0.5 mm wide at the upper part of the frond, 1 mm wide at the lower part, with petiole of at least 1.5 cm long, 3 mm wide. Lamina inserted in flanks of rachis. Secondary veins forming an acute angle, bending gradually outward, dividing once near the rachis, numbering 15–18 per centimetre at middle of frond.

Remarks: Two specimens belonging to this species were collected by Toru OISHI from Plant bed A, which are shown in Pl. 13, figs. 3–4. The middle and lower parts of the frond have the petiole of 1.5 cm long and 3 mm wide (Pl. 13, fig. 3). The specimen shown in Pl. 13, fig. 4 is an almost complete frond, 7 cm long and 6 mm wide.

The frond of this species is small in size but the thick petiole indicates that the specimens represent simple fronds and not pinnae of a compound frond.

Many small types of fronds of *Taeniopteris* were reported from China and Korea. KAWASAKI (1931, 1934) described three small types of fronds from Korea; *Taeniopteris spatulata*, *T. shirakii* and *T. lanceolata*. First species, *Taeniopteris spatulata* McCLELL, was reported from Kobosan Series (p. 163, pl. 60, figs. 158–161), which is different from the present species in having denser secondary veins nearly perpendicular to the rachis. The second species, *Taeniopteris shirakii* KAWASAKI, was from Jido Series (p. 165, pl. 62, figs. 170–171). This species is spatulate in form with round apex and has denser secondary veins than the present species. The third species, *Taeniopteris lanceolata* KAWASAKI from Jido Series, is different from the present species in having lanceolate frond with acute apex.

STOCKMANS and MATHIEU (1939, 1957) reported four species of small type of frond from the Chao Ko Chwang Series of Kaiping, China. In *Taeniopteris tongshanensis* STOCKMANS et MATHIEU (1957, pp. 37–38, pl. 5, figs. 3, 3a) and *T. aff. jejunata* GRAND'EURY (STOCKMANS et MATHIEU, 1939, p. 88, pl. 20, figs. 8, 8a) the frond is the widest at the middle part, narrowing to apex and base, but in *Taeniopteris oishii* the frond is linear and has coarser secondary veins than the former. The fronds of *T. pinnata* STOCKMANS et MATHIEU (1939, p. 89, pl. 20, fig. 6) and *T. yernauxi* STOCKMANS et MATHIEU (1939, pp. 89–90, pl. 20, figs. 4–5) are linear in form and about 5 cm in length. The former is different from *T. oishii* in having the denser secondary veins. The latter resembles *T. oishii* in the form of the frond and venation of secondary veins but the specimens figured by STOCKMANS and MATHIEU (1939) are fragmentary and the lower part of the frond is not preserved, and they have denser secondary veins (24 per centimetre) than those of *T. oishii* (15–18 per centimetre). Therefore Maiya specimens are

assigned to new species.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Holotype, NSM-PP5685 (Pl. 13, fig. 4). Paratypes, NSM-PP5675 (Pl. 4, fig. 1), PP5676 (Pl. 4, fig. 2), PP5529 (Pl. 4, fig. 3), PP5534 (Pl. 4, fig. 4), PP5687 (Pl. 5, fig. 5), PP5684 (Pl. 13, fig. 3).

Taeniopteris ? laciniata KAWASAKI

Plate 1, fig. 4; pl. 12, fig. 3

Taeniopteris ? laciniata, KAWASAKI, 1931, pl. 60, fig. 21; 1934, pp. 168–169.

Remarks: KAWASAKI (1931, 1934) reported a *Taeniopteris*-like frond from Jido Series of Korea and he described this frond under the name of *Taeniopteris ? laciniata*, which is characterized by the frond with laciniated and fimbriated margin.

The specimen shown in Pl. 1, fig. 4 and Pl. 12, fig. 3 (counterpart of Pl. 1, fig. 4) is fragmental but referable to KAWASAKI's species by the characteristic frond with fimbriated margin.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: Hypotypes, NSM-PP5583 (Pl. 1, fig. 4), PP5681 (Pl. 12, fig. 3).

Taeniopteris sp.

Plate 5, figs. 3, 4; pl. 8, fig. 4; pl. 10, fig. 3

Remarks: Two fragmentary specimens are shown in Pl. 5, figs. 3 and 4. Both fronds are the apical parts of the frond. Secondary veins in fig. 3 are giving off at angle of 45° to the rachis, pursuing straightly to the margin and the veins in fig. 4 are arising up at angle of 45° to the rachis, bending gradually upward.

The specimen shown in Pl. 8, fig. 4 is the basal part of the frond. The longitudinally striated rachis is stout, 4 mm wide, with decurrent lamina on both sides.

Pl. 10, fig. 3 shows the frond of 19 cm long and 4.5 cm wide, in which the venation is not visible.

The specimens mentioned above are all fragmentary and too incomplete to assign to any species.

Horizon: Plant bed A (*Parafusulina* Zone).

Depository: NSM-PP5556 (Pl. 5, fig. 3), PP5677 (Pl. 5, fig. 4), PP4902 (Pl. 8, fig. 4), PP5680 (Pl. 10, fig. 3).

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Explanation of Plates 1–13

All figures in natural size, except otherwise stated.

Locality: Furudate, Maiya, Tôwa-cho, Tome-gun, Miyagi Prefecture.

Horizon: Plant beds A and B of Nishikôri Formation, *Parafusulina* Zone, Lower Permian.

Depository: National Science Museum, Tokyo (NSM).

Plate 1

Figs. 1–3. *Taeniopteris* cf. *schenkii* STERZEL. 1, large frond, hypotype, NSM-PP5489 from Plant bed A; 2, part of Fig. 1; 3, upper part of frond, hypotype, NSM-PP5491 from Plant bed A.

Fig. 4. *Taeniopteris?* *laciniata* KAWASAKI. Hypotype, NSM-PP5583 from Plant bed A.

Plate 2

Fig. 1. *Taeniopteris paradensissima* ASAMA, n. sp. Holotype, NSM-PP5493 from Plant bed A.

Fig. 2. *Taeniopteris* cf. *schenkii* STERZEL. Lower part of frond, hypotype, NSM-PP5490 from Plant bed A.

Fig. 3. *Taeniopteris arakawae* ASAMA, n. sp. Middle part of frond with shell, paratype, NSM-PP5542 from Plant bed A.

Plate 3

Fig. 1. *Taeniopteris thailandica* ASAMA. Hypotype, NSM-PP5673 from Plant bed A.

Fig. 2. *Taeniopteris latecostata* HALLE. Hypotype, NSM-PP1291b from Plant bed A.

Figs. 3, 4. *Taeniopteris paradensissima* ASAMA, n. sp. 3, venation of lower part of the counterpart of Pl. 2, fig. 1; 4, venation of upper part of the counterpart of Pl. 2, fig. 1.

Plate 4

Figs. 1–4. *Taeniopteris oishii* ASAMA, n. sp. 1, upper part of frond, paratype, NSM-PP5675 from Plant bed A; 2, middle part of frond, paratype, NSM-PP5676 from Plant bed A; 3, middle part of frond, paratype, NSM-PP5529 from Plant bed A; 4, middle part of frond, paratype, NSM-PP5534 from Plant bed A.

Figs. 5, 6. *Taeniopteris latecostata* HALLE. 5, lower part of frond, hypotype, NSM-PP5498 from Plant bed A; 6, middle part of frond, hypotype, NSM-PP5494 from Plant bed A.

Fig. 7. *Taeniopteris arakawae* ASAMA, n. sp. Middle part of frond, paratype, NSM-PP5554 from Plant bed A.

Plate 5

Fig. 1. *Taeniopteris latecostata* HALLE. Lower part of frond, hypotype, NSM-PP1291a from Plant bed A.

Fig. 2. *Taeniopteris nystroemii* HALLE. Hypotype, NSM-PP1290 from Plant bed A.

Figs. 3, 4. *Taeniopteris* sp. A. 3, NSM-PP5556 from Plant bed A; 4, NSM-PP5677 from Plant bed A.

Fig. 5. *Taeniopteris oishii* ASAMA, n. sp. Middle part of frond, paratype, NSM-PP5687 from Plant bed A.

Plate 6

Figs. 1–3. *Taeniopteris nystroemii* HALLE. 1, upper part of frond, hypotype, NSM-PP5504 from Plant bed B; 2, hypotype, NSM-PP5506 from Plant bed A; 3, lower part of frond, hypotype, NSM-PP5509 from Plant bed A.

Fig. 4. *Taeniopteris linearifolia* ASAMA, n. sp. Paratype, NSM-PP5574 from Plant bed A.

Fig. 5. *Taeniopteris arakawae* ASAMA, n. sp. Holotype, NSM-PP5538 from Plant bed A.

Plate 7

- Figs. 1–3. *Taeniopteris arakawae* ASAMA, n. sp. 1, paratype, NSM-PP5678 from Plant bed A; 2, rounded apex, paratype, NSM-PP5553 from Plant bed A; 3, middle part of frond, paratype, NSM-PP5551 from Plant bed A.
- Figs. 4, 5. *Taeniopteris maiyaensis* ASAMA, n. sp. 4, upper part of frond, paratype, NSM-PP5514 from Plant bed A; 5, middle part of frond, holotype, NSM-PP5517 from Plant bed A.

Plate 8

- Fig. 1. *Taeniopteris maiyaensis* ASAMA, n. sp. Middle part of frond, paratype, NSM-PP5516 from Plant bed A.
- Figs. 2, 3. *Taeniopteris arakawae* ASAMA, n. sp. 2, lower part of frond, paratype, NSM-PP5545 from Plant bed A; 3, middle part of frond, paratype, NSM-PP5540 from Plant bed A.
- Fig. 4. *Taeniopteris* sp. B. Lower part of frond, NSM-PP4902 from Plant bed A.

Plate 9

- Figs. 1, 2. *Taeniopteris arakawae* ASAMA, n. sp. 1, paratype, NSM-PP5536 from Plant bed A; 2, paratype, NSM-PP5537 from Plant bed A.
- Fig. 3. *Taeniopteris linearifolia* ASAMA, n. sp. Paratype, NSM-PP5679 from Plant bed A.
- Figs. 4, 5. *Taeniopteris setamaiensis* ASAMA et MURATA. Hypotype, NSM-PP5496 from Plant bed A.

Plate 10

- Fig. 1. *Taeniopteris nystroemii* HALLE. Hypotype, NSM-PP5511 from Plant bed A.
- Fig. 2. *Taeniopteris linearifolia* ASAMA, n. sp. Upper part of frond, paratype, NSM-PP5571 from Plant bed A.
- Fig. 3. *Taeniopteris* sp. C. NSM-PP5680 from Plant bed A.
- Fig. 4. *Taeniopteris latecostata* HALLE. Hypotype, NSM-PP5499 from Plant bed A.

Plate 11

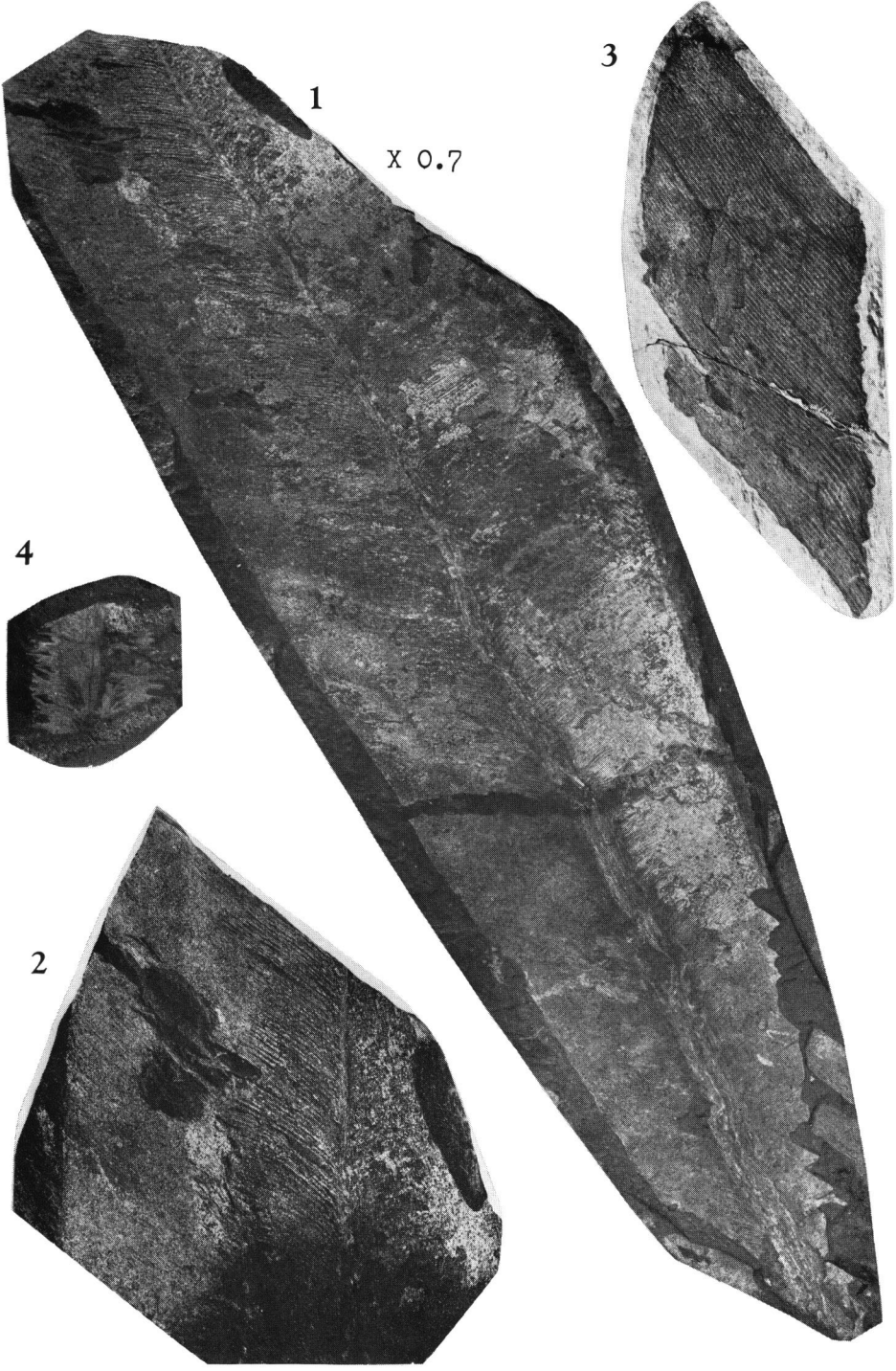
- Figs. 1–4. *Taeniopteris arakawae* ASAMA, n. sp. 1, middle part of frond, paratype, NSM-PP5550 from Plant bed A; 2, middle part of frond, paratype, NSM-PP5541 from Plant bed A; 3, lower part of frond, paratype, NSM-PP5560 from Plant bed A; 4, middle and lower part of frond, paratype, NSM-PP5539 from Plant bed A.
- Figs. 5–8. *Taeniopteris linearifolia* ASAMA, n. sp. 5, middle part of frond, paratype, NSM-PP5582 from Plant bed A; 6, middle part of frond, paratype, NSM-PP5576 from Plant bed A; 7, paratype, NSM-PP5572 from Plant bed A; 8, upper and middle part of frond, holotype, NSM-PP5573 from Plant bed A.

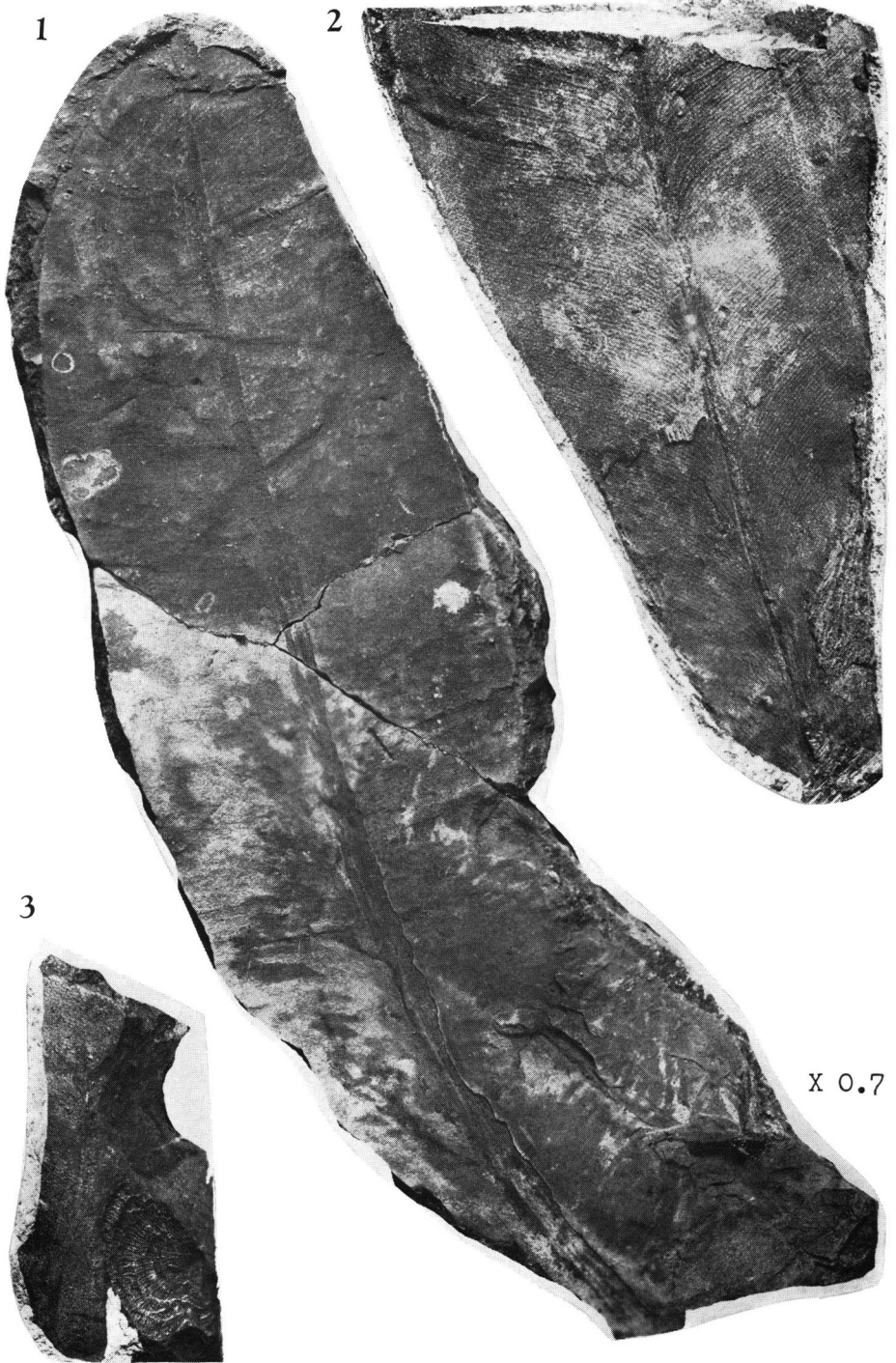
Plate 12

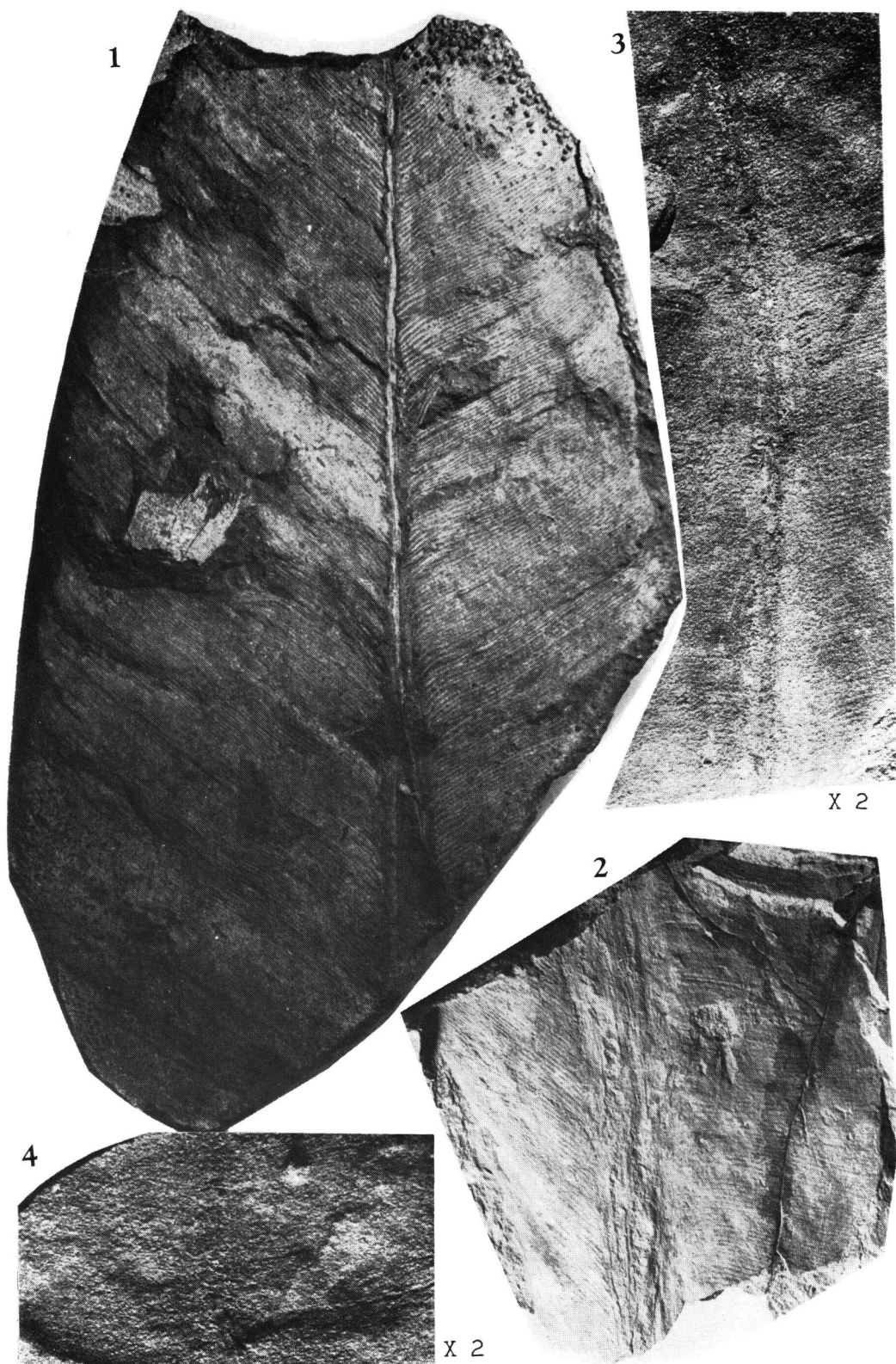
- Figs. 1, 2 *Taeniopteris arakawae* ASAMA, n. sp. 1, paratype, NSM-PP5557 from Plant bed A; 2, paratype, NSM-PP5561 from Plant bed A.
- Fig. 3. *Taeniopteris laciniata* KAWASAKI. Hypotype, NSM-PP5681 from Plant bed A.
- Figs. 4, 5. *Taeniopteris nystroemii* HALLE. 4, hypotype, NSM-PP5512 from Plant bed A; 5, hypotype, NSM-PP5513 from Plant bed A.

Plate 13

- Figs. 1, 2. *Taeniopteris linearifolia* ASAMA, n. sp. 1, upper and middle part of frond, paratype, NSM-PP5682 from Plant bed A; 2, venation of middle part of frond, paratype, NSM-PP5683 from Plant bed A.
- Figs. 3-5. *Taeniopteris oishii* ASAMA, n. sp. 3, lower part of frond, paratype, NSM-PP5684 from Plant bed A; 4, holotype, NSM-PP5685 from Plant bed A; 5, venation of middle part of frond of Plate 4, Fig. 3.
- Fig. 6. *Taeniopteris* cf. *schenkii* STERZEL. Middle part of frond, hypotype, NSM-PP5686 from Plant bed A.









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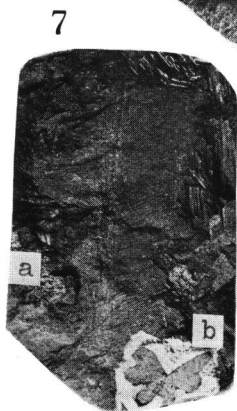
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5



6



7

a

b



4

