

Eocene Ephedraceous palynomorphs of Taiwan

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Abstract. Twenty-two taxa of the form genus *Ephedripites*, the fossil gymnospermous palynomorphs of *Ephedra*, are described from Eocene sediments offshore from the Keelung area in northern Taiwan. Twelve new species and three new varieties in Taiwan are described.

Keywords: Eocene Ephedraceous palynomorphs; Taiwan area; Taxonomy.

Introduction

Ephedra, a truly xerophytic genus, grows best on sandy or rocky sites such as deserts and mountains. *Ephedripites* (named for the fossil pollen of *Ephedra*) is distributed sporadically in the Mio-Pliocene formations of Taiwan (Chaw, 1980; Huang, 1981; Shaw, 1984). This study shows that *Ephedripites* is also present in Eocene sediments in the area.

Gnetales, the most advanced order of the subclass Coniferophytæ, is represented at present by three genera *Ephedra*, *Gnetum*, and *Welwitschia*. Because their pollen and plant bodies all have large differences, each one can clearly be distinguished as a family. The furrow is absent in *Ephedripites*, and we can theorize that the plicate condition permits the exit of the pollen tube to be between any of the ribs. Pollen grains of the genera *Vittatina* and *Costapollenites* from the Permian are somewhat similar to those of the genus *Welwitschia*, and *Ephedra*-like pollen has been found in rocks ranging in age from the Triassic to the present (Tschudy, 1969). The macrofossil evidence of Ephedraceae extends back only as far as the Cretaceous (Chaloner, 1969).

The palynological investigation of Eocene sedimentary rocks in Taiwan began in 1988. A total of eighteen cores of Eocene age offshore from the Keelung area in northern Taiwan were collected. These samples were brought to the Chinese Petroleum Corporation Micropaleontological Laboratory for the preparation of pollen slides. On examination, many fossil palynomorphs were identified, the description of which began in 1990. The first part of the work on the Ephedraceous palynomorphs is now being published, although the work is still continuing. When the taxonomic findings of the fossil palynomorphs are completed, the author plans to report them in a subsequent publication. The last complete report will include a checklist of the Eocene fossil flora and pollen stratigraphy of the offshore Keelung area.

The taxonomic treatment of Tertiary fossil palynomorphs has been debated by many palynologists for a long time (Faegri et al., 1964; Huang and Chen, 1967;

Boulter, 1979). In this paper, I have adopted artificial form generic names for nomenclature.

Materials and Methods

Cores samples from the OK-1 well offshore from the Keelung area in northern Taiwan were made available to the author (Figure 1). A total of eighteen side wall cores were prepared by the Chinese Petroleum Corporation Micropaleontological Laboratory for a palynological study.

The extraction of fossil palynomorphs was made by using the method of the author (Shaw, 1984), including the treatment of 10% KOH for the dissolution of humic material. Heavy solution of $ZnCl_2$ for flotation (S. G. 1.8–2.2) and also 30% of HCl, 52% of HF were used for maceration of the laterite pebble samples, which were collected from the exploration well.

Photomicrographs were taken with a Zeiss Axiophot microscope equipped with an automatic camera using

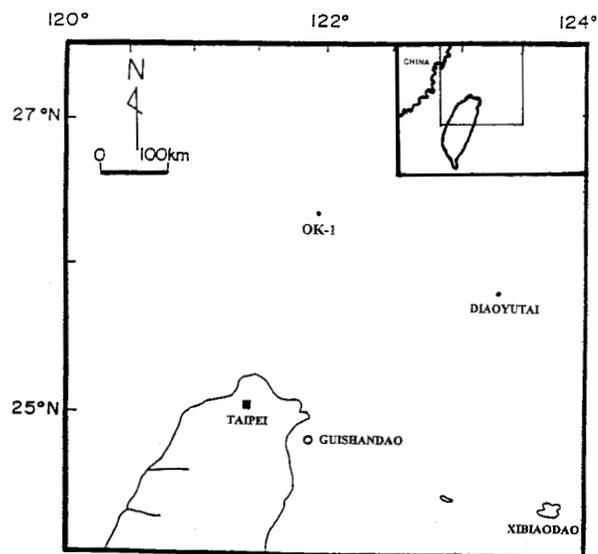


Figure 1. Locality map of OK-1 well in the Keelung area offshore of Taiwan.

Kodacolor Gold (ASA 100) film. For fossil identification, the standard references used by Krutzsch (1971), Jansonius and Hills (1976), Huang (1976, 1979, 1981), Sung and Tsao (1978), Zhu et al. (1985), were adopted. The fossil slides are catalogued and stored at the Micropaleontology Laboratory, Chinese Petroleum Corporation.

Results and Discussion

Twelve taxa of *Ephedripites* are distributed sporadically in the Miocene-Pliocene formations of middle and northern Taiwan (Chaw, 1980; Huang, 1981; Shaw, 1984). Surprisingly enough, twenty-two taxa of *Ephedripites* appear in the Eocene formation offshore from the Keelung area of northern Taiwan. Good and accurate taxonomic treatment is important for biostratigraphy. In the process of continually building up knowledge of the Eocene microflora of Taiwan, this paper reports one family, one form genus, and twenty-two taxa of the Eocene fossil gymnospermous palynomorphs. Twelve new species, and three new varieties are described from the OK-1 well drilled in the Keelung area.

Systematic Taxonomic Treatment

Order Gnetales, Family Ephedraceae, Genus *Ephedripites* Bolkhovitina, 1953 ex Potonié 1958.

Type species: *Ephedripites mediolobatus* Bolkhovitina ex Potonié 1958.

Diagnosis: Grains ellipsoidal to fusiform, with 3–12 longitudinal ridges.

Key to the Subgenus (Compiled from Krutzsch 1961, 1971)

1. Grains encircled type; surface view striate Subgenus *Spiralipites*
1. Grains plicate type; surface view ridges.
 2. Cross-grid pattern between grooves present Subgenus *Distachyapites*
 2. Cross-grid pattern between grooves absent Subgenus *Ephedripites*

EPHEDRIPITES subgen. **DISTACHYAPITES** Krutzsch 1961, Geologie, Beiheft 32, p. 20.—TYPE species: *Ephedripites (Distachyapites) eocenipites* (Wodehouse) Krutzsch., l.c., p. 27.

Diagnosis: "Ephedroid pollen with a low number of ribs (approx. 3–8) and with a zig-zag line between the ribs; ribs are usually straight or slightly sinuous but strongly spiraling."

Key to the Species (Compiled from Huang, 1981; Shaw, 1984; Sung & Tsao, 1978; Zhu et Wu, 1985 and this study)

1. Grains in equatorial view subprolate to perprolate, with obtuse angle.

2. Grains large, more than 45 μ in length.
 3. Grain length over width larger than 2.2.
 4. Grain ridge 1.5–2 μ thick 2. *E. (D.) parafusiformis* var. *taiwanensis*
 4. Grain ridge less than 1 μ thick 10. *E. (D.) membranus*
 3. Grain length over width less than 2.0 1. *E. (D.) eocenipites* var. *formosensis*
2. Grains small, less than 40 μ in length.
 5. Grain ridge less than 3 μ thick.
 6. Grains large, prolate, more than 30 μ in length 3. *E. (D.) scabridus*
 6. Grains small, subprolate, less than 29 μ in length 4. *E. (D.) formosanus*
 5. Grain ridge more than 3 μ thick .
 7. Grains large, more than 28–33 \times 16–20 μ 5. *E. (D.) fushunensis*
 7. Grains small, less than 23 \times 14 μ 6. *E. (D.) fushunensis minimus*
1. Grains in equatorial view lenticular, with acute angle.
 8. Grain length over width larger than 2.6.
 9. Grains large, more than 50 μ in length 9. *E. (D.) quadriplicatus*
 9. Grains small, less than 50 μ in length 7. *E. (D.) baculatus*
 8. Grain length over width less than 2.6.
 10. Grain ridge 2 μ thick 8. *E. (D.) miocenus*
 10. Grain ridge less than 1 μ thick 11. *E. (D.) nanlingensis*

1. *Ephedripites (D.) eocenipites* (Wodehouse) Krutzsch, 1961 var. *formosensis* Shaw, var. nov. Figure 2A–F

Holotype: Slide OK-1 1365- (1); Figure 2A–B; film P13-35-36, P13-34-35; CPC Micropaleontology Lab.

Description: Grains with 4–5 ridges; prolate, the pole rounded; fusiform; 46–55 \times 26–28 μ , grooves as long as the P axes; grain length over width about 1.7–2; exine psilate; sexine with distinct cross-grid; ridges 1–1.5 μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,365 m).

Taxonomic affinity: This species and the other ten species described in this section are similar to the extant species of *Ephedra*.

Comment: This variety differs from the typical variety in having a smaller size.

Note. This species is named after the Formosa island of the type locality.

2. *Ephedripites (D.) parafusiformis* Zhu & Wu, 1985 var. *taiwanensis* Shaw, var. nov.

Figure 2G–H and Figure 3A–B

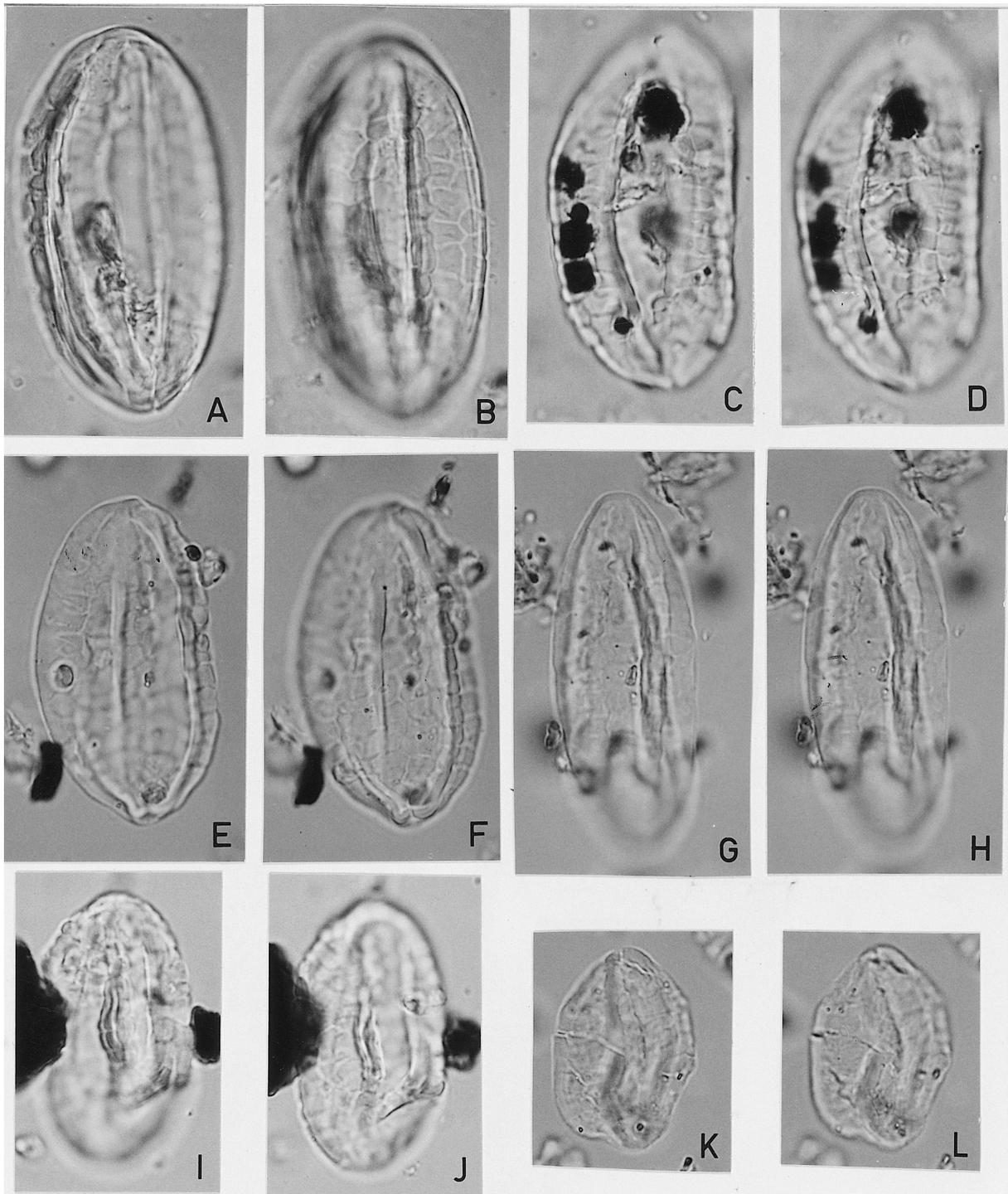


Figure 2. A–F, *Ephedripites* (*D.*) *eocenipites* (Wodehouse) Krutzsch var. *formosensis* Shaw var. nov. (Film P13:35-36, P13:34-35, S9:38, S9:37, S5:24, S5:25); G–H, *Ephedripites* (*D.*) *parafusiformis* Zhu & Wu var. *taiwanensis* Shaw var. nov. (Film S6:9, S6-10); I–J, *Ephedripites* (*D.*) *scabridus* (Wodehouse) Krutzsch (Film S7:23, S7-24); K–L, *Ephedripites* (*D.*) *formosanus* Shaw sp. nov. (Film S8:2, S8-1). (All $\times 1150$)

Holotype: Slide OK-1 1768- (5); Figure 3A–B; film S5-22, S5-23; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; prolate, the pole rounded; fusiform; $50\text{--}67 \times 17\text{--}21 \mu$, grooves as long as the P axes; grain length over width about 2.3–3.3; exine

psilate; sexine with distinct cross-grid; ridges $1\text{--}1.5 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,768 m).

Comment: This variety differs from the typical variety in having a smaller size.

Note. This species is named after the Taiwan area of the type locality.

3. *Ephedripites (D.) scabridus* Song & Zheng, 1981.

Figure 2I–J

Holotype: Slide OK-1 1669- (1); film S7:23, S7:24; CPC Micropaleontology Lab.

Description: Grains with 4–5 ridges; prolate, the pole rounded; fusiform; $38 \times 22 \mu$, grooves as long as the P axes; grain length over width about 1.7–1.8; exine psilate; sexine with distinct cross-grid; ridges $1.5\text{--}2 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

4. *Ephedripites (D.) formosanus* Shaw, sp. nov.

Figure 2K–L

Holotype: Slide OK-1 1638- (2); Figure 2K–L; film S8:1, S8:2; CPC Micropaleontology Lab.

Description: Grains with 4–5 ridges; subprolate, the pole rounded; fusiform; $28\text{--}30 \times 19\text{--}21 \mu$, grooves as long as the P axes; grain length over width about 1.4–1.5; exine psilate; sexine with distinct cross-grid; ridges $1.5\text{--}2 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,638 m).

Comment: This species differs from *Ephedripites (D.) fushunensis* Sung & Tsao by having thinner ridges $1.5\text{--}2 \mu$ and a smaller size.

Note. This species is named after the Formosa island of the type locality.

5. *Ephedripites (D.) fushunensis* Sung & Tsao, 1978.

Figure 3E–J

Holotype: Slide OK-1 1545- (1); film P10-29-28, P10-30-29; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; prolate, the pole rounded; fusiform; $28\text{--}33 \times 16\text{--}20 \mu$, grooves as long as the P axes; grain length over width about 1.4–1.7; exine flat verrucate; sexine with distinct cross-grid; ridges $3\text{--}4 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,545 m).

6. *Ephedripites (D.) fushunensis* Sung & Tsao, 1978 var. ***minus*** Shaw, sp. nov.

Figure 3K–L

Holotype: Slide OK-1 1669- (4); film S6:29, S6: 28; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; subprolate-prolate, the pole rounded; fusiform; $22\text{--}24 \times 13\text{--}15 \mu$, grooves as long as the P axes; grain length over width about 1.4; exine flat verrucate; sexine with distinct cross-grid; ridges 3μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Comment: This variety differs from the typical variety in having a smaller size.

Note. This species is named after the minus size of the pollen.

7. *Ephedripites (D.) baculatus* Zhu et Wu, 1985.

Figure 4A–F

Holotype: Slide OK-1 1699-bl-(1); film P8-4-7, P8-5-8; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; perprolate, the pole acute; fusiform; $44\text{--}49 \times 13\text{--}18 \mu$, grooves as long as the P axes; grain length over width about 2.7–3.5; exine psilate; sexine with distinct cross-grid; exine $1.5\text{--}2 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

8. *Ephedripites (D.) miocenens* Huang & Chaw, 1981.

Figure 4I–L

Holotype: Slide OK-1 1699-bl-(1); Figure 4I–J; film P8-7-10, P8-8-11; CPC Micropaleontology Lab.

Description: Grains with 4 ridges; perprolate, the pole acute; fusiform; $44\text{--}48 \times 18\text{--}24 \mu$, grooves as long as the P axes; grain length over width about 1.9–2.5; exine psilate; sexine with distinct cross-grid; ridges $1.5\text{--}2 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

9. *Ephedripites (D.) quadriplicatus* Shaw, 1984.

Figure 7A–B

Holotype: Slide OK-1 1545-(1); film P10-18-17, P10-17-16; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; perprolate, the pole acute; fusiform; $58\text{--}62 \times 19\text{--}22 \mu$, grooves as long as the P axes; grain length over width about 2.8; exine psilate; sexine with distinct cross-grid; ridges $1.5\text{--}2 \mu$ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,545 m)

10. *Ephedripites (D.) membranus* Shaw, sp. nov.

Figure 3C–D

Holotype: Slide OK-1 1669- (4); film S6-18, S6-19; CPC Micropaleontology Lab.

Description: Grains with 4-ridges; prolate to perprolate, the pole rounded; fusiform; $54 \times 24 \mu$, grooves as long as the P axes; grain length over width about 2.3; exine psilate; sexine with distinct cross-grid; the ridge 1μ thick or less.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Comment: This species differs from other species by having thinner ridges about 1μ thick and membrane-like exine.

Note. This species is named after the membranous character of the exine.

11. *Ephedripites (D.) nanlingensis* Sun & He, 1980.

Figure 4G–H and Figure 7C–D

Holotype: Slide OK-1 1669-(1); film S7:25, S7:26; CPC Micropaleontology Lab.

Description: Grains with 4–5 ridges; prolate, the pole acute; fusiform; $50\text{--}57 \times 22\text{--}25 \mu$, grooves as long as the P axes; grain length over width about 2.1–2.3; exine

psilate; sexine with distinct cross-grid; the ridge 1–1.5 μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m)

EPHEDRIPITES subgen. **EPHEDRIPITES** Krutzsch 1961, *Geologie, Beiheft* 32, p. 20.—TYPE species:

Ephedripites (Ephedripites) mediolobatus Bolkhovitina ex Potonié 1958.

Diagnosis: “Ephedroid pollen with numerous ribs, in part spiralling along the longest axis; without characteristic Z-line, never with side branches; dehiscence slit very rare.”

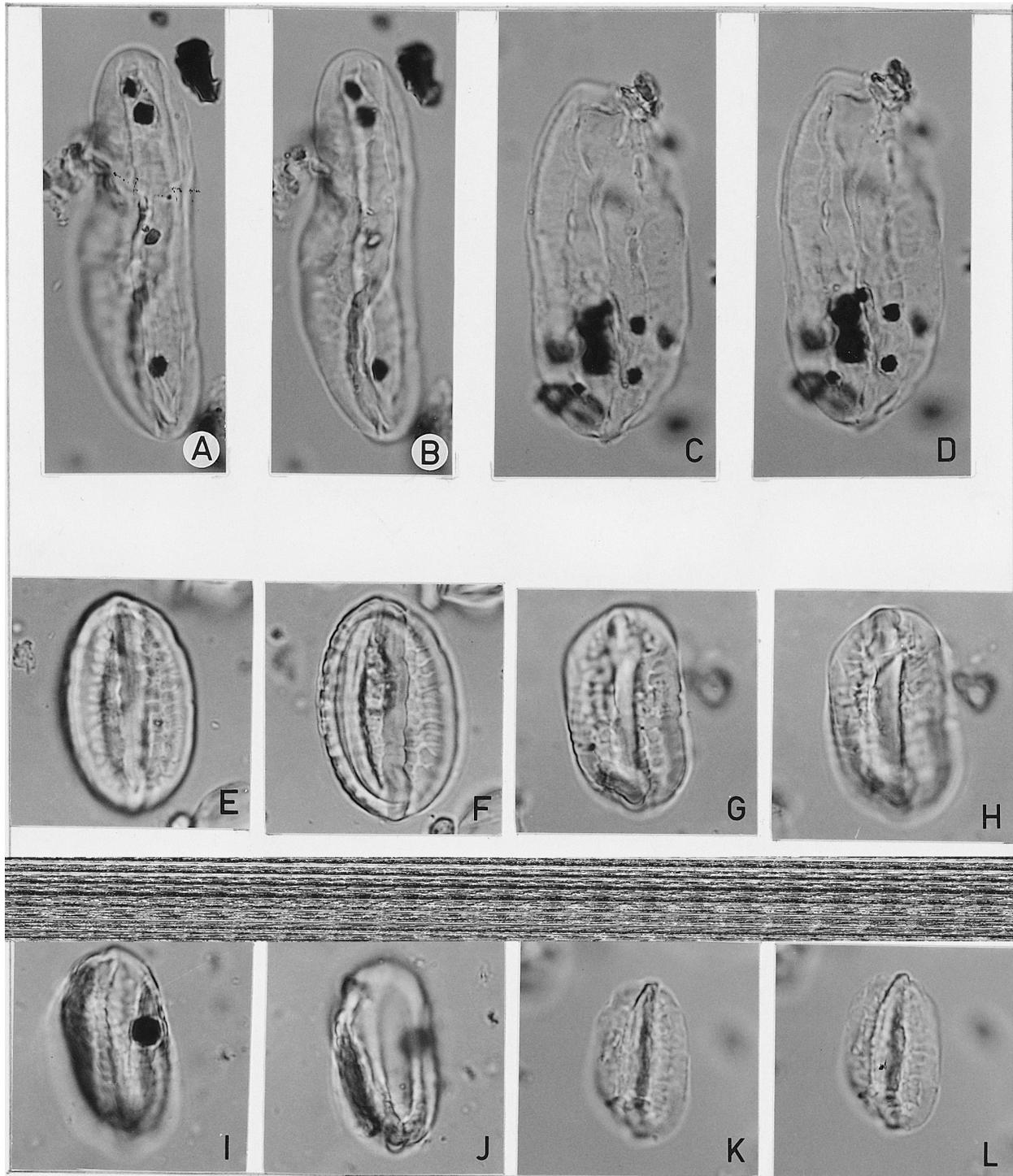


Figure 3. A–B, *Ephedripites (D.) parafusiformis* Zhu & Wu var. *taiwanensis* Shaw var. nov. (Film S5:23, S5:22); C–D, *Ephedripites (D.) membranus* Shaw sp. nov. (Film S6:19, S6:18); E–J, *Ephedripites (D.) fushunensis* Sung & Tsao (Film P10:29-28, P10:30-29, P10:5-4, P10:6-5, P14:5-6, P14:6-7); K–L, *Ephedripites (D.) fushunensis* Sung & Tsao var. *minus* Shaw var. nov. (Film S6:29, S6-28). (All $\times 1150$)

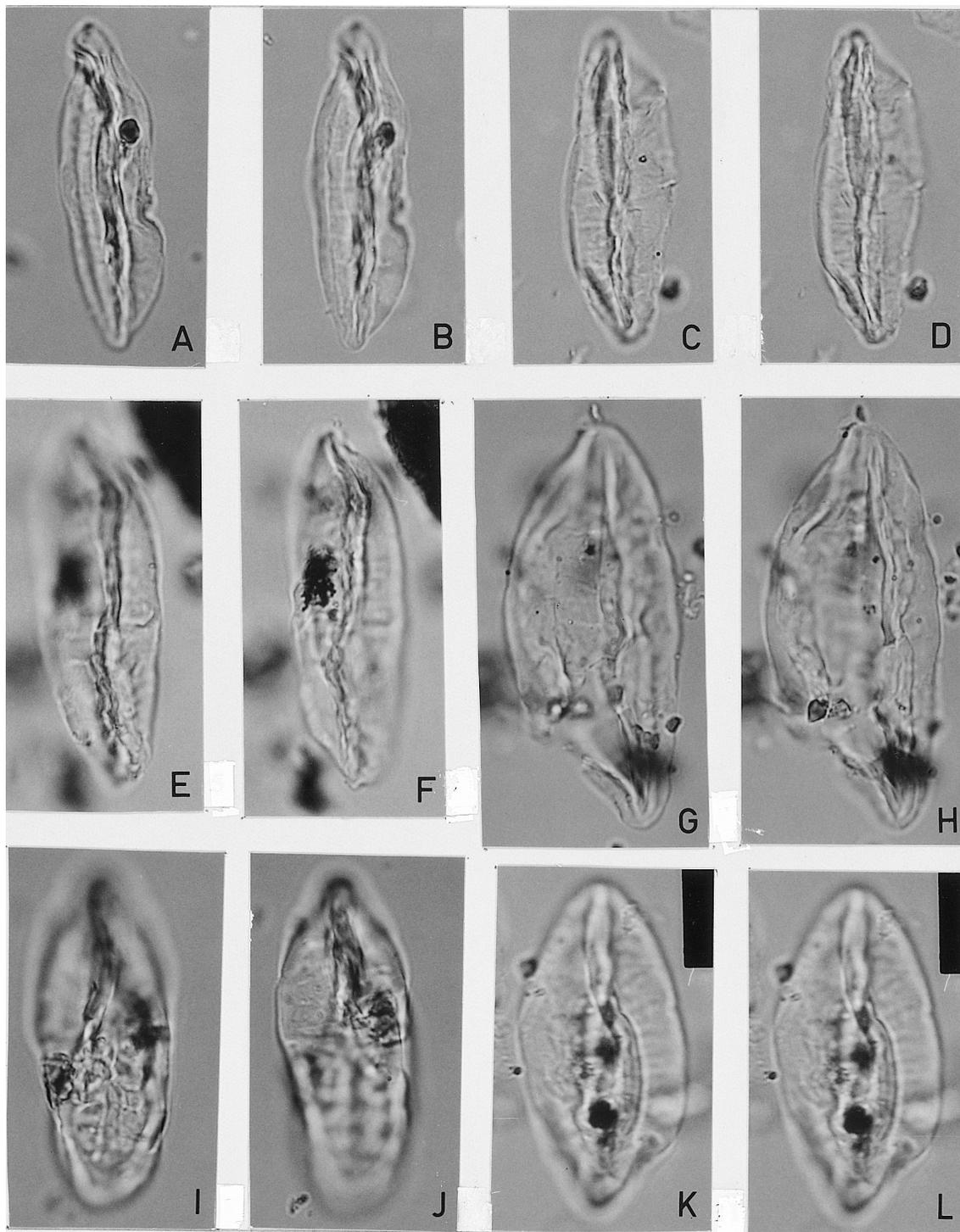


Figure 4. A–F, *Ephedripites (D.) baculatus* Zhu et Wu (Film P8:5-8, P8:4-7, S7:13, S7-14, P6:18-20, P6:17-19); G–H, *Ephedripites (D.) nanlingensis* Sun & He (Film S6:15, S6:6-14); I–L, *Ephedripites (D.) miocenus* Huang & Chaw (Film P8:7-10, P8:8-11, P5:22-24, P5-23-25). (All $\times 1150$)

Key to the Species (Compiled from Huang, 1976 and this study)

1. Grains in equatorial view perprolate, length over width larger than 2.6.
 2. Grains with 5 or more ridges, exine smooth.
 3. Grains large, more than $40\ \mu$ in length.

4. Grains more than $50\ \mu$ in length 1. *E. (E.) gracilis*
4. Grains less than $50\ \mu$ in length 2. *E. (E.) taiwanensis*
3. Grains small, less than $40\ \mu$ in length 5. *E. (E.) minor*

2. Grains with 4 ridges, exine scabrate
 4. *E. (E.) scabratus*
1. Grains in equatorial view prolate, length over width less than 2.3.
5. Grains with 10 or more ridges
 7. *E. (E.) polypticatus*
5. Grains ridges less than 10, exine scabrate.
6. Grains with 7–9 ridges, some of the ridges undulate
 6. *E. (E.) olivaeformis*
6. Grains with 5–6 ridges, the ridges not as above..
 3. *E. (E.) angularis*

1. *Ephedripites (E.) gracilis* Shaw, sp. nov.

Figure 5A–D

Holotype: Slide OK-1 1669- (3); Figure 5A–B; film S5-26, S5-27; CPC Micropaleontology Lab.

Description: Grains with 6–9 ridges; perprolate, the pole rounded to acute; $55\text{--}60 \times 14\text{--}16 \mu$ grooves as long as the P axes; grain length over width about 3.6–3.9; cross-grid absent; ridges 1.5μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Taxonomic affinity: This species and the other six species described in this section are similar to the extant species of *Ephedra*.

Comment: This species differs from other species in having a larger size (more than 55μ) and grains in equatorial view perprolate.

Note. This species is named after the graceful shape of the pollen.

2. *Ephedripites (E.) taiwanensis* Huang, 1976.

Figure 5E–H

Holotype: Slide OK-1 1788-bl-(4); film P1-27-29, P1-28-30; CPC Micropaleontology Lab.

Description: Grains with 6–9 ridges; perprolate, the pole rounded to acute; $43\text{--}46 \times 13\text{--}14 \mu$ grooves as long as the P axes; grain length over width about 3.3; cross-grid absent; ridges 1.5μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,788 m).

3. *Ephedripites (E.) angularis* Shaw, sp. nov.

Figure 5K–L

Holotype: Slide OK-1 1699-bl-(2); Figure 5K–L; film P7-10-12, P7-11-13; CPC Micropaleontology Lab.

Description: Grains with 5–6 ridges; prolate, the pole acute; $33 \times 15 \mu$; the grooves as long as the P axes; grain length over width about 2.2; exine psilate; ridges about 1.5μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Comment: This species differs from *Ephedripites (E.) olivaeformis* Shaw in having fewer ridges (5–6 ridges) and ridges are not undulate.

Note. This species is named after the angulate shape of the pollen.

4. *Ephedripites (E.) scabratus* Shaw, sp. nov.

Figure 6G–H

Holotype: Slide OK-1 1588-bl-(3); Figure 6G–H; film P9-4-6, P9-3-5; CPC Micropaleontology Lab.

Description: Grains with 4 ridges; perprolate, the pole acute; $47 \times 14 \mu$ grooves as long as the P axes; grain length over width about 3.4; cross-grid absent; exine scabrate; ridges about 1μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,588 m).

Comment: This species differs from other species in having scabrate exine.

Note. This species is named after the scabrate sculpture of the exine.

5. *Ephedripites (E.) minor* Shaw, sp. nov.

Figure 5I–J and Figure 7E–F

Holotype: Slide OK-1 1788-(5); Figure 5I–J; film S5-28, S5-29, S5-30; CPC Micropaleontology Lab.

Description: Grains with 5–6 ridges; perprolate, the pole rounded to acute; $33\text{--}38 \times 10\text{--}12 \mu$ grooves as long as the P axes; grain length over width about 3.0–3.8; cross-grid absent; the ridge 1.0μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,788 m).

Comment: This species differs from *Ephedripites (E.) taiwanensis* Huang in having a smaller size.

Note. This species is named after the smaller size of the pollen.

6. *Ephedripites (E.) olivaeformis* Shaw, sp. nov.

Figure 6I–L

Holotype: Slide OK-1 1768-(5); Figure 6I–J; film S7:1, S7:2; CPC Micropaleontology Lab.

Description: Grains with 7–9 ridges; prolate, pole acute; $28\text{--}33 \times 17\text{--}19 \mu$; the grooves as long as the P axes; grain length over width about 1.6–1.8; some of the ridges dense unit wavy shape (undulate); exine psilate to scabrate; ridges 1.5μ thick.

Stratigraphic occurrence: Eocene (OK-1 well, 1,768 m).

Comment: This species differs from *Ephedripites (E.) undulatus* Shaw 1984 in having fewer ridges (less than 10). *Ephedripites (D.) undulosus* Ke & Shi 1978 also has undulate ridges, but it belongs to another subgenus.

Note. This species is named after the olivary shape of the pollen.

7. *Ephedripites (E.) polypticatus* Shaw, sp. nov.

Figure 7I–L

Holotype: Slide OK-1 1638-(5); Figure 7I–J; film S8:21, S8:22; CPC Micropaleontology Lab.

Description: Grains with 12–15 ridges; prolate, the pole acute; $33\text{--}38 \times 17\text{--}22 \mu$; the grooves as long as the P axes; grain length over width about 1.7–1.9; exine psilate; the ridge 1μ thick.

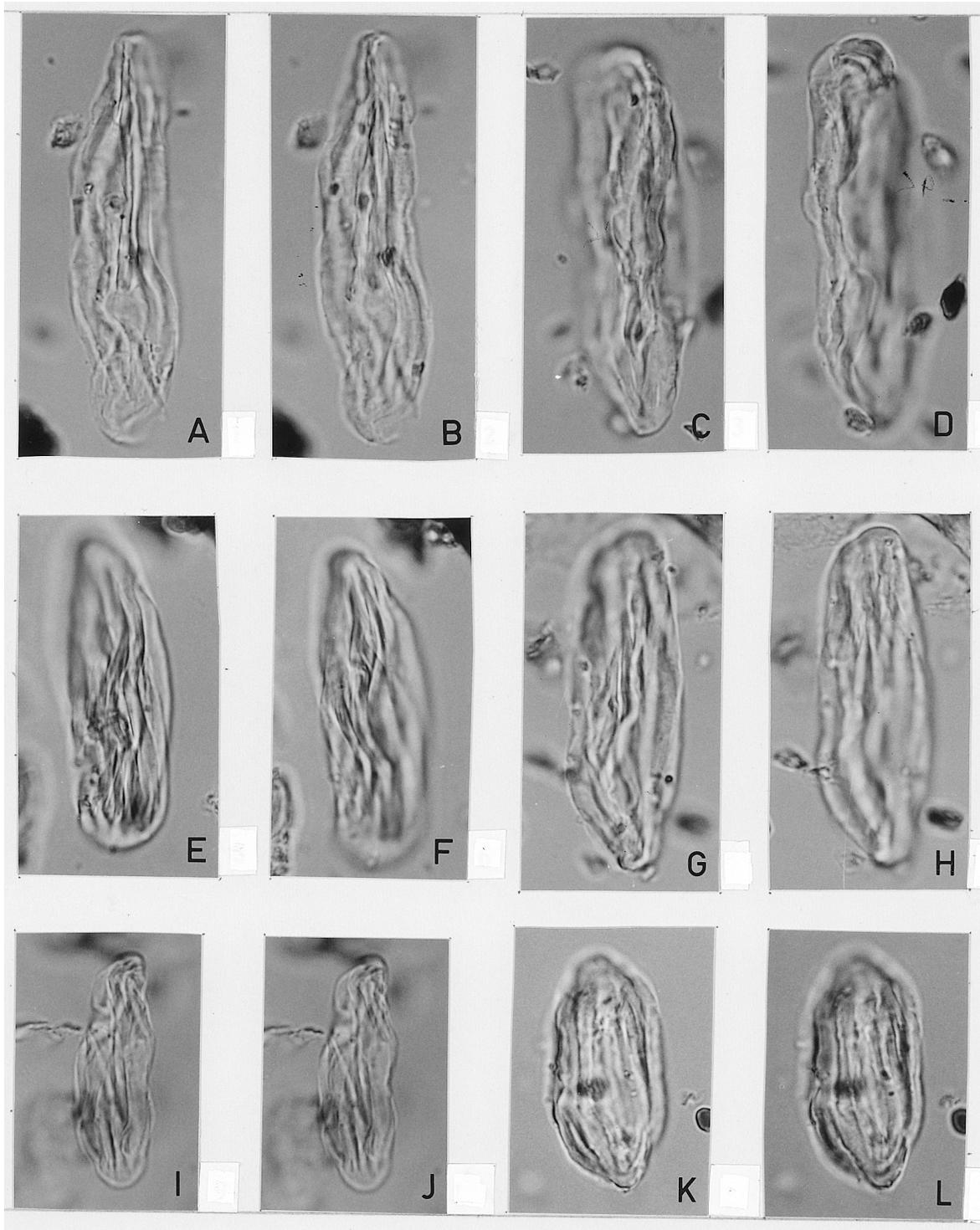


Figure 5. A–D, *Ephedripites (E.) gracilis* Shaw sp. nov. (Film S5:26, S5:27, S6:8, S6-7); E–H, *Ephedripites (E.) taiwanensis* Huang (Film S4:4, S4:3, P1:28-30, P1:27-29); I–J, *Ephedripites (E.) minor* Shaw sp. nov. (Film S5:29, S5:30); K–L, *Ephedripites (E.) angularis* Shaw sp. nov. (Film P7:12-14, P7-10-12). (All $\times 1150$)

Stratigraphic occurrence: Eocene (OK-1 well, 1,638 m).

Comment: This species differs from others in having twelve or more ridges.

Note. This species is named for the frequent plication of its pollen.

EPHEDRIPITES subgen. **SPIRALIPITES** Krutzsch 1970, Atlas, v. 7 p. 43.—TYPE species: *Ephedripites (Spiralipites) praeciarus* (Khlonova) Krutzsch, ibid.

Diagnosis: “A subgenus (of *Ephedripites*) with numerous rotated ribs and without zig-zag lines, and mostly found in the upper Cretaceous.”

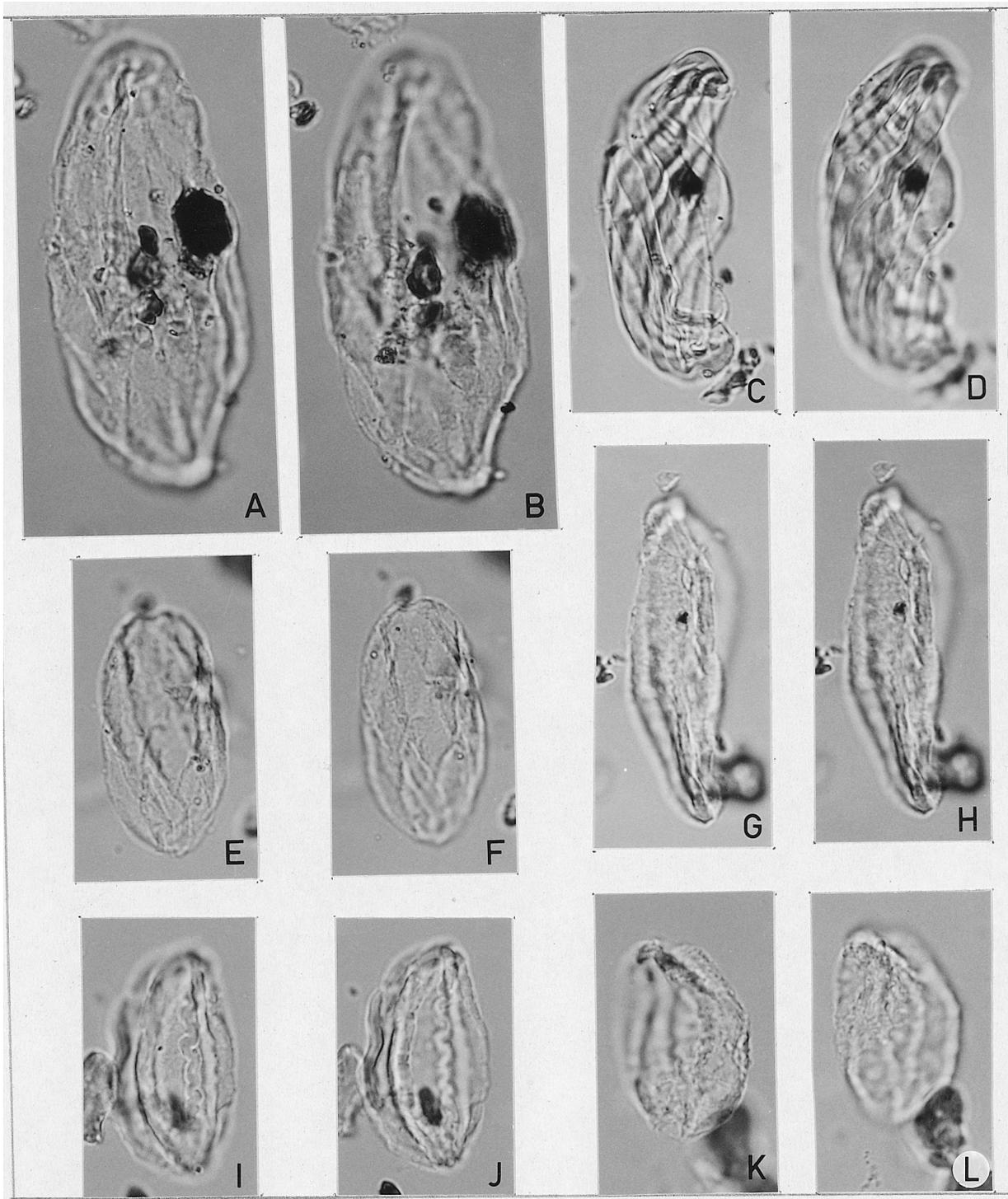


Figure 6. A–B, *Ephedripites (S.) perprolatus* Shaw sp. nov. (Film P7:6-8, P7:5-7); C–D *Ephedripites (S.) densistriatus* Shaw sp. nov. (Film P15:15-17, P15:16-18); E–F, *Ephedripites (S.) pengchiahsuensis* Shaw sp. nov. (Film P14:17-18, P14:18-19); G–H, *Ephedripites (E.) scabratus* Shaw sp. nov. (Film P9:3-5, P9:4-6); I–L, *Ephedripites (E.) olivaeformis* Shaw sp. nov. (Film S7:1, S7:2, S7:20, S7-19). (All $\times 1150$)

Key to the Species

- | | | |
|---|---|------------------------------------|
| 1. Grain length over width less than 3.0. | 3. Grains large, more than 55 μ in length | 1. <i>E. (S.) perprolatus</i> |
| 2. Grain muri in line shape, about 0.5 μ wide | 3. Grains small, less than 45 μ in length | 2. <i>E. (S.) pengchiahsuensis</i> |
| 3. <i>E. (S.) densistriatus</i> | 1. Grain length over width larger than 3.5 | 4. <i>E. (S.) tenuissimus</i> |
| 2. Grain muri in line shape, about 2–3 μ wide. | | |

1. *Ephedripites* (*S.*) *perprolatus* Shaw, sp. nov.

Figure 6A–B

Holotype: Slide OK-1 1699-bl-(2); film P7-5-7, P7-6-8; CPC Micropaleontology Lab.

Description: Grains encircled type, with 8–10 ridges; perprolate; $65 \times 27 \mu$; the pole rounded to obtuse; grain length over width about 2.4; surface view striate, striae 2–3 μ wide, the muri in line shape, about 3 μ wide.

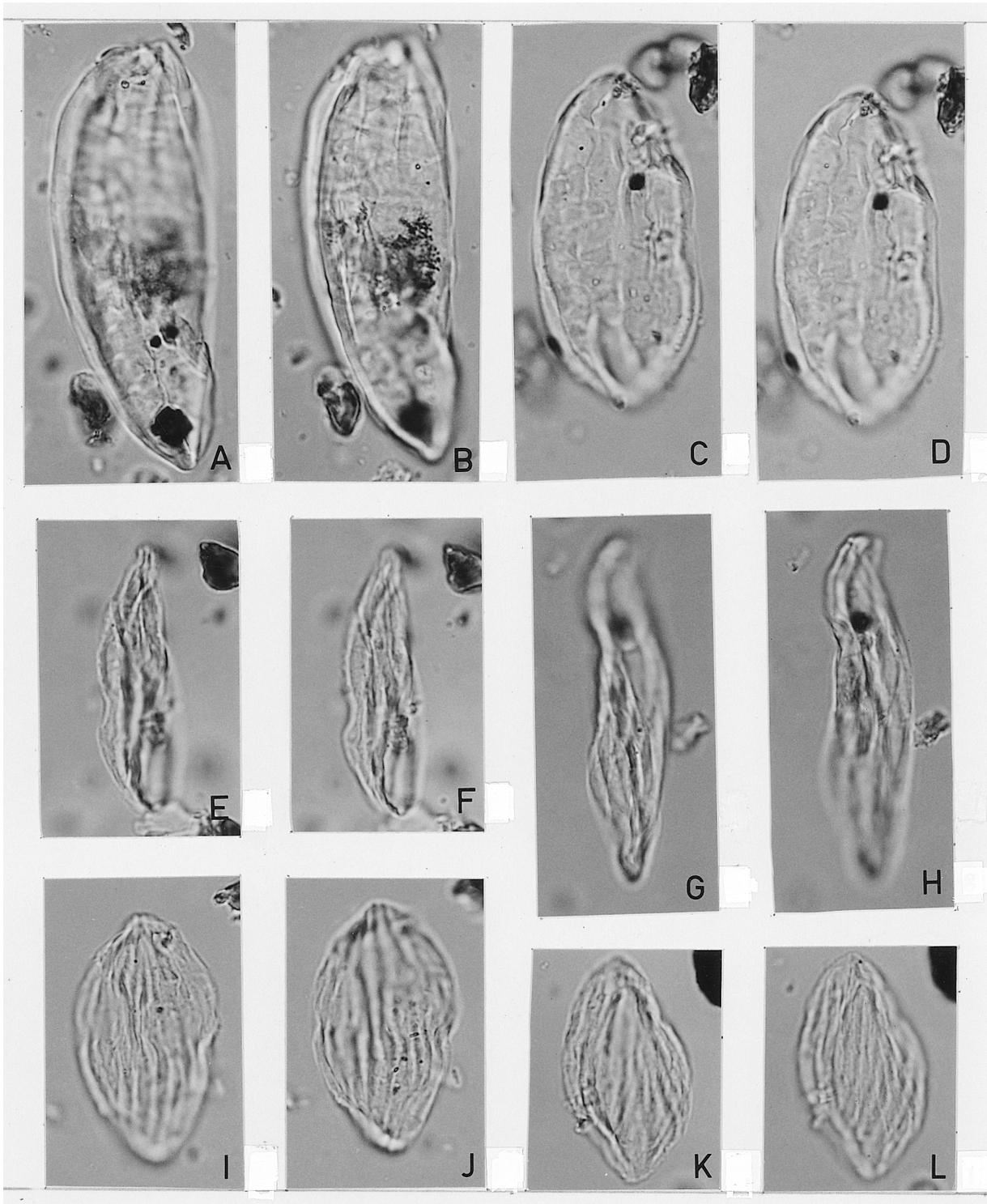


Figure 7. A–B, *Ephedripites* (*D.*) *quadriplicatus* Shaw (Film P10:18-17, P10:17-16); C–D, *Ephedripites* (*D.*) *nanlingensis* Sun & He (Film S7:25, S7-26); E–F, *Ephedripites* (*E.*) *minor* Shaw sp. nov. (Film P15:9-11, P15:8-10); G–H, *Ephedripites* (*S.*) *tenuissimus* Shaw sp. nov. (Film P7:28-30, P7:29-31); I–L, *Ephedripites* (*E.*) *polyplacatus* Shaw sp. nov. (Film S8:21, S8:22, P15:6-8, P15:5-7). (All $\times 1150$)

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Taxonomic affinity: This species and the other three species described in this section are similar to the extant species of *Ephedra*. It belong to the subgenus *Spiralipites*, which is mostly found in the Upper Cretaceous (Jansonius and Hill, 1976).

Comment: This species differs from *Ephedripites* (*S.*) *clathratus* (Stover) Zhu & Wu 1985 and *Ephedripites* (*S.*) *Huangshiensis* Zhu & Wu 1985 by having fewer ridges (ten or less) and differs from *Ephedripites* (*S.*) *pengchiahsuensis* Shaw by having a larger size (more than 45 μ in length).

Note. This species is named after the perprolate shape of its pollen.

2. *Ephedripites* (*S.*) *pengchiahsuensis* Shaw, sp. nov.

Figure 6E–F

Holotype: Slide OK-1 1719- (1); film P14-17-18, P14-18-19; CPC Micropaleontology Lab.

Description: Grains encircled type, with 7 ridges; prolate to perprolate; $34 \times 17 \mu$; the pole rounded; grain length over width about 2.0; surface view striate, striae 1–2 μ wide, the muri in line shape, about 3–4 μ wide.

Stratigraphic occurrence: Eocene (OK-1 well, 1,719 m).

Comment: This species differs from *Ephedripites* (*S.*) *clathratus* (Stover) Zhu & Wu 1985 and *Ephedripites* (*S.*) *Huangshiensis* Zhu & Wu 1985 by having fewer ridges (ten or less) and differs from *Ephedripites* (*S.*) *perprolatus* Shaw by having a smaller size (less than 45 μ in length).

Note. This species is named after the Pengchiahsu basin of the type locality.

3. *Ephedripites* (*S.*) *densistriatus* Shaw, sp. nov.

Figure 6C–D

Holotype: Slide OK-1 1788-bl-(1); film P15-15-17, P15-16-18; CPC Micropaleontology Lab.

Description: Grains encircled type, with 9–10 ridges; perprolate; $47 \times 19 \mu$; the pole rounded; grain length over width about 2.5; surface view striate, striae 2–3 μ wide, the muri in line shape, about 0.5 μ wide.

Stratigraphic occurrence: Eocene (OK-1 well, 1,788 m).

Comment: This species differs from *Ephedripites* (*S.*) *clathratus* (Stover) Zhu & Wu 1985 and *Ephedripites* (*S.*) *Huangshiensis* Zhu & Wu 1985 by having fewer ridges (ten or less) and differs from *Ephedripites* (*S.*) *pengchiahsuensis* Shaw, and *Ephedripites* (*S.*) *perprolatus* Shaw by the murri in line shap, about 0.5 μ wide.

Note. This species is named after the character of the dense striae.

4. *Ephedripites* (*S.*) *tenuissimus* Shaw, sp. nov.

Figure 7G–H

Holotype: Slide OK-1 1699-bl-(2); film P7-27-29, P7-28-30, P7-29-31; CPC Micropaleontology Lab.

Description: Grains encircled type, with 6–8 ridges; perprolate; $47 \times 19 \mu$; the pole acute; grain length over width about 4.5; surface view striate, striae 2 μ wide, the muri in line shape, about 0.5 μ wide.

Stratigraphic occurrence: Eocene (OK-1 well, 1,669 m).

Comment: This species differs from *Ephedripites* (*S.*) *clathratus* (Stover) Zhu & Wu 1985 and *Ephedripites* (*S.*) *Huangshiensis* Zhu & Wu 1985 by having fewer ridges (ten or less) and differs from *Ephedripites* (*S.*) *pengchiahsuensis* Shaw, *Ephedripites* (*S.*) *perprolatus* Shaw, and *Ephedripites* (*S.*) *densistriatus* Shaw by the grain length over width larger than 3.5.

Note. This species is named after the tenuissimus shape of the pollen.

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