

Early Cretaceous flora from central Jilin and northern Liaoning, northeast China

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The Early Cretaceous sediments widely distributed in the central Jilin and northern Liaoning of Northeast China called as Shahezi Formation contain Ruffordia-Onychiopsis flora. About 100 species belonging to 50 genera are described from these strata. In this article, the authors restudied the flora and described 7 new species—fungi: unnamed fungus, *Microthyricites shaheziensis* sp. nov.; ferns: *Atyrium dentosum* (sp. nov.); Bennettitales: *Nilssoniopteris latifolia* (sp. nov.), *N. introventus* (sp. nov.), *Nilssoniopteris* sp. nov.; Ginkgoales: *Sphenobaiera szetana* (sp. nov.). Judging from the composition and characteristics of the flora, it has been considered that it may belong to the Siberian-Canadian province phytogeographically. The age of the flora should be considered as Early Cretaceous.

Key-words—Ruffordia, Onychiopsis, Nilssoniopteris, Early Cretaceous (China).

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सारांश

उत्तरपूर्व चीन में उत्तरी लियाओनिंग एवं केन्द्रीय जिलिन से प्रारम्भिक क्रीटेशियस वनस्पतिजात

झेंग शावलिन एवं झांग वु

उत्तरपूर्व चीन के केन्द्रीय जिलिन एवं उत्तरी लियाओनिंग में दूर-दूर तक विस्तृत प्रारम्भिक अवसाद जो शहेजी शैल-समूह के नाम से जाने जाते हैं, में रफोर्डिया ओनाइकिऑप्सिस वनस्पतिजात से अभिलक्षणित हैं। इस स्तरों से अभी तक 50 प्रजातियाँ एवं 100 जातियाँ वर्णित की जा चुकी हैं। प्रस्तुत शोध-पत्र में इस वनस्पतिजात का पुनः अध्ययन किया गया है तथा सात नई जातियाँ वर्णित की गई हैं जिनमें एक कवक, माइक्रोथाइरियेसाइटिस शहेजियेन्सिस नव जाति, एथाइरियम डेन्टोसम नव जाति, निल्सोनियाऑप्टेरिस लेटिफोलिया नव जाति, नि. इन्ट्रोवीनियस नव जाति, नि. नव जाति एवं स्फीनोबेयरा स्जियाना नव जाति सम्मिलित हैं। इस वनस्पतिजात की संरचना और लक्षणों के आधार पर यह प्रस्तावित किया गया है कि भौगोलिक दृष्टि से यह साइबेरियन-कैनेडियन प्रान्त से सम्बन्ध व्यक्त करता है। इस वनस्पतिजात की प्रारम्भिक क्रीटेशी आयु प्रस्तावित की गई है।

THE Late Mesozoic strata are most extensively developed in the central Jilin and northern Liaoning of North-east China where the Early Cretaceous coal-bearing deposits mainly occur in many small fault basins and contain abundant fossil plants. Some of them were first described by Krasser (1906) and later by Yabe and Oishi (1933), Oishi(1933), Sze *et al.* (1963) and Yang and Sun (1982), etc. Uptil now, there is no agreement on the age of plant assemblage of the Shahezi Formation. Recently the authors(1986-1987), restudied the flora and collected specimens from

many localities including the type locality of Shahezi Formation (see Text-figure 1). About 100 species of fossil plants have been recognized, belonging to 50 genera, including a new genus, 7 new forms or species and a few new combinations.

STRATIGRAPHY AND PLANT FOSSILS

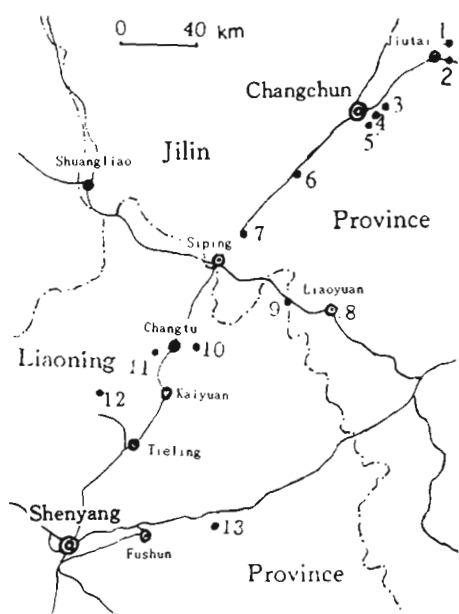
The Early Cretaceous coal-bearing strata of the central Jilin and northern Liaoning have different names in different areas. The following table shows the correlation between the different formations :

Table 1

Jutai-Changtu	Liaoyuan-Pinggang	Tiefa	Nanzamu-Nieerku
Yingcheng Formation	Changan Formation	Fuxin Formation	Nieerku Formation
Shahezi Formation		Shahai Formation	Lishugou Formation

The localities and stratigraphic positions of the fossil plants are as follows:

1. Lutai, Jutai city, the Yingcheng Formation.
2. Yingcheng, Jutai city, the Yingcheng Formation and the Shahezi Formation.
3. Yangcaogou, Changchun City, the Yingcheng Formation.
4. Shibeiling, Changchun City, the Shahezi Formation.
5. Taojiatun, Changchun City, the Shahezi Formation.
6. Liufangzi, Huaide County, the Yingcheng Formation.
7. Mengjialing, Lishu County, the Yingcheng Formation.
- 8-9. Liaoyuan-Pinggang, Liaoyuan City, the Changan Formation.



Text-figure 1—Showing the fossil localities. 1. Lutai, 2. Yingcheng, 3. Yangcaogou, 4. Shibeiling, 5. Taojiatun, 6. Liufangzi, 7. Mengjialing, 8. Liaoyuan, 9. Pinggang, 10. Shahezi, 11. Dawa, 12. Tiefa, 13. Nieerku.

- 10-11. Shahezi-Dawa, Changtu County, the Shahezi Formation.
12. Tiefa City, the Shahai-Fuxin Formation.
13. Nieerku, Nanzamu Town, Xinbin County, the Nieerku Formation.

FOSSIL PLANT ASSEMBLAGE OF THE SHAHEZI FORMATION

1. Plant assemblage of the Shahezi Formation consists of following species:

Fungi—Unnamed fungus, *Liaoningnema multinoda* Zheng et Zhang, *Microthyriacites shaheziensis* sp. nov., *Perisporiacites shaheziensis* Zheng et Zhang, *Stigmatacites polymorphus* Zheng et Zhang;

Equisetales—*Equisetum burejense* Heer;

Ferns—*Coniopteris arctica* (Prynada), *C. burejensis* (Zal.), *C. depensis* Lebedov, *C. fittonii* (Seward), *C. nympharum* (Heer), *C. saportana* (Heer), *C. setacea* (Pryn.), *C. vachrameevii* Vassil., *Dicksonia silapensis* (Pryn.), *Acanthopteris gothanii* Sze, *A. onychioides* (Vassil. et K.-M.), *Gonatosorus ketovae* Vachr., *Dryopterites erecta*, *Athyrium cretaceum* Chen et Meng, *A. dentosum* sp. nov., *A. fuxinense* Chen et Meng, *Ruffordia goeppertii* (Dunker), *Onychiopsis elongata* (Geyler), *Cladophlebis argutula* (Heer), *Cl. delicatula* Yabe et Oishi, *Cl. lobulata* Samyl. *Cl. (Gleichenites?) munda*, *Cl. obesus* Chang, *Cl. pseudolobifolia* Vachr. *Cladophlebis* sp. nov?, *Sphenopteris johnstrupii* Heer;

Bennettitales—*Pterophyllum* cf. *propinquum* Goepfert, *P.* cf. *sensinovianum* Heer, *Tyrmia* cf. *polylovii* Pryn, *Nilssoniopteris beyrichii* (Schenk), *Nilssoniopteris* n. sp.;

Cycadales—*Nilssonia schauburgensis* (Dunker), *N. sinensis* Yabe et Oishi, *Ctenis concinna*;

Ginkgopsida—*Ginkgo chinensis* Lee, *G. crasinervis* Yabe et Oishi, *G. digitata* (Brongn.), *G. huttonii* (Sternb.), *G. manchurica* (Yabe et Oishi), *G. orientalis* (Yabe et Oishi), *G. ex gr. sibirica* Heer, *Baiera concinna* (Heer), *B. gracilis* (Bean), *B. kidoi* Yabe et Oishi, *B. minima* Yabe et Oishi, *Czekanowskia rigida* Heer, *C. setacea* Heer, *Sphenobaiera longifolia* (Pomel), *Ixostrobus heeri* Pryn.;

Conifers—*Pityocladus* cf. *longifolius* (Nathorst), *P.* cf. *yabei*, *Pityophyllum lindstroemii* Nathorst, *P. staratchinii* (Heer), *Pityolepis* sp., *Sphenolepis kurriana* (Dunker), *Elatides curvifolia* (Dunker), *Cunninghamia asiatica* (Krassil.), *Cephalotaxopsis mag-*

nifolia Fontaine, *Parataxodium jacutense* Vachr., *Taxus intermedius* (Hollick), *Sabinites neimongolica* Tan et Zhu, *Cephalotaxopsis* sp., *Pagiophyllum triangulare* Pryn., cf. *Lindleycladus lanceolatus* (L.H.), *Podozamites latifolius* (Heer), *Scarburgia triangularis* Meng, *Carpolithus jidongensis* Zheng et Zhang;

Silicified wood—*Phyllocladoxylon* cf. *eboracense* (Holden).

Table 2

Group	Number of genera	Number of species	Percentage (%)
Fungi	5	5	6.67
Ferns	10	26	34.67
Equisetales	1	1	1.33
Bennettitales	6	8	10.67
Cycadales			
Ginkgopsida	5	15	20.00
Conifers	14	18	24.00
Others	2	2	2.66
Total	43	75	100

2. The percentage of different groups are as follows :

Based upon the above statistics, following points concerning the characteristics of this assemblage may be given :

1. Ferns (34.67%) and conifers (24.00%) are the most dominant groups. Ginkgopsida (20.00%) and Cycadales (including Bennettitales) (10.67%) rank next in importance. Fungi (6.67%) and Equisetales, etc. are scarce.
2. Dicksoniaceae comprising 4 genera (*Coniopteris*, *Dicksonia*, *Acanthopteris*, *Gonatosorus*) with 12 species occupies a dominant position. Schizaeae-

ceae (*Ruffordia*), Sinopteridaceae (*Onychiopsis*) and Athyriaceae (*Athyrium*) are represented only by 1-2 species, respectively. *Cladophlebis*, *Sphenopteris* and *Dryopterites* constitute a rather large proportion.

3. Bennettitales consist of 4 species and 3 genera; Cycadales 4 species and 3 genera. They are represented by *Pterophyllum*, *Tyrmia*, *Nilssoniopteris*, *Nilssonina* and *Ctenis*, respectively.
4. Ginkgopsida of the plant assemblage consists of 15 species belonging to *Ginkgo*, *Baiera*, *Sphenobaiera*, *Czekanowskia*, *Ixostrobus* which are possibly the main coal forming plants.
5. Coniferopsida is the most important group of the assemblage. The ancient Pinaceae consists of 5 species and 3 genera (*Pityocladus*, *Pityophyllum*, *Pityolepis*). Taxodiaceae consists of 4 species and 4 genera (*Sphenolepis*, *Elatides*, *Cunninghamia*, *Parataxodium*), Taxaceae 2 species and 2 genera (*Taxus*, *Cephalotaxopsis*), Cheirolepidiaceae 1 species and 1 genus (*Pagiophyllum*), Cupressaceae 2 species and 1 genus (*Sabinites*), Podozamitales 3 species and 2 genera (cf. *Lindleycladus*, *Podozamites*), etc.

On the evidence of the fossil plant, the assemblage of the Shahezi Formation may belong to the Early Cretaceous of the Siberian-Canadian phytogeographic province (Vachrameev, 1964; Vachrameev *et al.*, 1978).

All the specimens are housed in Shengyang Institute of Geology and Mineral Resources, Chinese Academy of Geosciences and registered under SG1-10.

PLATE 1

- 1, 2. Unnamed fungus; 1, showing parasitic mycelium on upper cuticle of *Nilssoniopteris latifolia* (sp. nov.). X 100.
2. A part of fig. 1, X 400. SG 110309. Liaoyuan Coal Mine; Changan Formation.
3. *Microthyriacites shaheziensis* sp. nov., holotype: a rounded ascumata, X 400. SG110314. Shahezi Coal Mine, Changtu County; Shahezi Formation.
4. *Ruffordia goeppertii* (Dunker) Seward: sterile leaf. SG110289. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
- 5, 6. *Cladophlebis* sp. nov.
5. Ultimate pinnae of sterile leaves.
6. Part of fig. 5 showing the denticulate margins of pinnules. X 2. SG110303. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
7. *Coniopteris fittonii* (Seward) Zheng et Zhang : A fertile leaf (on left) and sterile leaves, actual size. SG110288. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
8. *Cladophlebis lobulata* Samylna: showing lobed first basicopic band across pinnules. X 2. SG110302. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
- 9-11. *Athyrium dentosum* sp. nov.
9. A fertile leaf.
10. A part of fig. 9, showing fertile pinnules, X 2.
11. A part of fig. 9, showing sporangia and margin of fertile pinnule, X 36. SG110304. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
- 12, 13. *Athyrium cretaceum* Chen et Meng.
12. Showing a fertile leaf.
13. A part of fig. 12, X 12. SG110301. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
- 14, 15. *Athyrium fuxinense* Chen et Meng.
14. A sterile leaf.
15. Fertile pinnules. SG110298, SG110299. Yingcheng Coal Mine; Shahezi Formation.

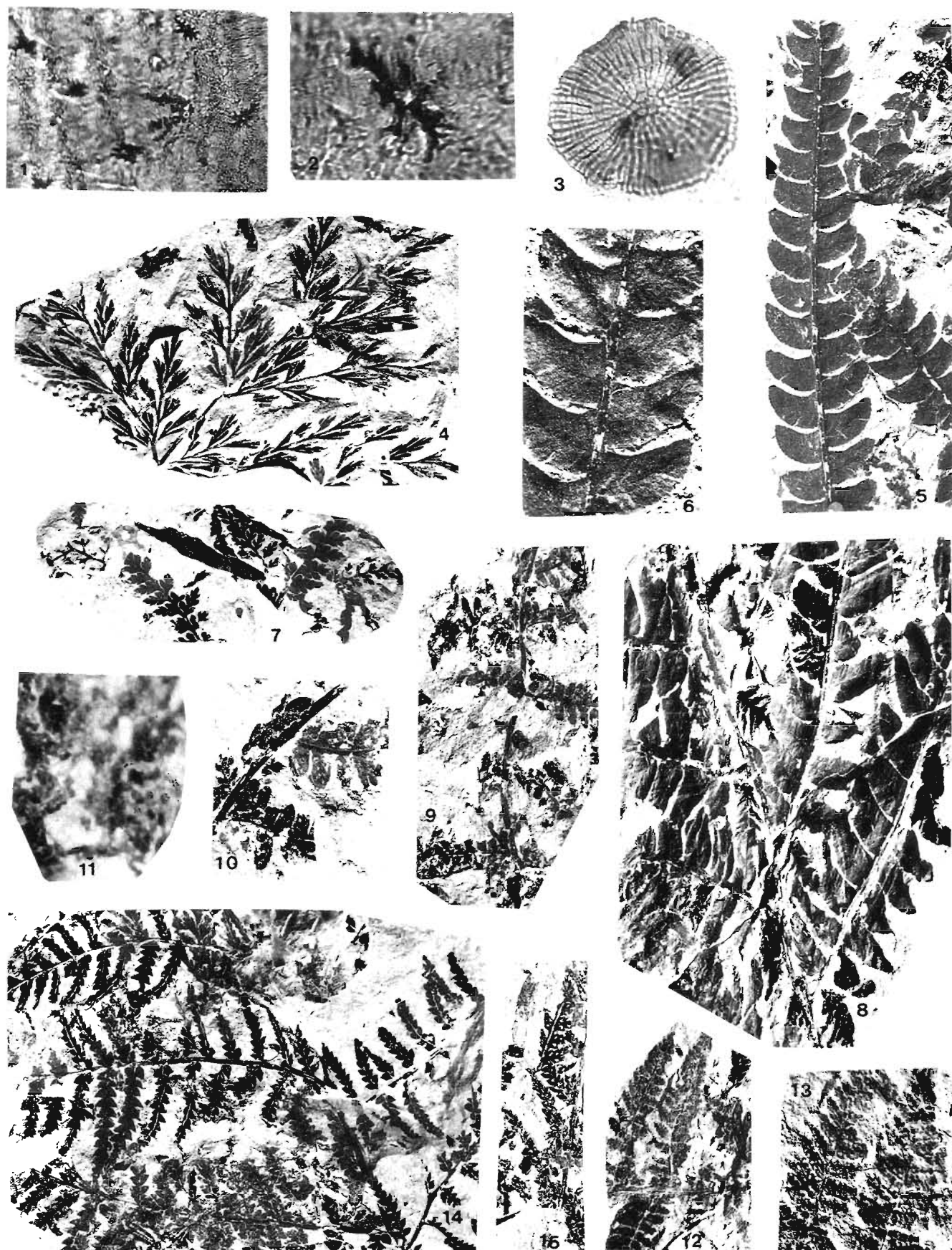


PLATE 1

SYSTEMATIC DESCRIPTION

Unnamed fungus

Pl. 1, figs 1-2

Description—Ascomata irregularly radiate, composed of polymorphic, furcellate hyphae, about 50-70 μ m in size. Hypha yellow-brown, transparent or translucent; foot cells rather wide, narrowing very gradually towards the apex. Ascospores unknown.

Discussion and comparison—This new form of fungus is parasitic on the lower surface of *Nilssoniopteris latifolia* (sp. nov.). The hyphae appear to break into the stomatal pits of cuticle to form a bundle of conidiophore. The foot cells were possibly germinated from the sporodichium below stomata and one or a few of the foot cells gave rise to conidiophores. The systematic position of this fungus seems with the living member *Cymadothea trifolii* (Pers.) Wolf. of Dothideaceae (Gaumann, 1951, p. 136, fig. 172), but the material is insufficient for detailed study.

Localities and horizons—Liaoyuan Coal Mine, Changan Formation; Shahezi Coal Mine, Shahezi Formation.

Microthyriacites shaheziensis sp. nov.

Pl. 1, fig. 3

Description—Ascostoma large, round, flattened, astomate, 130 μ m in diameter, composed of stout, thick-walled, completely united hyphae radiating from a central group of polyhedral cells, with intermittently concentric diaphragms, outer margin of the ascostoma entire or sinuous. Ascospores unknown. On the cuticular surface of *Nilssoniopteris* sp. nov.?

Discussion and comparison—The present species resembles *Microthyriacites plicatus* Zheng et Zhang from the Early Cretaceous Fuxin Formation in Fuxin Basin (Zheng et Zhang, 1986, p. 432; pl. II, figs 3-4), but the latter is characterized by dense hyphae. *Microthyriacites fuxinensis* Zheng et Zhang from the same horizon (Zheng et Zhang, 1986, p. 432, p. II, figs 8, 9) is different from the new species chiefly in the thinner cell-walls, and in the frequently thickened

outer margin of the ascostoma and the quadrilateral central cells.

Locality and horizon—Shahezi, Changtu County; Shahezi Formation.

Athyrium dentosum sp. nov.

Pl. 1, figs 9-11

Description—Fertile leaves bipinnate, elongated. Main rachis slender, about 1.5 mm thick, slightly curved, surface smooth but with an indistinct longitudinal rib. Ultimate pinnae subopposite, arising at intervals of about 2 cm and at an angle of 90° in lower part of leaf but at shorter intervals and smaller angles above, linear-lanceolate, up to 2 cm long and 7-8 mm wide, with obtuse to pointed apices. Pinnules straight, approximately opposite, arising at angles of 80°-90°, similar in shape and size on both sides of the pinna, oblong to lingulate, mostly 3-4 mm long and 1.5-2 mm wide, with entire margins in lower parts of the pinnule but being dentate in upper parts. Midrib straight, conspicuous, but lateral veins inconspicuous, basal pair of veins forked once, others simple, about 4-5 pairs per pinnule. Sori borne singly on the anterior branch of lateral veins, hoof-shaped or ovate. Each sorus composed of more than 15-25 sporangia. Sporangia elliptic in shape, diameter about 150-200 μ m. Annulus nearly vertical, incomplete. Spores unknown.

Discussion and comparison—In general gross morphology of frond, the hoof-shaped or ovate sorus, the new species resembles the living genus *Athyrium*. It seems to be closely related to both *Athyrium cretaceum* and *A. fuxinense* (Chen & Meng, 1988, pp. 42-43; pl. 13, figs 5-9; pl. 14, figs 1-11; text-fig. 14b; pl. 14, figs 12-13; pl. 15, figs 1-5; text-fig. 14a). In *A. cretaceum*, the fertile leaves are very similar indeed, but differ in having triangular or elongated triangular pinnules, and with 6 pairs of lobes.

Localities and horizon—Yingcheng, Jiutai City; Shahezi Formation.

PLATE 2

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| 1-5. <i>Pterophyllum angustifolium</i> Deng | 6. A fragment of leaf. |
| 1. Fragments of leaf. | 7. Lower cuticle, showing stomata and trichome bases; vein in middle. X 200. |
| 2. Lower cuticle, stomata and trichome bases, X 100. | 8. Lower cuticle, midrib on left. X 100. |
| 3. Upper cuticle, midrib on left, showing epidermal cells. X 100. | 9. Upper cuticle, showing cell shapes on midrib. X 200. |
| 4-5. Stomata, X 400. SG110305. Liaoyuan Coal Mine; Changan Formation. | 10. A stoma, X 400. SG110312. Yangcaogou Coal Mine, Changchun City; Yingcheng Formation. |
| 6-10. <i>Nilssoniopteris introventus</i> sp. nov. | |

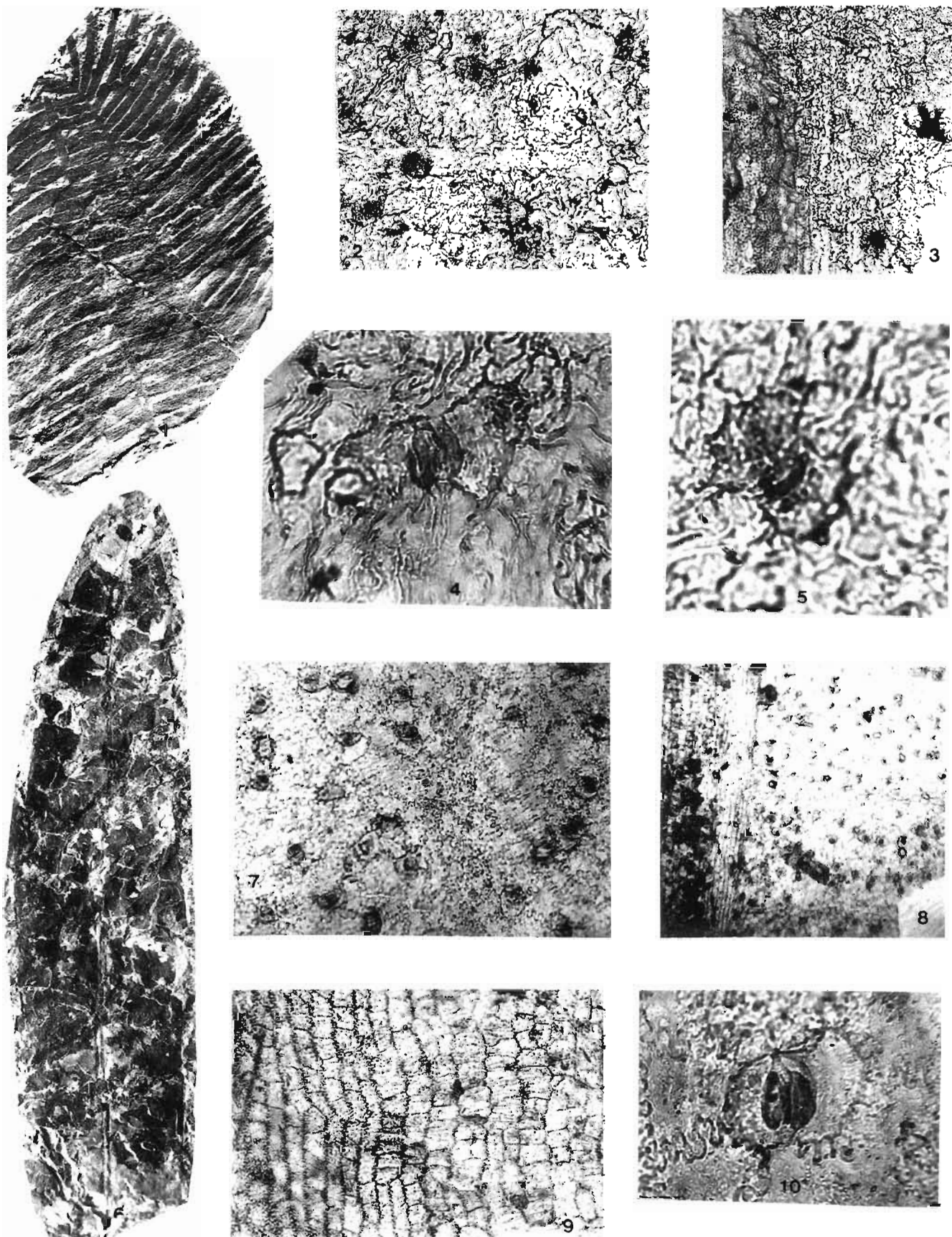


PLATE 2

Nilssoniopteris introvenius sp. nov.

Pl. 2, figs 6-10

Description—Leaf lanceolate, up to 13 cm long, 3.2 cm broad at middle, gradually narrowing towards the upper and lower parts. Apex obtuse, base unknown. Substance of lamina thin. Midrib smooth, slender, straight; lower part about 1 cm thick. Veins indistinct, simple, arising at a concentration of 15-20 per cm. Margin usually slightly recurved and forming a thickened, nearly entire edge. Cuticle moderately thick. Upper cuticle without stomata or trichomes. Cells more or less rectangular or polygonal; walls inconspicuous, rather strongly sinuous. Cuticle of the midrib thicker, cells arranged in regular rows, longitudinally and transversely rectangular; walls strongly marked. Trichome bases rare.

Lower cuticle with stomata in bands between veins. Epidermal cells between veins polygonal, but rectangular and forming 3-4 longitudinal rows along veins. Cell outlines distinct; anticlinal walls sinuous; surface finely granular. Stomata scattered, irregularly oriented, about 25 x 38 μm . Subsidiary cells large; anticlinal wall usually tightly folded, forming radiate ridges on the periclinal walls. Guard cells well cutinised. Trichomes always present, but varied in number, most common between veins. Trichome bases consisting of one or two cells.

Cuticle of the abaxial side of midrib very thick, showing narrow rows of uniform rectangular cells; walls straight or slightly sinuous.

Discussion and comparison—In general shape, the new species resembles *Nilssoniopteris prynadae* Samyl. from the Zyryanka Basin, Russia (Samylina, 1964, p. 75; pl. 16, fig. 8; pl. 18, figs 4-10), but in the latter species, the subsidiary cells are strongly cutinised with usually straight anticlinal walls, without radiate ridges on the periclinal walls.

Locality and horizon—Yangcaogou, Changchun City; Yingcheng Formation.

Nilssoniopteris latifolia sp. nov.

Pl. 3, figs 1-5

Description—Middle segments of the leaf 5 cm wide at the widest part. Margin of lamina flat and entire. Substance of lamina thick. Midrib smooth. Vein distinct, straight, arising at a concentration of 20-22 per cm, simple or occasionally once forked near margins.

Cuticles thick, upper cuticle without stomata or trichomes. Cells most rectangular and forming regular longitudinal rows along veins; anticlinal walls strongly folded, but without ridges on the periclinal walls. No papillae present. Lower cuticle with stomatal bands between veins, stomatal bands equal in breadth or only slightly broader than non-stomatal bands along veins. Epidermal cells between veins polygonal, and scarcely forming distinct rows. Cell outlines marked; anticlinal walls strongly sinuous; surface walls flat, finely granular and not papillate. Stomata about 20 x 30 μm , irregularly oriented, often oblique to veins. Subsidiary cells small; anticlinal walls thick, slightly sinuous. Guard cells strongly cutinised, not sunken. Trichomes present, commonly along veins. Trichome bases consisting of one or two cells, rarely more. Basal cells smaller than epidermal cells; anticlinal walls thick and less sinuous.

Discussion and comparison—Leaves of this new species vary greatly in width. The narrower leaves have simple veins, while the wider ones with forked veins. In general shape, it is easy to be confused with *Nilssonia thomasi* (Harris, 1964, p. 37; fig. 15). In the new species, however, the cuticle is much thicker and entirely different in structure. The present species is not perfectly known. So far as the middle part alone is concerned, the leaf differs in no respects in general

PLATE 3

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| <p>1-5. <i>Nilssoniopteris latifolia</i> sp. nov.
 1-2. Fragments of leaf.
 3. Lower cuticle, showing stomata and trichome bases (veins on left and right), X 200.
 4. Upper cuticle, X 200.
 5. Lower cuticle, showing a stoma, X 400. SG110309, SG110310. Liaoyuan Coal Mine; Changan Formation.</p> <p>6-12. <i>Nilssoniopteris shaheziense</i> sp. nov.
 6-7. Fragments of leaf. SG110313, SG110314.
 8. Upper cuticle, showing cells (a vein on the left), X 200.
 9. Upper cuticle, showing stomatal bands between veins (veins on both lateral), X 200.
 11-12. Lower cuticles, showing stomata, X 400. Shahezi Coal Mine,</p> | <p>Changtu County; Shahezi Formation.</p> <p>13A. <i>Nilssonia shaumburgensis</i> (Dunker) Nathorst :
 Fragment of leaf. SG110308. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.</p> <p>13B. <i>Nilssonia stnensis</i> Yabe et Oishi:
 Fragment of leaf. SG110308. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.</p> <p>14. <i>Neozamites verchojanensis</i> Vachrameev :
 A fragment of leaf (from Yang Xue-lin and Sun Li-wen, 1982) No. M7806. Mengjialing, Lishu County; Yingcheng Formation.</p> <p>15. <i>Elatides curvifolia</i> (Dunker) Nathorst : showing a shoot with male cone. SG110322. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.</p> |
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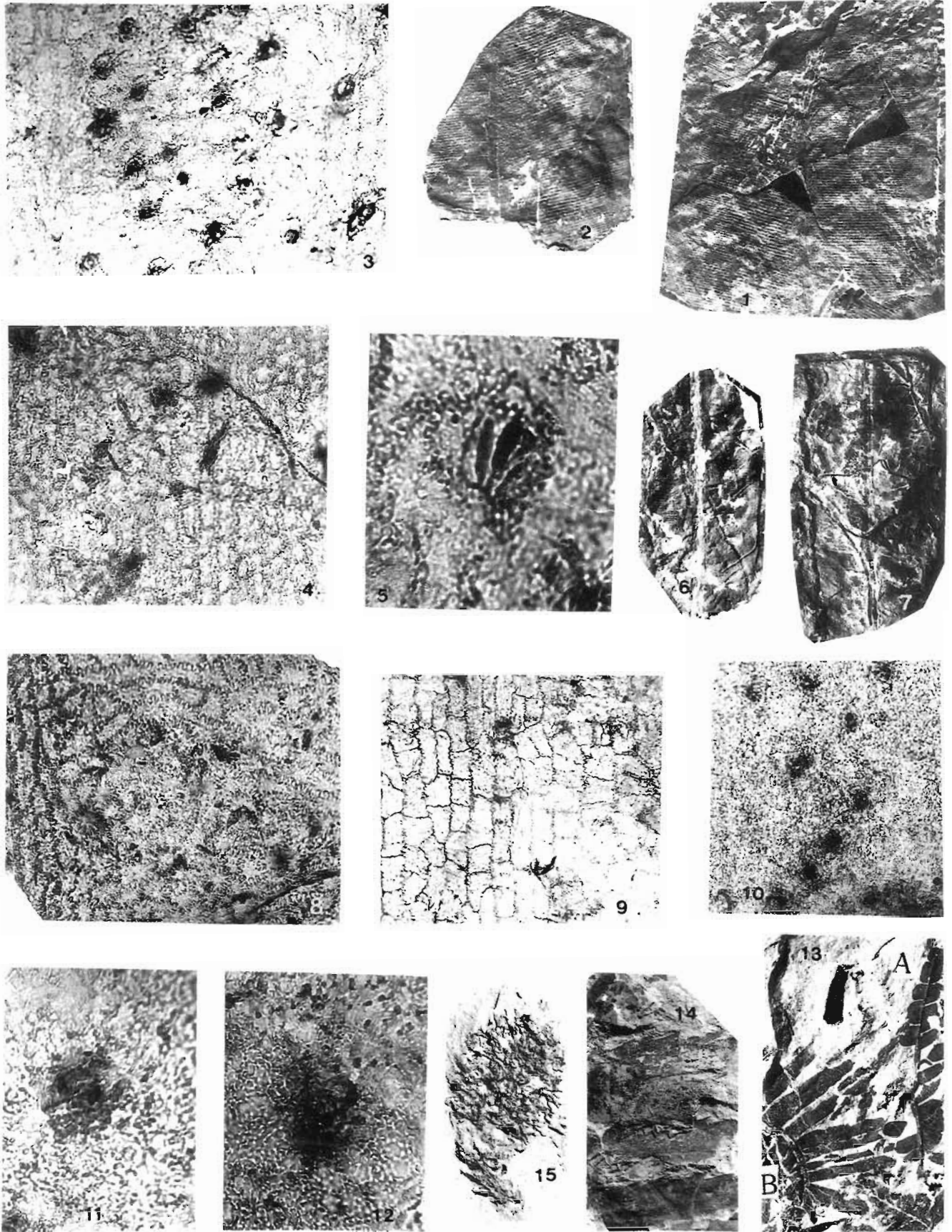


PLATE 3

outline from many leaves of *Nilssoniopteris*. The most similar species probably is *Nilssoniopteris* (*Siberiophyllum*) *californicum* described by Samylina (1963, p. 90; pl. 13, figs 2, 3; pl. 17, figs 1-3; pl. 18, figs 4-7) from the Aldan region. In the latter, the midrib is more thick and veins are sparse, arising at a concentration of 10 per cm, and its cuticle is different in structure.

Locality and horizon—Liaoyuan Coal Mine; Changan Formation.

Nilssoniopteris sp. nov.?

Pl. 3, figs 6-12

Description—Segments of middle part, 2-3.5 cm wide. Midrib about 2 mm wide, smooth below, with a longitudinal channel above. Substance of lamina thick, veins inconspicuous above, moderately conspicuous below, straight, arising at a concentration of 18-22 per cm, simple. Margins usually slightly recurved and forming a thick, apparently entire edge.

Cuticles thick, upper cuticle without stomata or trichomes. Cells along veins more or less rectangular, between veins polygonal; walls strongly marked, sinuous, forming "V" and "U"-shaped folds. Surface of cells flat, finely granular. Cells on midrib rectangular, forming longitudinal rows; walls marked, slightly sinuous.

Lower cuticle with stomata in bands between veins; bands along veins without stomata but with trichome bases. Epidermal cells showing inconspicuous outlines; surface finely granular; anticlinal walls sinuous. Stomata scattered, irregularly distributed, deeply sunken. Stomatal pits formed by epidermal cells of irregular size and shape, each bearing a large, hollow papilla; papillae hanging over the stomatal pit. Guard cells sunken.

Discussion and comparison—*Doratophyllum astatense* (Harris, 1932, p. 36; pl. 2, fig. 6; pl. 3, figs 7, 12, 14; text-fig. 21) and *D. nathorstii* (Florin, 1933, p.

84; pl. 10, figs 1-11; pl. 13, fig. 1; text-figs 30, 31) similar to the present species, but differ in epidermal cells with straight walls and in having different stomata.

Locality and horizon—Shahezi Coal Mine, Changtu County; Shahezi Formation.

Sphenobaiera szeiana sp. nov.

Pl. 4, figs 1-6

Description—Leaf wedge-shaped, up to 14 cm long. Lamina divided 3 times, forming more than 8 linear ultimate segments, almost equal in width, about 5-6 mm wide at middle part of the leaf; apices unknown. Basal angle of leaf 15°-45°; angle of branching about 5°-15°. Dichotomies at intervals of 1-3 cm. Width of segments contracted at their base, gradually increasing in width upwards, at maximum width immediately below dichotomy. Veins conspicuous, probably 8-9 in a segment, 5 mm wide.

Cuticle amphistomatic, thick. Upper cuticle showing distinct vein strips, formed by rectangular cells in longitudinal rows. Cell walls conspicuous, straight, occasionally interrupted. Surface walls either not thick or with irregular patches of thickening. Trichomes absent. Stomata scattered, predominantly longitudinally oriented parallel to veins and of elongate-elliptical shape. Guard cells unsunken or slightly sunken; surface walls thin, but with cutinized ridges at proximal edges of aperture. Subsidiary cells usually 6 in number. Surface walls of subsidiary cells often similar to those of ordinary cells but with thickened margins net to guard cells. Lower cuticle divided into longitudinal strips with or without stomata. Non-stomatal strips showing rectangular or polygonal cells arranged in longitudinal rows. Epidermal cells of stomatal strips isodiametric, polygonal, irregular in arrangement. Anticlinal walls conspicuous, straight, less broad than those of the upper cuticle epidermal

PLATE 4

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| <p>1-6. <i>Sphenobaiera szeiana</i> sp. nov.
1. Showing a fragment of leaf. SG110319.
2. Lower cuticle, showing stomata and cell outlines (vein on middle), x 200.
3. Upper cuticle, showing stomata and cell outlines (vein on right), X 200.
4-5. Lower cuticle, showing stomata, X 400.
6. Upper cuticle, showing two stomata, X 400. Liaoyuan Coal Mine, Changan Formation.
7-10. <i>Cephalotaxopsis magnifolia</i> Fontaine.
7. A fragment of leaf. SG110285.
8. Upper cuticle, showing cell outlines, X 100.
9. Lower cuticle, showing a vein (on left) and the stomatal band, X 32.</p> | <p>10. Lower cuticle showing stomata, X 400. Dawa, Changtu County; Shahezi Formation.
11-13. <i>Sphenolepis kurriana</i> (Dunker) Schenk.
11, 13. Showing shoot with cone.
12. Showing a cone from fig. 11, X 2. SG110330, SG110331. Yingcheng Coal Mine, Jiutai City; Shahezi Formation.
14A. <i>Taxus intermedium</i> (Hollick) Meng et Chen : showing a fragment of leaf. SG110332. Shahezi Coal Mine, Shangtu County; Shahezi Formation.
14B. <i>Podozamites latifolius</i> (Meer) Krysh. et Pryn : showing a fragment of leaf. SG110332. Shahezi Coal Mine, Changtu County; Shahezi Formation.</p> |
|--|---|

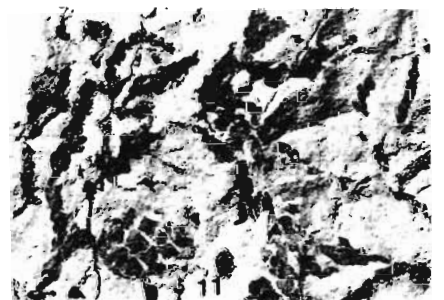
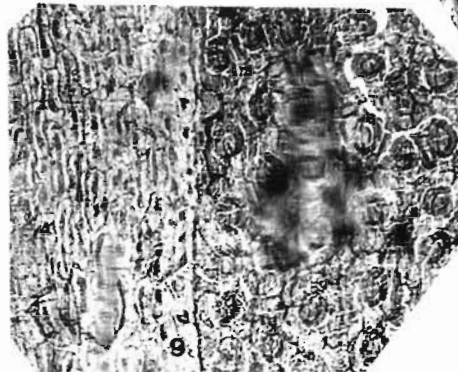
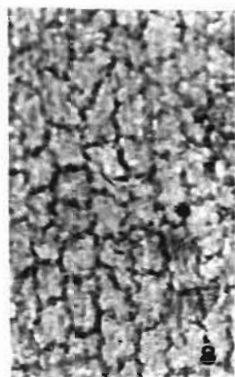
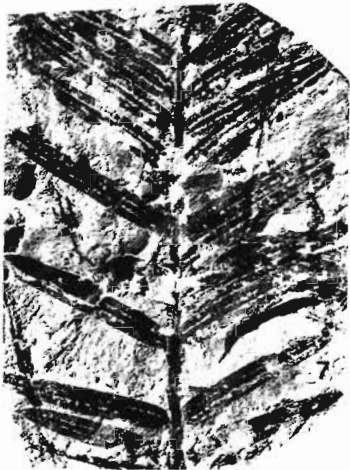
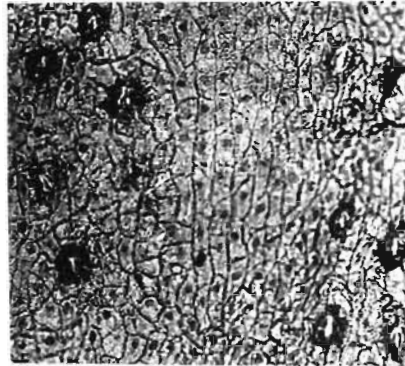


PLATE 4

cells. Surface walls with granular sculpture or radial striations, usually bearing a small solid papilla. Trichomes absent.

Stomata scattered or 3-5 in groups, sometimes arranged in longitudinal rows. Guard cells sunken in irregular stomatal pit surrounded by six subsidiary cells. Surface walls of subsidiary cells often more heavily cutinized than those of ordinary cells, usually bearing solid papillae projecting towards stomatal pit, occasionally lacking papilla but thickened over the whole surface. Encircling cells absent.

Discussion and comparison—None of the present specimens is complete and leaf apices not known. Among them the longest specimen, shown in Plate 4, fig. 1 is 14 cm long. Another specimen shows the leaf base 2 mm wide, becoming gradually broader above and up to 5 mm wide below the first dichotomy.

In the leaf shapes and venations the present species is rather similar to that of *Sphenobaiera longifolia* (Pomel.) Florin (Harris, 1974, p. 43, pl. 1, figs 3-5; text-fig. 15), but they can be easily distinguished from each other by their cuticles. In *S. longifolia*, no distinct vein strips and stomata are irregularly oriented on the upper cuticle.

Locality and horizon—Liaoyuan Coal Mine; Changan Formation.

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