REPORTS FROM THE SCIENTIFIC EXPEDITION TO THE NORTH-WESTERN PROVINCES
OF CHINA UNDER THE LEADERSHIP OF DR. SVEN HEDIN
– THE SINO-SWEDISH EXPEDITION –
PUBLICATION 55

IV:3 Palaeobotany

ANGARAN UPPER PERMIAN FLORA OF THE NAN-SHAN SECTION
(NORTHERN CHINA)

by
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in Memoriam

THE SVEN HEDIN FOUNDATION
FOLKENS MUSEUM (THE NATIONAL MUSEUM OF ETHNOGRAPHY)
STOCKHOLM 1992

THE SWEDISH NATURAL SCIENCE RESEARCH COUNCIL
(Naturvetenskapliga Forskningsrådet)
has contributed to the printing costs

ISSN 0348-0984

Printed in Sweden
BERLINGSKA BOKTRYCKERIET, LUND 1992

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Note. The fossil plant systematics of this memoir follows Meyen 1987. As regards the present state of the family Lebachiaceae cf. Meyen 1987, pp. 199, 201 (foot-note).

INTRODUCTION

This work provides a revision and description of the unique and well known collection of Upper Permian plant megafossils brought together in the early 1930's on the northern slopes of the Nan-shan Mountains (= Qinlianshan; Richthofen range) in the Bai-ta-he (Pei-t'a-ho) river basin SSE of Su-zhou (Su-chow) by the Swedish geologist Gerhard Bexell, a participant in the Sino-Swedish expedition under the leadership of Sven Hedin. A report of Bexell's geological and palaeontological investigations in Mongolia and Gansu 1929–1934 may be found in the "History of the expedition in Asia 1927–1935" (Bexell 1945), and another, covering the years 1930–1933 only, is given in the "Sven Hedin Central Asia atlas" (Norin & Montell 1966; Ambolt & Norin 1967). The atlas contains a map showing the route of the expedition (NJ47). The routes of its individual members may be seen in a map ("Tavl. 1") accompanying a report in Swedish by Hedin (1935) and his collaborators.

Bexell's collection was inspected by Halle (1935, 1937) who made preliminary identifications of the plant fossils which formed the basis for two papers on the distribution of the Late Palaeozoic floras in Asia. Bexell (1935) recognized four plant-bearing zones (A–D) in the Bai-ta-he river basin of which zones A, B and C were considered as being of Late Palaeozoic age while zone D was attributed to the Triassic. Halle considered the floras of zone A and zone B typically Cathaysian. He compared the plant assemblage of zone A with that of the Yuehmenkou series of North China and the Koten series of Korea (uppermost Carboniferous – lowermost Permian). The assemblage of the lower part of zone B was compared to that from the Lower Shihhotse series of North China and the Jido series of Korea; the assemblage of the upper part of zone B was compared to the *Gigantopteris* flora of the Upper Shihhotse series of China and the Kobosan series of Korea (Upper Permian).

Halle (1935) compared the plant assemblage of zone C to that of the suite II of the Kuznetsk Basin (cf. Neuburg 1948; Kolchuginskaya series of the present classification), and identified the following forms: *Phyllotheca deliquescens* (Goepp.) Zal., *P.* cf. *Schtschurowskii* Schmalh., *Callipteris* sp. (aff. *C. Zeilleri* Zal.), *C.? murenensis* Zal., *Iniopteris sibirica* Zal., *Brongniartites salicifolius* (Fischer) Zal., *Zamiopteris glossopteroides* Schmalh., *Rhipidopsis ginkgoides* Schmalh., *R. lobata* Halle, *Noeggerathiopsis scalprata* Zal.

Summarizing the biostratigraphical evidence presented by Bexell (1935) and himself, Halle (1937) arrived at the conclusion that the Upper Palaeozoic flora of the Kuznetsk basin and adjacent areas of North Asia is, on the whole, younger than the Upper Palaeozoic Cathaysian flora. Subsequent studies have not supported this view, however, and it has been established that the Upper Palaeozoic floras of Angaraland and Cathaysia are on the whole synchronous (Text-Fig. 16).

Because of the important biogeographical position of the floras at the boundary between the Angaran and Cathaysian floristic areas and due to the authority of Halle, the list of plants from zone C became, to a certain extent, classical and has been widely cited (e. g. Jongmans 1939; Meyen 1970; Durante 1971). Studying the list in light of our present-day knowledge of the Angaran Upper Palaeozoic flora, it is evident that it consists of taxa unique to different stratigraphic and biostratigraphic subdivisions. Thus *Noeggerathiopsis scalprata* Tschirk & Zal. was described from the middle-upper Carboniferous of the USSR North-East. "*Callipteris murenensis*" Zal. is also of the same age. *Phyllotheca deliquescens* (Goepp.) Schm. and *Zamiopteris glossopteroides* Zal. are representatives of the Lower Permian of Angaraland; *Iniopteris sibirica* Zal. is a typical representative of the Late Permian floras of the Taimyr Kuznetsk district of the Siberian province (Meyen 1970) whereas "*Brongniartites*" *salicifolius* Zal. occurs in the Upper Permian of the East-European province.

It is impossible to interpret unequivocally such a list which contains forms of different age and geographical origin. Meyen (1970) attributed it to the Far East province of the Angaran palaeofloristic area, primarily on the basis of the general stratigraphic (Uppermost Permian) and biogeographic (south of the Angaran palaeofloristic area) position of the zone C flora. His opinion was originally shared by the author (Durante 1971). Later, Meyen (Vakhrameev, Dobruskina, Meyen & Zaklinskaja 1978) correlated the flora of zone C with the so-called Korvunchanskaya flora of the Tunguska Basin dated at present as either Triassic or late Permian and Triassic (Sadovnikov 1981a, 1981b).

In 1977 and 1978, the present author was invited to Sweden by the Royal Swedish Academy of Sciences to study Bexell's Nan-shan collection which is kept in the Section of Palaeobotany of the Swedish Museum of Natural History, Stockholm. The journeys and the project as a whole were sponsored by two participants in the Sino-Swedish expedition 1927–1935, viz. Professor Erik Norin, the outstanding expert of the geology of Central Asia, and Professor Birger Bohlin who had himself studied Late Palaeozoic plants from localities in the Nan-shan region (Bohlin 1971, 1976). Professor Britta Lundblad, Head of the Section of Palaeobotany to 1986, gave me considerable assistance during my visits to Sweden and contributed to the completion of the investigations. In a preliminary account of the examination of the collection, it was concluded that the flora of zone C has little in common with Late Permian floras of the central parts of Angaraland, including the Kuznetsk Basin, but is similar to floras of the Tatarian stage of the Russian platform (Durante 1980).

GEOLOGICAL SETTING

The geological section in Text-Fig. 1 summarizes the stratigraphic position of the material collected by Bexell. It was briefly described by Bexell himself (Bexell 1935) and by Halle (1937). In a letter from Bexell to Halle dated November 10, 1951 (see Appendix 1) more detailed information may be obtained. Bexell writes as follows (translation from the Swedish): "Generally, the sections had to be synthesized from a large number of partial profiles from the same area. It was possible to measure the section at Hung-shui-pa-Shang-ho in one continuous outcrop, however, but some of the fossiliferous horizons indicated have been transferred from (nearby) parallel profiles."

It may be noted that the plant remains of zones A and B were collected at different localities, the geographical names of which are mentioned in Appendix 1. The Chinese palaeobotanists Li Xing-xue and Yao Zhao-qi (1980, p. 5) wrote as follows: "The 'Nanshan section' described by Bexell is not a natural, but a generalized, profile in that region. Stratigraphically, the four plant-bearing zones, namely A, B, C, D, mentioned ascendingly by Bexell are, however, correct". Some Chinese geologists (Shi & Liu 1981) reinvestigated Bexell's section and came to a similar conclusion. The remark regarding this synthetic character refers to the lower part of the section only. As to the upper part (zones C and D, and a variegated area between them), it is, as mentioned in Bexell's letter to Halle, measured along one profile – the Hong-shui-ba-shang-he (Hung-shui-pa-shang-ho) Valley.

According to Shi and Liu (1981) the Hong-shui-ba-shang-he locality of Bexell is a river, whose recent name (since 1958) is Yangluhe. It is the right tributary to the Hong-shui-ba-he, the great eastern tributary to the Bai-ta-he River. According to Shi and Liu, Bexell collected most of the Angaran Upper Palaeozoic fossil plants at Bingoutaizi in the upper part of the Yangluhe.

Zone C comprises green sandstones, 240 to 250 m thick, with subordinate horizons of dark grey siltstones containing plant remains (Bexell 1935). Plant-bearing horizons are concentrated in the lower (layers III, XIV, XV) and upper (layers IV, VII, VIII, XII, XVI and XVII) parts of the member. Most of the plant impressions (215) were from layer III. The rest of the horizons yielded 123 specimens.

The numbering of specimens needs special explanation. Bexell numbered the rock specimens of the zones C and D in the following way: letters H sh p sh H which stand for the Hong-shui-ba-shang-he River are followed by Roman numerals indicating the number of the layer and Arabic numerals indicating the number of the slab in the layer. All the letters and numerals were scratched directly on the rock specimens. In addition to these numbers, the fossils in the collection kept at the Swedish Museum of Natural History were provided with Arabic numerals with the abbreviation "Bex" preceding each set of numbers. The distribution of these numbers among the layers of the zone C is as follows: layer III: Bex 1 to 232; layer IV: Bex 233 to 264, layer VII: Bex 295 to 306; layer VIII: Bex 321 to 334; layer XII: Bex 366 to 391; layer XIV: Bex 410 to 421; layer XV: 438 and 439; layer XVI: 440 and 441; layer XVII: Bex 442 to 448. In this work both sets of numbers are used. For the slabs kept at the Swedish Museum of Natural History, the Museum's numbers are used while the others are marked with Bexell's original numbers. Further, I have in some cases numbered the fossils of a rock specimen separately, the number of the fossil following the number of the rock specimen after a dash. Thus letters following the number of the slab indicate that one slab has been divided into parts during the investigations.

MATERIAL AND METHODS

Plant remains from zone C, a total of 338 specimens, are represented mostly as impressions in metamorphozed siltstones and claystones. Compressions are sometimes preserved, but are unsuited for maceration being heavily metamorphozed, broken by cleavage and impregnated with calcite.

The impression/compression materials were studied in oblique reflected light under dissecting microscope. Drawings were made by tracing photographs magnified 3 to 7 times in the course of constant microscope corrections.

Due to the dark grey colour of the matrix, both the study and photography were difficult. In some cases bleaching of the specimens by submerging the surface of a specimen into a 40 % solution of hydrofluoric acid for 1 to 5 seconds proved helpful.

Following a request from the People's Republic of China, Professor Halle returned half the original Bexell collection to Chinese institutions in the beginning of the 1950's. To the extent possible the material was divided into two equivalent portions: if an impression of a certain species was sent to China its counterpart remained at Stockholm. In this connection part of the material was photographed for Halle by Mr. K. E. Samuelsson, the skilful technician employed at the Palaeobotanical Department during this period. According to journals still kept in the Section of Palaeobotany, 548 negatives were taken. This material was at my disposal during my studies in the Swedish Museum of Natural History, and prints from part of the negatives were made for me by Yvonne Arremo, B. Sc., technician to the Section of Palaeobotany. Mrs. Arremo used in part her own negatives, too. About half of the photographs in this publication were taken by the author herself and printed in the photolaboratory of the Geological Institute of the USSR Academy of Sciences. Some photographs were supplied by Professor Bohlin. From the above it may be evident that the illustrations of the present memoir also include specimens returned to China.

ACKNOWLEDGEMENTS

It is my duty to pay a tribute to the memory of the eminent scientist Professor Erik Norin who devoted his life to studying the geology of Central Asia, and spared no efforts to promote the present work, the result of which, to my regret, he did not see.

I am much obliged also to the late Dr. B. Bohlin for the organization and financial support of my studies during my first visit to Sweden. Thanks are also due to Prof. B. Lundblad, Section of Palaeobotany, Swedish Museum of Natural History, for constant support during my studies and help in preparing the MS and for drawing my attention to Bexell's letter (Appendix). I also thank Prof. E. M. Friis, Section of Palaeobotany, Swedish Museum of Natural History, for help in editing and preparing the MS for publication and to the other staff members of the museum: Y. Arremo, D. Guy-Ohlson, T. von Stryk and to my other Swedish friend, Mrs. M. Horn. With deep gratitude and grief I remember my deceased friends: A. Ekblom, R. Baechler, and the late G. Bohlin and E. Bohlin who did very much to make my stay in Sweden pleasant.

I am much obliged for advice and critical remarks from the deceased chiefs of the Geological Institute Laboratory of Palaeofloristics, Profs. S. V. Meyen and V. A. Vakhrameev, and grateful to my colleagues I. A. Dobruskina and A. V. Gomankov who kindly looked through the manuscript. I also thank K. A. Pechnikova, G. V. Kozlovskaya and K. Khullar for typing the manuscript, and G. N. Surovtseva for the English translation.

I thank Dr. Duan Shuying, Institute of Botany, Academia Sinica, Beijing, for modern transliteration of the geographical names mentioned in Appendix 1. In conclusion, I would like to express my gratitude to the Swedish Academy of Sciences and in particular to Mrs. S. Edblad who is in charge of the Swedish-Sovjet exchange of scientists. The work was supported in part by the Sven Hedin Foundation.

DESCRIPTION OF PLANTS

The Zone C plant assemblage is dominated by peltasperms and especially leaves of *Pursongia* constitute a prominent element. Various callipterids such as *Callipteris*, *Compsopteris* and *Comia* are also widely distributed as well as *Phylladoderma*-like leaves. Conifer shoots rate second to pteridosperms. Most of the conifers have been assigned to the form-genus *Geinitzia*, while the others are described as coniferous shoots *incertae sedis*. In addition to these two dominating plant groups, zone C comprises various fern-like plants of uncertain affinities attributed to the genera *Psygmophyllum*, *Psygmophyllopsis*, *Flabellofolium/Rhipidopsis*, *Plagiozamites* (?), cf. *Anomozamites*. True ferns (*Sphenopteris*, *Pecopteris*, *Cladophlebis*) are in subordinate amounts in the flora. Equisetopsids are represented by rare pith-casts and shoots of *Annularia*. Solitary leaves of cordaites have also been observed.

Fructifications are mainly represented by the genus *Peltaspermum* (Peltaspermaceae), as well as some coniferalean microstrobili and seed-bearing organs. Seeds are relatively rare, represented by the genera *Samaropsis*, *Carpolithes* (Pl. VII, Fig. 5) and *Sylvella* (Pl. IX, Fig. 7).

A description of most zone C species is given below. A comprehensive list of all species and their distribution in various plant-bearing layers of zone C is given in Table I.

Division: Pteridophyta

Class: Equisetopsida

Satellite genera of Equisetopsida
Genus *Annularia* Sternberg 1822
Annularia sp.
Plate I, Fig. 1; Plate II, Figs 1–2

Material: One impression of a single shoot, some fragments of whorls and photographs of two shoots which are no longer present in the collections, from layer III of zone C.

Description: Thin axes about 1 mm wide with whorls of narrow to lanceolate leaves, about 1 mm broad and more than 20 mm long and with a rather broad midrib. The whorls are spaced from 0.8 to 1 mm apart and are spread in the plane of the shoot. The leaf bases may be fused to form a small sheath.

In the best preserved whorls the number of leaves is 10 to 12. They are unevenly distributed in the plane. Three to four closely spaced lateral leaves can be seen even in poorly preserved whorls. Two pairs of leaves arranged at an open angle from lateral ones extend up- and downwards near the axis.

Remarks: The uneven and somewhat bilateral distribution of leaves in the whorl resembles that of the genus *Lobatannularia*. However, as the whorls exhibit neither fusion of leaves nor anisophylly, the shoots described here are assigned to the genus *Annularia*.

Class: Polypodiopsida

Satellite genera of the class Polypodiopsida
Genus *Cladophlebis* Ad. Brongniart 1849
Cladophlebis sp.1
Plate I, Figs 4–6

Material: Small fragments of pinnae of the last order from layer III, and one fragment from layer VII of zone C.

Description: Rachises are narrow, 0.3 to 0.5 mm wide and pinnules have a thin lamina, 0.5 to 1 cm long and 2.5 to 5 mm wide, tongue-like to sub-triangular in shape, slightly crescentiform-curved; the apices of the pinnules are acute to gently rounded. The midrib extends to the apex and the lateral veins (7 to 10) dichotomize once, rarely twice.

Remarks: The crescentiform shape of the pinnules permits an inclusion of the specimens in the form genus *Cladophlebis*. Poor preservation of the material, however, prevents a specific determination.

Cladophlebis sp. 2
Plate I, Fig. 8

Material: One fragment of a pinna of the penultimate order from layer III and one fragment from layer VII of zone C.
Description: The rachis is roughly striate and about 3 mm wide. Pinnae of the last order are more than 3 cm long, linear and attached at an angle of 50 to 60. Rachis of the pinnae of the last order, about 1 mm wide, overlaps the pinnule bases, and has on its lower side axial structure that looks either like a single rib or like a groove with marginal ribs. The pinnules are 8 to 9 mm long and 2.5 to 3 mm wide, with a thin lamina, mostly asymmetrical, with a convex lower and straight upper margin, sometimes slightly crescentiform-curved. The thin midrib is slightly decurrent and extends along two thirds of the pinnule. Dense lateral veins are once forked.
Remarks: Due to the asymmetrical shape of the pinnules and the venation pattern these imprints may be included into *Cladophlebis*, but the material does not permit a further specific determination.

Genus *Katasiopteris* Radczenko 1967

Fronds bi- or tripinnate with large pinnae. Pinnules are linear or subtriangular, often crescentiform, attached to the rachis with wide bases.

The margins of larger pinnules are lobed or wavy. Venation is very specific. The middle vein is straight; side veins dichotomize typically more than twice. After the first dichotomy the upper vein divides very quickly and among the three resulting veins the middle one branches at the beginning. In developed pinnules this vein divides two or three times whereas marginal veins of all side vein bundles are simple or dichotomize once.

Katasiopteris cf. *lata* Mogucheva
Plate I, Fig. 2, 3; Plate VI, Fig. 6.

Katasiopteris lata Mogucheva, 1973, p. 78, 79; Pl. XXI, Fig. 4; Pl. XXXII, Figs 1–3.

Material: One bi-pinnate fragment of a frond from layer VII of zone C (Plate I, Fig. 2, 3) and one photograph of a pinna no longer present in the collection (Plate VI, Fig. 6).
Description: The rachis of the frond or of the penultimate pinnae reaches a width of 6 mm and has a shallow furrow about 1 mm wide. Rachises of pinnae of the last order are 1.5 to 2 mm wide, attached at an angle of about 50°, and slightly decurrent. Pinnules are attached to the rachis by their broad base and are tongue-shaped, sometimes slightly crescentiform, with smooth margins, 15 to 16 mm long and 4.5 to 6 mm wide. The midrib is symmetrically placed and extends almost to the apex of the pinnule. Lateral veins (8 to 9 on each side) dichotomize 3 to 4 times, and form regularly composed bundles.
Remarks: The generic name *Katasiopteris* was proposed by Radczenko (Vladimirovich, Lebedev, Popov, Radczenko & Schwedov 1967) for specific ferns widely distributed in the Triassic Korvunchana flora of the Tunguska basin. Sadovnikov (1965) referred this plant to the genus *Lobatopteris* Wagner due to similarity in pinnule venation: the position of the third dichotomy of side veins is the same in *Katasiopteris* and *Lobatopteris*. They differ, however, in the structure of side venation in developed pinnules.

Genus *Pecopteris* (Brongniart) Sternberg 1825
Pecopteris cf. *anderssonii* Halle
Plate I, Fig. 7

Material: One fragment of a pinna of the last order, from layer III of zone C.
Description: The fragment, about 4 cm in length, comprises the middle part of a large slightly curved, parallel-margined pinna, 1.1 to 1.2 cm wide. The rachis is up to 0.8 mm wide with a considerable median depression, restricted in places by furrows on one or both sides.

Pinnules are 5 to 7 mm long and about 3 mm broad, attached at angles of 60° to 70°. They are tongue-shaped with parallel or slightly converging margins. Apex is obtuse and gently rounded. The midrib is decurrent and reaches almost to the apex of the pinnule where it becomes obscure among the lateral veins. The venation is dense, the midrib giving off 6 to 7 lateral veins on each side, and each vein dichotomizing twice, the distal branch alone appears to dichotomize for the second time.
Remarks: The almost geometrically regular shape of the pinnules with the regular branching of the lateral veins is comparable to the Cathaysian pecopterids from the Central Shansi Shihhotse series (*P. norinii*, *P. anderssonii*, *P. taiyuanensis* etc.). Our specimen is similar to *P. anderssonii* in the large size of the pinnae of the last order, the size of the pinnules and the mode of branching of lateral veins. Two other *Pecopteris* species with slightly different morphology were identified from zone C: *P.* ex. gr. *anthriscifolia* (Pl. VI, Fig. 1) and *P.* sp. (Pl. VI, Fig. 5).

Division: Pinophyta

Class: Ginkgoopsida

Order Peltaspermales
Family Peltaspermaceae
Genus *Callipteris* Ad. Brongniart 1849*

According to Meyen and Migdisova (1969) the genus *Callipteris* is essentially a form genus. However, the Nan-shan callipterids have been referred to the family *Peltaspermaceae* because it is more likely that they belong to the group of Angaran callipterids with characteristic peltaspermaceous cuticle (Meyen and Migdisova 1969) and eventually associated with *Peltaspermum*-like fructifications (Meyen, personal communication).

Callipteris bexellii Durante sp. nov.
Plate II, Figs 3, 4; Plate III, Figs 1–2; Plate X, Fig. 11;
Plate XI, Fig. 4; Text-Figs 2, 3 a–b.

Callipteris sp. 1 Durante, 1980, Text-figs 2a, b; 3a.

Derivation of name: In honour of G. Bexell who described the Upper Palaeozoic section of the Nan-shan ridge.

Diagnosis: Fronds at least bipinnate, forked in the apical part and diverging at angles of about 30 to 35°. Rachises up to 5 mm wide, coarsely striated, noticeably overlapped by pinnae of the last order and subsidiary pinnules by one third, sometimes by half of the width. Pinnae of the last order either alternating or nearly opposite and attached at angles of 50–70°, linear.

Holotype: No. Bex 302 (Plate XI, Fig. 11; Text-Fig. 2), Swedish Museum of Natural History.

Type locality: Yangluhe River

Type stratum: Layer VII

Age: Late Permian, Tatarian stage.

Material: More than ten fragments of pinnae from layer VIII and rare fragments from layer XIV of zone C.

Description: Rachises are up to 5 mm wide and coarsely striate. Pinnae of the last order are linear from 7 cm long in the apical part of the frond to more than 14 cm long in the middle part, and from 1.7 to 4 cm wide respectively. The pinnae taper gradually upwards and are crowned by a subtriangular segment consisting of some confluent pinnules (Pl. III, Fig. 2; Text-Fig. 3b). In the anadromous part of the pinna three to four basal pinnules are considerably smaller, so that the pinnae are anadromously constricted. In the catadromous part the basal pinnules also diminish, but more gradually. Three to four subsidiary pinnules attached to the main rachis immediately below the pinna, become narrower downwards.

Pinnules are 8 to 23 mm long and 3 to 6 mm wide, mostly tongue-shaped slightly crescent with a thick lamina surrounded along the margin by a narrow thinner rim (Plate XII, Fig. 4; Text-Fig. 3a); they overlap the rather wide (up to 3 mm) rachis of the pinna by almost half of its width. Anadromously the pinnules are constricted, and catadromously they are decurrent. The midrib usually extends up to the upper third of a pinnule, and is somewhat anadromously displaced in its basal part. In developed pinnules the midrib is gently sigmoid in shape. Lateral veins are simple or once forked.

Remarks: In general frond morphology, the new species resembles both the Angaran *Callipteris adzvensis* Zal. and the Euramerian *Callipteris conferta* (Sternb.) Brongn. In the epidermal characteristic both species are quite different. Since the cuticle is unknown in *C. bexellii* its affinity with one or the other species cannot be established. Morphologically, the new species differs from *C. conferta* in the more elongated pinnules, their larger size, absence of marginal lobation in larger pinnules and anadromous displacement of the midrib. The species is distinguished from *C. adzvensis* by a less regular, slightly crescent shape of developed pinnules, slightly sigmoidal shape and certain anadromous displacement of the midrib, a different shape of subsidiary pinnules, thicker lamina and marginal rim. The latter feature has not been observed previously in Angaran callipterids. Despite the absence of any direct data, including epidermal characters, the new species has been regarded as Angaran based on the following evidence:

1. Association with foliage of the *Compsopteris* and *Comia* types. Such an association is very characteristic of the Angaraland. The genus *Compsopteris* has not been definitely demonstrated to occur outside the Angaraland.

2. The stratigraphic position of the zone C flora. As indicated below, the presence of *Pursongia-Peltaspermum* association reliably determines the age of the flora as the latest half of the Late Permian (Tatarian age). The abundant occurrence of callipterids during that period is a characteristic feature of peripheral

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* *Callipteris* Brongniart is a later homonym of *Callipteris* Bory and has therefore been rejected (Kerp and Haubold 1988). The Nan-shan callipterids may instead be included in the genus *Feonia* established by Meyen (in Meyen & Migdisova 1969) as a subgenus of *Callipteris* for Angaran species.

parts of the Angaran kingdom. Outside this area foliage of this type is either very rare, or not observed at all.

Callipteris ex. gr. *bexellii* Durante sp. nov

Plate III, Fig. 3; Plate IV, Fig. 1, 2; Text-Fig. 3c.

Callipteris cf. *sahnii* Zal., Durante, 1980, Text-Fig. 3b

Material: Fragments of pinnae of penultimate and last orders from layer VII of zone C.

Description: A larger fragment (Pl. IV, Fig. 2) show the apical part of a frond. It is bipinnate and bifurcating in the upper part. The pinnae are 14 cm long and pinnules (in the middle part of a pinna) about 25 mm long. The specimen shown in Pl. IV, Fig. 1 and Text-Fig. 3c is part of a pinna of the last order with long (30 mm) parallel margined, linear, or more frequently somewhat curved pinnules.

Remarks: All fragments differ from typical specimens of *C. bexellii* in the absence of a rim along the pinnule margins and in the larger size of both pinnae and pinnules. Only more representative material will allow to decide whether the large-pinnulate forms are an independent species of *Callipteris*, or belong to *C. bexellii.*

Genus *Comia* Zalessky 1934

Comia (?) sp.

Plate XII, Fig. 12

Material: One fragment of a frond from layer III of the zone C.

Description: The fragment is about 5 cm long and 4 cm wide and constitutes the apical part of a once-pinnate frond. The rachis, up to 2.5 mm wide at the base of the fragment, bears at an acute angle large (2.5 to 2.8 cm long, 0.7 to 0.9 cm wide) lobate pinnules and a commensurable apical pinnule. The pinnule midrib is 1 mm wide, extending more than two thirds of the pinnule length. The lateral veins form more or less distinct bundles corresponding to the pinnule lobes. The pinnule lamina are transversely wavy, and the lobes are, as a rule, separated by folds from one another, which obscure the venation between the bundles. In some cases a simple, or once forked, vein corresponding to the fold may be observed.

Remarks: Although the general pattern of venation of pinnules appears to correspond to that of *Comia* it cannot be excluded that the present specimen represents the apical portion of a *Callipteris* frond with confluent pinnules.

Genus *Compsopteris* Zalessky 1934

The genus *Compsopteris* was established by Zalessky (1934b) and based on once pinnate fronds of the callipteroid type from the Pechora basin. Meyen and Migdisova (1969) described the epidermal features of *Compsopteris* and showed its affinity with peltaspermaceous pteridosperms. They also added to the morphological characteristics of the genus, having described a false paripinnate apex of the frond. Following Zalessky they used the combination *Compsopteris* (?) *wongii* (Halle) Zal. for the well known species *Protoblechnum wongii.*

Chinese palaeobotanists (Sheng & Li 1974; Gu & Zhi 1974, Pls. 82, 83) in their recent works widely usd the generic name *Compsopteris* not only for *C. wongii*, but also for other once-pinnate fronds which can be equally assigned to a dozen of other "morphological" genera.

Meanwhile, even within Angaraland the traditional use of *Compsopteris* as a "morphological" genus should be limited. Meyen (1979) pointed out that foliage of *Raphidopteris*, which has different epidermal features and belongs to a different systematic group, can be mistaken for *Compsopteris.*

The use of the generic name *Compsopteris* for Cathaysian species, should probably only be tentative as their epidermal structure remains unstudied.

Compsopteris cf. *adzvensis* Zalessky

Plate V, Fig. 6; Text-Fig. 4a.

Material: One fragment of a frond from layer III of zone C.

Description: The frond is once-pinnate with a wide (up to 5 mm), coarsely longitudinally striate rachis bearing at an angle of 35–45° large entire tongue-shaped pinnules up to 4.5 mm long. The pinnule planes are inclined at small angles to the rachis and anadromic parts of pinnules therefore appear to overlap the rachis slightly or be overlapped by the rachis.

The pinnules are noticeably contracted near the base and catadromously decurrent. Upwards they become broader, and taper very gradually to an acuminate apex.

The midrib of pinnules is prominent and extends to the apex. Lateral veins are thin, dichotomizing once or twice or rarely three times. In the basal part of the catadromous side of a pinnule the veins emerge directly from the rachis.

Remarks: The present specimen is very similar to the middle portion of fronds of the Pechoran *Compsop-*

teris adzvensis Zal. but in the absence of the frond apex it cannot be attributed to this species with certainty.

Compsopteris (?) *contracta* Gu and Zhi
Plate IV, Fig. 3; Plate V, Fig. 5

Material: Two fragments of once pinnate fronds from layer III of zone C.

Description: The two fragments of fronds differ slightly. In the most complete specimen (Pl. V, fig. 5) the rachis is about 4 mm wide and the pinnules rather narrow (9–10 mm wide) and linear. The rachis of the second fragment is up to 6 mm wide and the pinnules about 12–14 mm wide.

Features shared of both fragments are the linear shape of the rather long pinnules, strongly contracted rounded bases, attachment to rachis at a single point and thin leaf lamina with a strong midrib and weak side veins.

Remarks: The above features are typical for C. (?) *contracta* Gu and Zhi (1974). However, the characteristic type of lateral venation of this species has not been observed in the present material, probably due to poor preservation and for this reason it cannot be assigned to this species with certainty.

Compsopteris (?) sp. 1
Plate XIII, Fig. 2

Material: One fragment of fronds from layer III of zone C.

Description: The frond is once pinnate with broad, longitudinally and coarsely striate rachises about 6–9 mm wide, and linear pinnules with thin lamina. The fragment shows the lower part of the frond with a pair of small, almost opposite oval pinnules, about 1.5–2 cm long and 0.6 cm wide, attached to the rachis at almost right angles.

Upwards, the pinnules become larger, about 4.5 cm long and 1 cm wide, and their shape linear. The apices of the pinnules are obtuse, gently rounded. Mature pinnules are attached at angles of 35–70° and show deep anadromous basal sinuses and decurrent catadromous side.

Compsopteris (?) sp. 2
Plate V, Fig. 3, 4; Text-Fig. 4b.

"Brongniartites" sp. Durante, 1980, Text-Fig. 3.

Material: Three fragments of once pinnate fronds from layer III of zone C.

Description: In general morphology the fragments resemble *Compsopteris* (?) sp. 1, but pinnules are oval, sometimes slightly curved, with straight or irregularly undulating margins. The anadromous side of the pinnules is characterized by a deep basal sinus and the catadromous side is decurrent. Pinnules of the lower part of the frond are known only from a photograph (Plate V, Fig. 3), but they appear to be basally contracted. The apical part of the frond is shown in Text-Fig. 4b. The rachis is divided into two branches diverging at an angle of 30°. Each of the rachises serves as a midrib of the apical pinnule commensurable with developed pinnules of the frond. The apical pinnules are divided by a deep sinus in their basal part, their margins being overlapped. The external margins are decurrent.

Remarks: The features of the apex resembles those of C (?) *wongii* (Halle 1927, Gu & Zhi 1974), but the material differs otherwise in the shape of the pinnules.

Compsopteris (?) sp. 3
Plate XII, Fig. 1

Material: Three fragments of a frond from layer III of zone C.

Description: One pinnate frond with a rather thin rachis, about 4 mm wide, and very large, more than 7.5 cm long and 1.5 cm wide, linear pinnules with smooth margins. The anadromous side of the pinnule is characterized by a deep basal sinus reaching almost to the midrib. The catadromous side is decurrent. The prominent midrib is traced throughout the visible part of the pinnule; thin dense lateral veins appear to dichotomize not more than once or twice. Veins enter the pinnule directly from the rachis in the decurrent part.

Remarks: *Compsopteris* (?) sp. 3 has larger pinnules than the two other species described here. However, it strongly resembles the largest fronds of *Compsopteris adzvensis* Zal. and additional material is needed to decide whether it is a new species or may be included in that species.

Genus *Peltaspermum* Harris 1937

Radially symmetrical or (rarely) bilateral peltate female fructifications (peltoids) consisting of round umbrella-like discs with more or less convex upper and concave lower surfaces and stalks arising from the central part of disc. Seeds located on lower surface of peltoids either radially or bilaterally symmetrical.

Single peltoids or their compact aggregations (heads) distributed along axes.

Harris (1937) attributed to the genus *Peltaspermum* radially symmetrical peltoids that he first named cupular discs and showed their association with the *Lepidopteris ottonis* leaves (Harris 1932). The shoot structure was not established, but Harris supposed that the peltoids were arranged in two rows along the axis.

Later shoot structure has been comprehensively studied in four *Peltaspermum* species: *P. thomasii* Townrow, *P. incisum* Prynada, *P. buevichiae* Gomankov and Meyen, and *P. nanshanense* Durante. In the first two species peltoids are distributed in two rows along the shoot similar to the arrangement inferred for *P. rotula* by Harris (1937). Peltoids of the two other species are aggregated into compact, head-like structures. These are located along the axes in the same way as single peltoids in the first two species.

Another feature shared by *P. rotula*, *P. thomasii* and *P. incisum* is their association with *Lepidopteris* leaves, whereas *P. buevichiae* evidently belongs to plants with *Tatarina* or *Pursongia* leaves, the latter being the cuticle-devoid analogue of *Tatarina* (Gomankov & Meyen 1986).

Because of the association of different *Peltaspermum* species with different genera of vegetative leaves the genus *Peltaspermum* was believed to comprise several natural genera (Gomankov & Meyen 1986) and it was subsequently subdivided into two genera: *Peltaspermum* proper (sensu stricto) and *Peltaspermopsis* Gomankov. I disagree with Gomankov and Meyen for the following reasons:

1. There are more than two genera of vegetative leaves associated with *Peltaspermum*. Dobruskina (1980) suggested that *P. usense* Dobr. was related to *Scytophyllum* leaves. Further, *Peltaspermum* has been recovered in localities where *Lepidopteris*, *Scytophyllum* or leaves of the *Pursongia-Tatarina* type are absent. This indicates their possible affiliation with other types of leaves as well and the subdivision of *Peltaspermum* into two genera does not solve the problem.

2. It is very difficult to distinguish *Peltaspermum* and *Peltaspermopsis* in general palaeobotanical practice. Female fructifications of the peltaspermous type mainly occur in the form of single peltoids. The peltoids may be divided into several groups based on size, type of symmetry, extent of marginal dissection and some other features, but these groups do not coincide with the "natural" genera. Information on shoot structure and associated leaves is therefore required to identify the genera, but very limited data of the kind are available.

3. A division of *Peltaspermum* Harris into two genera eliminates *Peltaspermum* as an organ genus and simultaneously creates the necessity to introduce a new generic name for a single peltoid. Gomankov (in Gomankov & Meyen 1986) suggested *Lopadiangium* Zhao (Zhao, Mo, Zhang & Yao, 1980) for this purpose. According to the first diagnosis, this general name has been used for plate-like sporophylls falling into several segments. Gomankov assigned another diagnosis to this genus, corresponding mainly to Harris's diagnosis for *Peltaspermum*. Later the Chinese palaeobotanists Zhang Hong & Shen Guanglong (1987) came to the conclusion that *Lopadiangium* was a junior synonym of *Peltaspermum*.

The above indicates that *Peltaspermopsis* can hardly be recognized as a separate genus. It may, however, be separated on the basis of the organization of the fertile shoots and may possibly be regarded as a subgenus. This permits to keep *Peltaspermum* s.l. a uniform genus and to show its variability.

Subgenus *Peltaspermopsis* Gomankov 1986

Diagnosis: Radially symmetrical peltoids of *Peltaspermum* type joined in head-like aggregations.

Peltaspermum nanshanense Durante sp. nov.

Plate VI, Fig. 7; Plate VII, Fig. 7–8; Plate VIII, Figs 5–7; Plate X, Figs 9, 10; Plate XIV, Fig. 9; Text-Fig. 5 a–c.

Peltaspermum sp., Durante, 1980, Plate X, Figs 1–5, Text-figs 1 a–b.

Derivation of name: After the Nan-shan range.
Diagnosis: Peltoids 6 to 14 mm in diameter, clustered in compact aggregations. Upper surface convex with a central depression and 16 to 18 prominent radiating ridges. Lower surface concave with gentle radial crests. Periphery of peltoids surrounded by a festoony rim.
Holotype: No. Bex 75-1 (Plate VIII, Fig. 5; Text-Fig. 5a), Swedish Museum of Natural History.
Type locality: Yangluhe River
Type stratum: Layer III
Age: Late Permian, Tatarian stage
Material: About 20 dispersed peltoids and 2 'heads' each containing 5–6 peltoids from layer III of zone C.
Description: Compact aggregates of peltoids (heads) have occasionally been observed. The peltoids are 6 to 14 mm in diameter. Their upper surface (Text-Fig. 5a) is convex with a central depression from which 16 to

18 prominent ridges radiate to the margin. Along the periphery, the massive body of peltoid is surrounded by a festoony rim. Each festoon of this rim corresponds to a ridge.

The lower surface of the peltoid is concave. Gentle radial crests corresponding to the furrows of the upper surface divide this surface into gentle hollows in which oval structures (1.7 mm × 1 mm) noticeably detached from the rest of the peltoid surface (Text-Fig. 5c) are observed near the outer margin of the disc. Similar structures are usually interpreted as ovule scars.

The massive stalk of the peltoid is 2 to 3.5 mm long with a diameter at the base of 1 to 1.3 mm. The stalk becomes broader upwards and grades into the lower surface of a disc. Sections through assemblages of peltoids indicate that they aggregated in compact more or less spherical "heads". In sections passing through a longitudinal axis of such a "head" (Plate VIII, Figs 5, 7; Text-Fig. 5b) peltoids arranged in various planes is observed, their stalk being closely spaced on a rather short axis. It is noteworthy that separate peltoids generally occur in pairs, and if the disc of one of the peltoids lies on the bedding plane the other is seen in oblique or perpendicular section (Plate VIII, Fig. 6). Such pairs appear to be parts of the "heads". The "heads" are probably arranged in a two-ranked or helical way of the fertile shoots (see description of *Peltaspermum* sp. below).

Remarks: Subgenus *Peltaspermopsis* of the genus *Peltaspermum* includes three species: *Peltaspermum buevichiae* (Gomankov) Durante, *P. nanshanense* Durante sp. nov. and *P. multicostatum* Zhang, described from the same formation as our new species (Zhang Hong & Shen Guanglong 1987).

The new species differs from *P. buevichiae* in having oval and somewhat larger seed scars (0,5 to 1 mm in *P. buevichiae*) while the diameter of the peltoids is slightly smaller. *P. multicostatum* is more dissected (into 20–25 lobes) and is larger in diameter (almost 14 mm). As compared with other *Peltaspermum* species the new species differs from *P. thomasii* Harris (Townrow 1960) and *P. incisa* Prynada ex. Stanisl. (Stanislavsky 1976) by the compact structure of the fertile shoot. This apparently also distinguishes the material from *P. rotula* Harris (Harris 1932, 1937) which has a two-ranked arrangement of peltoids on the shoot. It differs further from *P. rotula* by the somewhat larger dimensions of seed scars, and from *P. thomasii* in the radial symmetry of the peltoids and a larger number of seed scars. It differs from *P. incisa* Prynada (Stanislavsky 1976) in the presence of a central depression on the upper surface of the peltoid, the absence of tubercular sculpture on the surface and in the entire, undissected discs.

Peltaspermum sp.
Plate VIII, Figs 8, 9

Material: One shoot fragment from layer III of zone C.

Description: The fragment is about 5.5 cm long with an axis of helical or two-ranked ball-like aggregates ("heads") of peltoid-like organs. The distance between two neighbouring "heads" is 1.5 to 1.6 cm. The axis is up to 3 to 4 mm wide and coarsely striated. The lower part shows one or two (?) lateral branches about 1 mm wide and 1.5 to 2 mm long setting off obviously to the left. The "heads" crown similar axes of the second order. They reach 1 to 1.2 cm in diameter. The internal structure is mostly obscure; only a system of radially symmetrical elements overlying one another is visible.

A well preserved single peltoid-like disc is shown in Plate VIII, Fig. 9. It is 0.7 cm in diameter and has the shape of a flattened cup with a peduncle, 0.8 mm wide. The lower surface of the disc joins the peduncle at an obtuse angle of about 120–130°. The margin appears to bent abaxially and the outer edge of the disc shows radiating narrow projections, divided by concave contours of the matrix. The narrow projections appear to correspond to sinuses between marginal lobes, and the concave contours to marginal lobes.

Remarks: The present specimen has been tentatively referred to the genus *Peltaspermum*. Based on the compact arrangement of the discs into globular "heads", the specimen can be compared with the *P. buevichae* – *P. nanshanense* group. The mode of attachment of such "heads" to a shoot of a higher order remains obscure.

Genus *Pursongia* Zalessky 1933

The generic name *Pursongia* is currently used in various ways (Meyen 1969). Zalessky (1933) established *Pursongia* for leaves similar to *Glossopteris* but distinguished from these by the presence of woody interveinal striae. Neuburg (1948, 1956) attributed to *Pursongia* leaves with rare anastomoses between veins. Meyen (1969), however, having studied well-preserved material from the same deposits (Tatarian stage of the northern Russian platform) from which *Pursongia* was originally described as well as *Pursongia* specimens labelled by Zalessky, arrived at the conclusion that anastomoses are in fact absent. This conclusion was supported by studies of transparent compressions and cuticular preparations.

Cuticular studies have revealed a great microstructural variety in *Pursongia*-like leaves. Zalessky's type material has been lost, and it is not clear what microstructural type corresponds to the type species *P. amalitzkii*. Therefore Meyen (1969) reserved the generic name *Pursongia* for leaves without epidermal characteristics, and established a new genus *Tatarina* Meyen for leaves with known epidermal features.

Pursongia from zone C of the Nan-shan section is the non-cuticular variant of *Tatarina*. This is evident not only from morphological similarity, but also from the fact that *Tatarina* is closely associated with fructifications of *Peltaspermum*, showing the same types of stomata.

The *Pursongia-Peltaspermum* assemblage was observed in layer III of zone C. Leaves of *Pursongia* are noticeably predominant over other leaf types and *Peltaspermum nanshanense* are clearly predominant among the fructifications. Thus, despite the absence of cuticular characteristic in the Nan-shan *Pursongia*, there are good reasons to assume that the *Pursongia-Peltaspermum* assemblage from zone C is comparable to the *Tatarina-Peltaspermum* assemblage from the Tatarian of the Russian platform, and the Nan-shan *Pursongia* has therefore also been assigned to the Peltaspermaceae.

Halle (1937) attributed most of the *Pursongia* leaves to *Zamiopteris glossopteroides* (Schmalhausen) Zal. and Chinese palaeobotanists have been identifying these leaves in the same way until now (Gu & Zhi 1974). *Pursongia* and *Zamiopteris* are morphologically very similar indeed, but epidermal characteristics indicate that they belong to different systematic groups (Meyen 1969, 1987).

The most significant morphological difference is the presence of a midrib in *Pursongia*, or more correctly, a structure that was interpreted as a midrib until Meyen showed for *Tatarina* that it was actually a strand of hypodermal tissue, i.e. a false midrib that in most cases is indistinguishable in gross morphology from a true one.

Pursongia elegans Durante sp. nov.

Plate VI, Figs 2–4; Plate VII, Figs 3–4; Plate VIII, Figs 1, 3–4; Plate X, Figs 7–8; Text-Fig. 6.

Zamiopteris glossopteroides (Schmalh.) Zal., Gu & Zhi 1974, Plate 110, Figs 5–7.

Pursongia, sp. Durante 1980, Plate X, Figs 8–10.

Derivation of name: From the elegant shape (Lat.: elegans).

Diagnosis: Leaves simple, in average 8 to 12 cm long and 5 to 2.5 cm wide, narrowly to broadly lanceolate, seldom grading into obovoid, usually broadest in the upper part of leaf. Apex rounded or slightly acute and leaf base narrow, wedge-shaped or sometimes attenuated. The false midrib 2–4 mm wide at the base of the leaf narrowing quickly towards the apex.

Holotype: No. Bex 124-1 (Plate VIII, Figs 3–4; Text-Fig. 6), Swedish Museum of Natural History.

Type locality: Yangluhe River.

Type stratum: Layer III.

Age: Late Permian, Tatarian stage.

Material: More than 20 leaves and fragments of leaves from layer III of zone C.

Description: Reconstruction of the species (see diagnosis) was mainly based on rare complete leaves and larger fragments. The nature of the false midrib may be illustrated by the holotype of the new species. At the base of the leaf this structure looks like a strong hypodermal band rather than a real midrib because it covers a part of leaf lamina and cuts lateral veins. In the upper part of the leaf, the midrib shows great similarity with a lateral vein.

In one of the photographs provided by Dr. B. Bohlin, a short shoot of *P. elegans* has several leaves attached (Pl. VIII, Fig. 1).

Remarks: The new species differs from *P. amalitzkii* Zal. and *P. angustifolia* Zal. in its smaller size and from *P. angustifolia* and *P.* (al. *Tersiella*) *beloussovii* Radczenko in its lanceolate shape. Further it differs from *P.* (*T.*) *serrata* Srebrodolskaja in having smooth leaf margins (Zalessky 1933; Zalessky & Tschirkova 1937; Radczenko & Srebrodolskaja 1961).

Family Cardiolepidaceae

Genus *Phylladoderma* Zalessky 1913

Phylladoderma (?) sp.

Plate XII, Figs 2–3, 5–6; Text-Fig. 7

Material: Several entire leaves and more than a dozen leaf fragments from layer III of zone C.

Description: The fossil specimens are 4.5 cm to more than 10 cm long and 1 to 2.2 cm wide, with parallel veins not entering the margins. The leaf base is wedge-shaped or rounded wedge-shaped. The apex is acute, sometimes apparently mucronate. The acuminate nature of the apices may be due to infolding of the margins.

In the best preserved material with leaf bases intact the lower part of the leaf is thickened with transverse wrinkles and indistinguishable veins. At a more distal position of the leaf six to eight veins may be observed. They dichotomize once within a few millimeters and then parallel each other to the margin of the leaf, somewhat converging near the apex. One of the leaves exhibits a venation pattern resembling anastomoses (Text-Fig. 7). This as well as the obscured venation in some leaves are probably preservational artifacts. Transparent compressions of *Phylladoderma (Aequistomia)* from Meyen's collection often show laterally displaced veins touching each other possibly due to decomposition of a thick mesophyll.

Remarks: Parallel venation as described above, occurs in *Phylladoderma, Glossophyllum, Yuccites (Pelourdea), Phoenicopsis* and some other genera. In this study the generic name *Phylladoderma* has been adapted based on the following:

1. *Phylladoderma* often have ill-defined veins.
2. It may form false anastomoses due to the fleshy nature of the leaf lamina.
3. It is a typical element in the Upper Permian associations of the Angaraland boundary regions in which the Northern slope of the Nan-shan is situated.

The morphological diversity of *Phylladoderma* is unclear so far. The best known species is *Phylladoderma arberi* Zal. (Neuburg 1960). According to studies by Meyen and Gomankov (1971), the leaves attributed to this species by Neuburg exhibit a great diversity in epidermal characters and do, in fact, correspond to several epidermal species. Other species of *Phylladoderma* (*P. volgensis* Esaulova (1977) and *P. stenuifolia* Salmenova (1978)) have been established recently based on morphological features only.

The genus *Phylladoderma* has been affiliated with Cordaitales (Zalessky 1914) and Ginkgoales (Neuburg 1960). Meyen, who studied associated female fructifications of *Cardiolepis* with seeds of *Nucicarpus*, first referred the plants to the conifers (Meyen 1977; Meyen 1976–1978) and later to the order Peltaspermales (Meyen 1982).

Class: Ginkgoopsida or Cycadopsida leaves (?)
cf. *Anomozamites* sp.
Plate X, Fig. 1–6; Text-Fig. 8

Material: Several fragments of pinnae from layer XVI of zone C and photographs of three fragments from the same layer, missing in the collection.

Description: The length of the fragments available reaches 5 cm. The width of fully developed pinnae is 1 to 1.5 cm and the rachises are up to 0.8 to 1 mm wide, characterized by a distinct keel surrounded on both sides by deep furrows. Pl. X, Fig. 2 and Text-Fig. 8 illustrates the largest fragment with fully developed pinna. Pinnule lamina sometimes overlap the rachis and are evidently not attached to the margin, but to the axial keel. It is possible, however, that such overlapping of the rachis is due to flattening of convex pinnules during burial. The pinnule laminae are indeed in some cases noticeably convex. This is confirmed by the fact that their distal parts are frequently covered by sediment.

Whether the pinnules are arranged at some distance from each other, or their margins slightly overlapping, they are generally arranged on the rachis in pairs, although the pairs may be somewhat displaced relative to one another. The shape of fully developed pinnules is subsquare (5 to 8 mm × 5 to 8 mm), sometimes wider than long. Smaller pinnules from pinna fragments are subsquare to rectangular in outline, usually longer than wide (Plate X, Fig. 6). Distal margins of pinnules are straight or more or less rounded. The anadromous portions of the pinnules are slightly separated from the rachis by small sinuses while the catadromous portions are decurrent. The pinnules are connected with a narrow band devoid of veins.

Within the developed pinnule there are usually 7 to 8 (sometimes up to 10) veins arranged more or less perpendicular to the rachis and dichotomizing from one to three times. Closer to the base of a pinnule the veins become sharply curved, and their basal parts are parallel to the rachis coinciding with one another. Due to poor preservation it has not been possible to establish whether there is one basal vein entering the catadromous part of the pinnule and giving raise to all the other veins, or more (most probably two) basal veins arising independently from the rachis.

In addition to pinnae of the last order a poorly preserved fragment of a rather broad (3 to 4 mm) rachis was recognized bearing a semicircular transversely elongated pinnule, about 3 mm long and 7 mm wide. The pinnule appears to be noticeably overlapped by the rachis. The presence of such a broad rachis with pinnules similar in general structure but somewhat differing in shape, indicate that the leaf was probably multipinnate (at least bipinnate).

Remarks: The systematic position of the fossil described here is unclear. In the subsquare and rectangular shape of pinnules it mostly resembles the genus *Anomozamites*, but differs in the uniform shape and dimensions of pinnules. In *Anomozamites* the width and thus the shape of pinnules frequently varies within one pinna. They also differ in the venation pattern. Veins in *Anomozamites* are perpendicular to the rachises up to the very base of the pinnules and pass out directly from them.

In pinnule venation the fossil is rather similar to *Odontopteris* Brongniart (1825). It should be noted that the traditional concept of the odontopteroid venation requires a revision. According to Brongniart's diagnosis and the generally accepted concepts, the veins of *Odontopteris* pinnules enter directly from the rachis. However, S. V. Meyen (personal communication) studying the originals of the type species *Odontopteris brardii* Brongn. and other species at the Museum of Natural History in Paris arrived at the conclusion that either one or two veins enter the base of the pinnules of *O. brardii* and *O. minor* Brongn. (Retallack 1980) and their subsequent branching providing the entire system of the pinnules veins. Both cases (one or two veins) appears to be a result of one type of branching, viz. one vein can divide into two either at the base of a pinnule, or in the cortical zone of the rachis. A similar pattern is also observed in the present fossil with sometimes two or three veins passing into the bases of the pinnules.

Despite some similarity in the basal branching of the veins, the present material cannot be included in *Odontopteris*, as the character of the pinnules venation is different. Venation in *Odontopteris* is more or less radiate in contrast to the parallel venation of the present material. Further, the pinnules of *Odontopteris* are mostly rounded or oval and exhibit great variety in shape within a single pinna. However it is necessary to note that Gorelova (1984) described a similar plant from upper Permian of the Kuzbass using the generic name *Odontopteris*.

The present plant is also comparable to some *Dicroidium* species, particularly to varieties of the type species (*D. odontopteroides* var. *moltense* Retallack; *D. odontopteroides* var. *crassum* (Menendez) Retallack), *D. zuberi* (Szajnocha) Archangelsky, and *D. zuberi* var. *sahnii* (Seward) Retallack (Retallack 1980) characterized by pinnules that are subsquare or rectangular. In *Dicroidium*, as well as in *Odontopteris*, the pinnule veins are usually shown as entering from the rachis. However, the drawings by Townrow (1957, Text-fig. 4, D–J; Text-fig- 7, D, E; Text-fig. 10, K) show that only one vein enters small relatively undeveloped pinnules of various species of *Dicroidium*. As the general type of basal venation does not change from undeveloped to developed pinnules within the pteridosperms it can be assumed that one, strongly decurrent vein enters the developed pinnules and subsequently give raise to the remaining veins. If this assumption is correct, the morphological similarity of the present material and *Dicroidium* is significant. However, *Dicroidium* is restricted to Triassic deposits of Gondwana. Further its epidermal characteristics and its relation to certain fructification type have been fully established, whereas none of these characteristics are known for the present material.

The last group of genera comparable to the plant described here is the *Ptilozamites-Ctenozamites* group (simplipinnate *Ptilozamites* and double-pinnate *Ctenozamites*) characterized by uniform size and shape of pinnules within a single pinna. The pinnules are subtriangular or subrhombic to rectangular. They are broadly attached to the rachis and parallel veins are thought to enter directly from the rachis. Yet, in some *Ctenozamites* the tendency to form bundles of veins is observed. In *C. minor* Stanislavsky (1976) the near-basal part of the upper pinnule vein is strongly decurrent and confluent with the base of the next vein. This feature, however, may be difficult to recognize due to either destruction or poor preservation of the lower parts of the pinnules.

Similarity of the present material to *Ctenozamites* is also evident by details in the structure of the supposed rachis of penultimate order. A single fragment of such a rachis has wide semicircular transversely elongated pinnules similar to intermediate pinnules of some *Ctenozamites*, particularly *C. minor*.

Despite the similarity of the present fossil to representatives of the genera *Ctenozamites* and *Ptilozamites*, there are some differences in venation and shape of pinnules that prevent the identification of the plant with one of these genera.

Thus, the Nan-shan material cannot be referred to any of the discussed genera and it possibly belongs to a new genus. The material available is, however, insufficient to form the basis of a new taxon.

Class Pinopsida

Order Pinales
Family Lebachiaceae
Genus *Sashinia* Meyen 1978
cf. *Sashinia* sp.
Plate XIV, Fig. 8; Text-Fig. 9

Material: One fragment of a fertile shoot from layer III of zone C.

Description: The specimen is about 5 cm long and 1.2 cm wide with a relatively thin, slightly curved axis with spirally arranged lateral branches spaced 2.5 to 3 mm apart and more or less arched. They are 6 to 7 mm long and about 1 mm wide, with thickened and strongly abaxially curved apices. In some of the lateral branches the curved apex appear to be adpressed to the branch beneath forming an abaxial and oval thickening in its apical part (Text-fig. 9).

Remarks: In shape and size the lateral branches with apical thickenings resemble the seed-stalks of cordaites and conifers, especially those of the genus *Sashinia*. The oval terminal thickenings were first described by Meyen (1978) as seeds. Later, Gomankov and Meyen (1986) established that the seed was attached to the stalk under the thickened and abaxially bent apex. The present specimen is too poorly preserved to clarify the nature of the shoot and its affiliation with *Sashinia*. The most significant difference is the loose arrangement of seed-stalks on the axis in the present material, whereas they form a terminal bundle in *Sashinia* (Meyen 1978).

The axillary complex of *Sashinia* may be regarded as a dwarf shoot (brachyblast), whereas the present shoot is a long shoot (autoblast). Co-existence of brachyblasts and autoblasts on a single vegetative shoot is, however, well known and could also be the case for fertile shoots of the *Sashinia* type.

The possible affinity of the present specimen with *Sashinia* is partly supported by its association with vegetative coniferous shoots referred to the genus *Geinitzia*. In the *Tatarina* flora of the Russian platform, *Sashinia* is associated with *Quadrocladus* which is morphologically identical to *Geinitzia*. The two genera were separated by Meyen (1981) based on the absence (*Geinitzia*) or presence (*Quadrocladus*) of epidermal characters. In general appearance (axis with loosely arranged seed-stalks) the present shoot closely resembles *Krylovia* Chachlov (= *Samarospadix* Neuburg) (Neuburg 1948) that is a female fructification of the Angaran Rufloriaceae (Meyen 1987), but leaves of this family are totally absent in zone C.

Form genera of vegetative shoots

Genus *Geinitzia* Endlicher 1847

Geinitzia sp.

Plate III, Fig. 4; Plate V, Fig. 2; Plate XII, Fig. 4; Plate XIV, Figs 1–3, 7; Text-Fig. 10

Material: About 40 separate leaves and fragments of shoots from layer III, IV and XIV of zone C.

Description: The gross morphology of the plant is unclear. The material comprises branches of the last order with axes of different width, bearing small, spirally arranged leaves, 3.5 to 6 mm long and up to 1 mm broad. The leaves are crescentiform-curved or straight, rounded and somewhat dorsi-ventrally flattened in transsection. The degree of appression of the leaves to the axis in various shoots varies. Three fragments (A, B and C) of shoots of the penultimate order bear the same kind of leaves. The structure of these shoots exhibits some variation. Specimen A (Plate XIV, Fig. 7; Text-Fig. 10) has on the axis of the penultimate order considerably longer leaves, 10 to 15 mm, perhaps more, than specimen B (Plate XIV, Fig. 3) whose leaves are 4 to 6 mm long while the leaves of the last order shoots are shorter, about 4 mm in specimen A; 4 to 5 mm in specimen B. However, specimen B appears to bear larger leaves also. One of them, 25 mm in length, is attached near the base of the shoot and may subtend a lateral (fertile?) branch.

Specimen C (Plate III, Fig. 4; Plate XII, Fig. 4) is represented by a fragment of a leaf-bearing axis with more closely adpressed leaves, their length apparently exceeding 8 mm. In axils of some leaves short shoots have been observed. Only one of these is well defined. It is 7 mm long and about 2 mm wide and consists of a compact aggregate of small leaves up to 3 mm long and 0.5 mm wide.

All three specimens show appreciable heterophylly, variously expressed. In specimen A, the heterophylly is by different leaf sizes on axes of various order, in specimen B, by the presence of a single large subtending (?) leaf on the axis of the penultimate order, and in specimen C, by the presence of heterophyllous long and short shoots. Association of all three specimens in a single bed as well as similarity in form and prevailing dimensions of the leaves, suggest that all of them belong to the same plant. If this assumption is correct, the ratio of length between the shortest leaves (on the short shoot of specimen C) and the longest ones (on the axis of specimen A) would be 1:5.

Remarks: In general leaf morphology (form and sizes, heterophylly, presence of long and short shoots) the present conifer can be compared with *Quadrocladus* from the *Tatarina* flora of the Russian platform (Gomankov & Meyen 1986). In the West European *Quadrocladus* neither heterophylly, nor short shoots have been recorded (Schweitzer 1960).

Adequate comparison of the Nan-shan and Russian material is hardly possible due to difference in preservation. Well-preserved Russian *Quadrocladus-Geinitzia* species differ mainly in cuticle characters and small morphological details of the leaves (Gomankov & Meyen 1986). Complete shoots are rare. Only one case of heterophylly (*Q. dvinense*) has been described.

The poorly preserved Nan-shan conifers are without cuticles, though their shoot construction is generally discernable. At least three types of heterophylly have been recognized here. One of them (the above type C) is similar to that in the Russian Q. *dvinense* species.

The Nan-shan *Geinitzia* and the Russian *Quadrocladus* show great similarity in leaf and shoot morphology. However, to determine whether these groups of conifers belong to the same natural genus more evidence is needed.

Genus *Walchia* Sternberg 1825

Walchia (?) sp.

Plate XIV, Fig. 4

Material: One fragment of the apical part of a shoot from the layer III of zone C.

Description: The specimen is about 2.5 mm long and 2.5 cm wide and comprises a shoot of the penultimate order with a thin axis bearing alternating branches of the last order at intervals of about 5 to 6 mm. The branches are attached at an open angle and arranged in one plane. Axes of both orders are densely covered by spirally arranged small leaves, 1.5 to 2 mm long and 0.3 to 0.5 mm wide, attached to the axis at angles of 20–40°.

Remarks: The fragment resembles *Walchia* in the two-ranked arrangement of the branches of the last order, and in the very small leaves, densely crowded on the axis.

Pinales incertae sedis

Coniferous shoots

Plate XIV, Figs. 5, 6

Material: Two fragments of axes from layer III of zone C.

Description: The axes are thin, about 1 mm wide, bearing 6 to 15 mm long leaves, 0.5 to 1 mm thick and apparently rounded in transsection, resembling long leaves of *Geinitzia*, but are apparently not dorsi-ventrally flattened.

Coniferous male strobili

Plate XII, Figs 7–9

Material: Four compact strobili from layer III of zone C.

Description: One entire strobilus (with counterpart) is 1.8 cm long and 1.1 cm wide (Plate XII, Figs 8, 9) and a similar fragment is 1.6 cm long and 1 cm wide. Two other strobili are badly preserved. The fragment exhibits a coarsely ribbed axis and crowded microsporophylls. The structure of the sporophyll is most obvious on the entire strobilus. The sporophylls are distinctly declined downwards in the basal part of the strobilus, while attached to the axis at a right angle in its middle part, and bending upwards at an acute angle in the apical part.

The sporophylls appressed to the axis are apparently subtriangular or ovally-triangular in outline. Some sporophylls spread in the bedding plane seem to become gradually narrower towards the base. Others have a thin stalk-like projection. The shape of the proximal part of the microsporophylls cannot be established unequivocally due to insufficient preservation. Longitudinal sections of microsporophylls show that their distal part bends upwards under an almost right angle. The bending appears to coincide with thicker tissue of a microsporophyll. The distal parts have not actually been preserved but indirect observations indicate that they terminated in a long mucro.

The expanded portion of the microsporophylls is longitudinally striated. Veins have not been observed. In some places aggregates of small oval or ovoid bodies, about 0.5 cm long, which seem to be superimposed on the microsporophylls have been observed. They are regarded here as sporangia. The character of the attachment is not clear and the poor preservation of the material prevents reliable interpretation.

Remarks: The general structure of the microstrobilus suggests a relationship to conifers or some cordaites (genus *Cladostrobus*). The affinity with cordaites may be convincingly rejected, however, as neither details of microsporophyll structure nor associated leaves support a relationship. In *Cladostrobus* the sporophylls have dorsal furrows and the genus is known to be associated with cordaitean leaves of the genus *Rufloria* with dorsal furrows. Such leaves have not been recovered in zone C at all. Further, they appear to be absent in synchronous deposits throughout Angaraland. Within the Angaran area *Rufloria* disappeared by the rise of the *Tatarina* flora, an analogue to the flora of zone C. Leaves and shoots of conifers on the other hand have been recorded in layer III of the zone C associated with the strobilus (see above).

The poor preservation of the microstrobili prevents a reliable generic identification but an affiliation with *Dvinostrobus* Gomankov and Meyen (1986) is possible. The microsporophylls of *Dvinostrobus* are loosely arranged on the axis and consist of a distal lamina and a stalk bearing sporangia on short dichotomously branching sporangiophores. The cuticular structure of the distal lamina is analogous to that of *Quadrocladus.*

The affiliation with *Dvinostrobus* is to some extent based on the assumption that vegetative shoots of *Geinitzia*, fertile shoots of *Sashinia* and the microstrobili, all recovered from layer III of zone C, belong to the same plant and are, to a certain extent, allied to the *Quadrocladus-Sashinia-Dvinostrobus* plexus from the *Tatarina* flora of the Russian platform. Some other microstrobili of related conifers, particularly *Darneya* and *Sertostrobus* from the Triassic of West Europe and *Rhenania* from the European Zechstein, are characterized by having peltate microsporophylls and are thus distinguished from the present material.

Satellite genera of the division Pinophyta.
Genus *Psygmophyllum* Schimper 1870

The genus *Psygmophyllum* has been variously treated. Schimper (1870) included in the genus both the fern-like fronds of *P. cuneifolium* (Kutorga) and *P. expansum* (Brongniart) from the Permian of the Cis-Urals and the Euramerian Carboniferous species *P. flabellatum* (Lindley & Hutton). Later Saporta (1878) showed that the species of *Psygmophyllum* belonged to different genera. Permian species from Ural have pinnately dissected leaves, whereas leaves of *P. flabellatum* (Lindley & Hutton) are simple. A similar conclusion was reached by Arber (1912). Saporta retained the Uralian species in the genus but excluded *P. flabellatum* (Lindley & Hutton). Arber, on the contrary, designated the latter as the type species of the genus *Psygmophyllum*. European paleobotanists mostly follow the work of Saporta. For the same reason Høeg (1967) also excluded *P. flabellatum* from *Psygmophyllum* and selected that species as type for his genus *Ginkgophytopsis*. Japanese palaeobotanists (Asama 1966, 1967; Kon'no 1968) have generally followed Schimper and included *P. flabellatum* into the genus. It is noteworthy that even in the restricted sense (excluding *P. flabellatum*) the genus *Psygmophyllum* is a rather heterogenous genus and includes pinnate leaves with both small wedge-shaped (*P. cuneifolium*) and large palmate (*P. expansum*) segments.

Judging from available illustrations there are no transitional forms between these very different leaf types. As *P. expansum* was selected by Høeg as the type species of *Psygmophyllum*, the species *P. cuneifolium* should most probably be ascribed to another genus (its similarity with some types of *Raphidopteris praecursoria* leaves were stressed by Meyen, 1979).

Accepting *P. expansum* as the type species of the genus two other genera, namely *Syniopteris* Zalessky (1929a) and *Iniopteris* Zalessky (1934b) should also be included in *Psygmophyllum*. This was also suggested by Burago (1982). Neuburg (1948) incidentally mentioned the possible synonymy of *Syniopteris* and *Iniopteris*.

Burago's emended diagnosis of the genus *Psygmophyllum* is given here with minor changes. "Leaves symmetrical petiolar, rounded or elliptical in outline. Rachis forked, its branches forming rachises of two central pinnae of first order radiating at angles 20°–60°. At the point of furcation or somewhat lower two rachises of two shorter basal pinnae arise. Both central and basal pinnae are asymmetrical, their outer parts being more developed and more intensely dissected. Outer parts of central pinnae, frequently bearing 2 to 5 pinnae of the second order are most intensely developed and dissected. The lamina attached to rachises of the first and second orders more or less deeply dissected into lobes or pinnules". Burago's study was based primarily on material of *Syniopteris demetriana* Zal. from Southern Primorie. This circumscription of the genus needs some alterations to include also the leaf structure of the *S. nesterenkoi* Zal. type (Zalessky, 1929a) which has an entire lamina, but the same general pattern of the leaf structure (system of rachises branching).

According to Burago the identity of *Syniopteris, Iniopteris* and *Psygmophyllum* is supported by the following observations. The largest leaf fragment of *P. expansum* first presented by Eichwald (1860, p. 1, pl. XIII, Fig. 17) and later by Zalessky (1929b) may be regarded as a whole leaf. Eichwald illustrated two large *Psygmophyllum*-like segments arranged at an angle to one another, in such a way that they can be regarded as parts of a forked leaf. Close to the supposed point of divergence of these segments two smaller segments (analogues of the basal pinnae) radiate from both sides. Thus the specimen of *P. expansum* illustrated by Eichwald appears to be an entire leaf, not the apical part of a shoot, as assumed by Zalessky (1929b), and is in general structure identical to that of *Syniopteris* and *Iniopteris*.

The identity of the *Syniopteris, Iniopteris* and *Psygmophyllum* leaves is supported not only by a common structure but also by the specific venation pattern that may be termed psygmophylloid. Rachises of all orders are thick ligneous structures in their basal parts and grade upwards first into bunches and later aggregations of veins. Therefore the terms "rachis" or "axial zone" has been applied here instead of "midrib".

Psygmophyllum sp.

Plate XI; Figs. 1, 5; Text-Fig. 11

Material: Two fragments of psygmophylloid leaves preserved on a single slab and obviously belonging to a single fully developed leaf from layer IV of zone C, as well as a photograph of another fragment missing in the collection.

Description: The fragment studied from the photography is 14 cm long and constitutes a well-preserved apical part of leaf including the point of divergence of the axial zones of two segments (Plate XI, Fig. 1). The leaf segments diverge at an angle of about 30°, then run almost parallel to one another and converge again towards the apex. Near the point of divergence, the inner portion of the lamina is a few millimeters wide and expands upwards to exceed 1.5 cm. It is difficult, however, to estimate the entire width and character of the margin, as the segments are mostly overlapping and only near the place of convergence they are divided by a drop-like sinus. The outer part of the lamina is about 1 cm wider near the point of divergence up to more than 4 cm in its broadest part. On the left lobe (the outer part of the right one is not preserved) the lamina is dissected by deep subtriangular sinuses into three lobes. The shape of the basal lobe is unclear, the two following are subtriangular, almost linear, about 6 cm long and 1.2 to 1.5 cm wide.

The two fragments are 10 cm and 5 cm long respectively and arranged in one plane at an angle of about 50° (Plate XI, Fig. 5; Text-Fig. 11). They appear to be a part of a forked leaf similar to that figured in Plate XI, Fig. 1), but probably derived from a larger and more developed leaf. The lobes diverge at a wider angle without overlapping. The inner parts of the lobes are 2 to 2.5 cm wide, and lobately dissected. The outer parts appear to be broader and deeply dissected. This is indicated by a single ramification preserved on the left lobe and exceeding 5.5 cm in length.

The axial zone of the lobes, 2 to 4 mm wide, resembles a longitudinally striated rachis (the visible lower part of the left lobe in Plate XI, Fig. 5), a woody midrib, or a compact axial bundle of veins. In the lateral ramifications of the axial zones those of the second order may also be observed, but they are thinner, 1 to 2 mm, and probably grading upwards into a bundle of flabellate veins. The inner parts of the lobes are supplied with secondary veins only. These are thin, dense, strongly decurrent, and usually dichotomizing three to four times.

Remarks: The characteristics of the two leaf fragments described here are those of the genus *Psygmophyllum*. However, their specific affinities remain obscure due to insufficient and poorly preserved material (basal lobes of both fragments are unknown). Further, specific features and intraspecies variations within this genus are not sufficiently known and the present material can equally be affiliated with some specimens of *P. expansum* (see Zalessky 1929b, Fig. 2). *P.* (al. *Iniopteris*) *sibirica* (Zal.) Burago and *P.* (al. *Syniopteris*) *demetriana* (Zal.) Burago 1982.

cf. *Psygmophyllum demetrianum* (Zalessky) Burago

Plate VII, Fig. 2

Material: One photography of a slab from layer XIV of zone C showing two rachises.

Description: The rachises are up to 19 cm in length diverging at an acute angle, and probably belonging to the same leaf. They are broad and convex at the base, narrowing upwards to become very narrow near the apex. The leaf lamina is dissected into segments with deep sinuses. The segments are 7 to 9 mm wide, narrowing near the apex where they are fused and grade into narrow lobes. The veins are more or less parallel.

Remarks: As the specimen is incomplete, it is not possible to establish whether it is a forking part of a pinnately dissected leaf, or the apical part of a *Psygmophyllum*-like leaf.

The dimensions of the fragments, the structure of the rachises and the acute angle of divergence, along with the presence of other *Psygmophyllum* species in zone C suggest that the fossils may be imprints of *Psygmophyllum* and they resemble *P. demetrianum* in the dissection of the leaf lamina into rather small segments.

Genus *Psygmophyllopsis* Durante gen. nov.

Psygmophyllum, Halle 1927, pp. 214–218, Pl. 57, 58

Diagnosis: Leaves petiolate, round, oval or fan-shaped, divided into two or more oval lobes by more or less deep sinuses. When divided into more than two segments, the central segments are typically larger than the lateral. Each segment has its own more or less compact truss of veins, resembling a narrow rachis of the "Psygmophyllum"-like type. Trusses within the segments dichotomize into units corresponding to lobes of the second and third order.

Type species: *Psygmophyllopsis norinii* Durante sp. nov.

Specific composition: *Psygmophyllopsis norinii* Durante sp. nov., *P. multipartitum* (Halle) Durante comb. nov.

Psygmophyllopsis norinii Durante sp. nov.
Plate XII, Fig. 10, 11; Plate XIII, Fig. 4, 5; Text-Fig. 12a–b.

Derivation of name: After the Swedish geologist Professor E. Norin in recognition of his work in Central Asia.

Diagnosis: Leaves small, petiolate, round or fan-shaped, divided by deep sinuses into 2 or 4 undissected or lobately-dissected segments of more or less regular oval outlines with a truss of veins grading from the petiole into each segment. The venation in segment almost radiate.

Holotype: No. Bex 296 (Plate XII, Fig. 11, Text-Fig. 12a).

Type locality: Yangluhe River.

Type stratum: Layer VII of zone C.

Age: Late Permian.

Material: Six leaves from layer III and VII of zone C.

Description: The six leaves differ somewhat in size. The holotype is a large fragment of an almost completely circular petiolate leaf, almost as long as wide, about 6.5 to 7 cm. The leaf, as a whole, is symmetrical. A deep sinus almost reaching the petiole, divides the leaf into two almost equal halves. Two other deep sinuses dissect each of the halves into two unequal segments: a marginal and a central. The marginal segments are more or less of regular oval shape, about 1.5 × 2 × 3.5 cm and smaller than the central that exceed 5 cm in length. The marginal segments grade from the petiole at an angle of about 50° while the central segments grade at an angle of about 20°.

The central segments also differ from the marginal in their more complex morphology, being narrow at the base, widen and simultaneously divided higher up. One segment that is less damaged than the others, exhibits a large grading lobe separated from the rest of the segment plate by a short but wide subtriangular sinus. The character of venation suggests the existence of an additional lobe in a more apical position, not preserved in the fossil.

At least three veins dichotomizing in the lower part of the segment up to 4 times, grading from the petiole into the base of each segment. The venation in the marginal segments is more or less fan-shaped, concentration of veins in their axial parts being insignificant. In the central segments, particularly in their lower parts, some veins arranged along the axis of the segment can be distinguished as well as lateral veins that grade to the margin. The zone of axial veins may dichotomize preceeding separation of a supplementary lobe.

Among three other leaves assigned to this species the specimen figured in Plate XIII, Fig. 5 is most similar in shape and size to the holotype, but differs from the holotype in having much stronger developed marginal parts, that are comparable in size to the central segments of the leaf. The lateral sinus of the leaf is very deep compared to the axial sinus, and differs in this respect from the holotype.

The two other leaves attributed to the new species are less dissected than those described above. The leaf illustrated in Plate XII, Fig. 10, text-Fig. 12b, differs from the holotype in being more elongated with length of leaf lamina 8.5–9 cm and the width not exceeding 5 cm. The leaf has a long petiole. It is divided into two segments by a deep sinus coinciding with the vertical axis of the leaf. One of these segments is clearly dissected into two lobes of tentatively equal width, only the central lobe being preserved. This dissection is indicated both by the character of venation (division of the vein truss that enters the segment in two parts), and the existence of a distinct narrow fold that grades along the axis of the right segment and probably is a continuation of the sinus dividing lobes. The more heavily damaged left segment also exhibits a division of vein truss in two parts. No fold has, however, been observed on the axis of the segment. Among the four lobes into which the leaf is supposedly divided, the central lobe of the right segment is best preserved. It is elongated-oval in shape with a subtriangular softly rounded apex. Similar lobe apeces and sinuses dividing them, can be observed on a fragment of another leaf (Text-Fig. 12b) which probably belongs to the same shoot.

The fourth leaf is represented in the collection by a counterpart of the specimen shown in Plate XIII, Fig. 4. The part itself is lacking in the collection. In its weak segmentation this leaf resembles that of Plate XII, Fig. 10 and in its shape and dimension, the holotype. The width of the leaf lamina somewhat exceeds its length (about 4 cm). The sinus tentatively coinciding with the axis of the leaf, divides it into two segments, of which the left, judging from the venation patterns, is divided into two lobes, whereas the right one is undissected. The latter has an obovate shape and is characterized by a rounded apex. The left segment has central lobe only that in shape is similar to the right segment, although somewhat narrower.

Remarks: The holotype resembles leaves of *Psygmo-*

phyllum in general shape. However, ligneous rachises, diagnostic or *Psygmophyllum* were found neither in the leaf bases of the new genus, nor in the axial parts of the segments. Other leaves assigned to the new genus differs further from *Psygmophyllum*, in being divided into two or three parts in contrast to the four in *Psygmophyllum* and in having marginal segments similar to the central ones.

In addition to the new species I also include *Psygmophyllum multipartitum* Halle into the genus *Psygmophyllopsis*. They agree with *Psygmophyllopsis* in their fan-shaped leaves and psygmophylloid venation and differ from *Psygmophyllum* in having different leaf structure. The new species differs from *Psygmophyllopsis multipartitum* (Halle) Durante in the distinct bilateral symmetry and division of the leaf into no more than four segments, in the smaller dimensions of the leaf and in having a thinner petiole.

Genus *Rhipidopsis* Schmalhausen 1879
Rhipidopsis aff. *palmata* Zalessky
Plate VII, Fig. 6, Plate IX, Fig. 6

Material: Five specimens from layer IV of zone C and one specimen from an unassigned layer of zone C.
Description: Leaves oval, divided into 8 widely cuneiform segments that gradually decrease in size from the apical (more than 4 cm in length) towards the lateral (about 2 cm in length) and basal segments. The apical segments are dissected by small sinuses into two, perhaps three lobes while the lateral and basal segments apparently are undivided.
Remarks: The leaf resembles *R. palmata* in general shape and dimensions of the leaf, as well as the insignificant dissection of the segments. Contrary to *R. palmata*, however, it is characterized by having considerably wider segments, up to 3 cm.

Rhipidopsis cf. *palmata* Zalessky
Plate IV, Fig. 4, Plate XIII, Fig. 3

Material: Two leaves from layer XIV of zone C.
Description: The leaves have thin petioles and are round or oval in shape. They are dissected into 10 narrowly cuneiform segments, up to 7 cm in length, not adjoining one another, but separated by a space equal to half or one third the width of a segment. Rare, more or less entire segments exhibit dissection by deep (over one third the length of a segment) sinuses into two, sometimes, perhaps three parts.
Remarks: Amongst described species of *Rhipidopsis* the present material is more similar to *R. palmata* Zalessky in leaf form and segment dissection than to any other species. The shape of the segments differs, however, from that of *R. palmata* and the material may represent a new species, but the scarcity of material does not make it possible to solve this problem.

Rhipidopsis sp. 1
Plate IX, Fig. 5

Material: Three leaves from layer IV of zone C.
Description: The three leaves are arranged in a row on one plane of the slab and probably belong to the same shoot. One of the leaves is illustrated in Plate IX, Fig. 5. None of the leaves are complete, but their somewhat transverse-oval shape can be seen. Each leaf is dissected into 10 to 12 cuneiform radial segments, 3.5 to 6 cm long. The segments are tightly spaced or separated from each other by few millimeters. Lateral segments are approximately of the same length as the apical. The basal segments seem to be somewhat shorter and narrower. Each of the segments is separated into 3 to 4 narrow lobes by deep and narrow sinuses.
Remarks: The described material differs from all known species of *Rhipidopsis* in the regular rounded to transverse-oval shape and approximately equal size of the upper and lateral segments and it probably belongs to a new species. It is, however, not possible to establish a new species in the present work, as only photographs of the material were available.

Plantae incertae sedis
Genus *Flabellofolium* Stone 1973

Platyphyllum, Dawson 1882
Ginkgophytopsis, Høeg 1967 (?) (excluding type species)
Ginkgophyton, Burago 1976
Ginkgophytopsis, Burago 1977

The generic name *Flabellofolium* was proposed by Stone (1973) to substitute the preoccupied generic name *Platyphyllum* used to denote radiate *Ginkgo*-like Palaeozoic leaves. True *Platyphyllum* usually incorporated Devonian and some Carboniferous leaves with rare and distinct veins, whereas multiveined forms occurring in the Carboniferous but more characteristic in the Permian, are usually described under the generic name *Psygmophyllum* and *Ginkgophytopsis*.

Saporta (1878) was the first to suggest the exclusion of *Ginkgo*-like leaves from the genus *Psygmophyllum* and attributed them to *Ginkgophyllum*. Subsequently Zalessky (1918) distinguished them as a new genus *Ginkgophyton*. This generic name proved, however, to be preoccupied and was substituted by *Ginkgophytopsis* (Høeg 1967) with the type species *G. flabellatum* (Lindley & Hutton 1831) and with the following generic diagnosis: "Leaves large, fan-shaped, undivided, sometimes sinuous along the distal margin, less frequently sinuate. Venation is dense, veins are distinct, bifurcated. Petioles are long, decurrent, arranged spirally on the axis". Retallack (1980) criticized Høeg's diagnosis and pointed out that it only concerned the degree of dissection of a leaf whereas the existence of anastomoses between veins as mentioned by Seward (1919) for the type species of *Ginkgophytopsis flabellatum* had not been considered. Retallack (1980) gave the following emended diagnosis of genus *Ginkgophytopsis*: "Leaves cuneate, divided or frayed at the apex. Venation dense, anastomosing and dichotomizing, evenly radiating from base to apex, often obscure by copious woody interveinal striae. Leaf bases narrow, apetiolate, passing decurrently into slender woody axes on which they are helically arranged."

Retallack suggested that species agreeing with Høeg's diagnosis should be attributed to the genus *Flabellofolium* Stone (= *Platyphyllum* Dawson). I agree with this proposal. The use of the generic name *Ginkgophytopsis* should be confined to the type species until its structure has been adequately clarified.

The diagnosis given by Høeg (1967) for *Platyphyllum* and *Ginkgophytopsis* are, however, extremely similar. If we exclude from the diagnosis of *Ginkgophytopsis* the indications of a spiral arrangement of leaves on the axis (this being reliably known for *G. flabellatum* only) and of the petiolate character of the bases, unknown in most of species ascribed to *Ginkgophytopsis*, (Høeg 1967; Burago 1976, 1977), the only difference between the two genera are related to the density of venation and degree of distinctness of veins.

Thus, species attributed to the genus *Ginkgophytopsis* (sensu Høeg) can be included in the genus *Flabellofolium* Stone (= *Platyphyllum* Dawson) if the diagnosis of the latter is emended to include not only rare-veined, but also dense-veined forms. In this case, the species assigned by Burago to *Ginkgophyton* (Burago 1976) and later to *Ginkgophytopsis* (Burago 1977) should be included in *Flabellofolium*. These are *F. giganteum* (Burago), *F. majus* and *F.* sp. nov. The last name was used for the forms determined by Asama (1967) and Kon'no (1968) as *Psygmophyllum flabellatum*. Some species ascribed by Høeg (1967) to the genus *Ginkgophytopsis*, remain less clear. *G. gilkinetii* and *G. delvalii* can be attributed to *Flabellofolium*, but with a question mark, as these species are represented by poorly preserved fragments which fail to provide reliable evidence of leaf form. *G.* (?) *kidstonii* was given with a question mark by Høeg himself (1967), evidently because the leaves of this plant are much smaller than those of other species. Subsequently, Beck attributed *Ginkgophytopsis* sp. (Høeg 1967) to the progymnospermalean genus *Eddya*.

Flabellofolium should be regarded as a form genus, but in this respect it does not differ from *Ginkgophytopsis* Høeg, which included leaves of different ages, biogeographical distribution and systematic position.

Flabellofolium sp. 1

Plate XI, Fig. 3, Plate XIII, Fig. 6, Text-Fig. 13

Material: One fragment of a leaf from layer III of zone C and five fragments from layer IV of zone C.

Description: The leaves are cuneiform with a more or less entire leaf lamina. One of them (Table XI, Fig. 3; Text-fig. 13) is represented by an almost complete leaf, more than 5.5 cm long; only the very base and the apices of lobes are absent. Near the base the leaf is about 1 cm broad and expands into a fan-like blade up to 5 cm wide near the apex. The leaf lamina is even and entire for about three fourths of its length. Near the apical part the leaf is dissected into four lobes, the central lobes being 1.3 and 1.5 cm broad while the marginal lobes are more narrow, about 1 cm broad.

The sinuses dividing the lobes are approximately of same length and only the marginal, left sinus seems deeper, possibly as a result of mechanical rupture.

In addition to the four main lobes a narrow lobe is observed at the better preserved right part of the leaf which emphasizes the fan-like shape of the leaf.

The venation is radial. Veins parallel to the margin of the leaf appear to dichotomize three to five times. The density of veins is from 15 to 17 per 0.5 cm. On some small areas (on an imprint, not on a compression) it appears as if only every second vein are present (density of venation 8 veins per 0.5 cm). This may be a result of the preservation, or it is possible that some of the "veins" are not vascular but strands of hypodermal tissue.

The second fragment (Plate XI, Fig. 4) is represented only by the near-basal part of a subtriangular leaf. The margins of the leaf form an angle of 75–80°, the very base being torn off. The leaf lamina is longitudinally crimping and torn along the vertical axis. Possibly this rupture is a continuation of the axial sinus cutting the leaf. Venation is parallel, radial. Vein density is 8 to 10 per 0.5 cm. Thinner strands (intermediate veins?) are sometimes seen between veins.

Flabellofolium sp. 2

Plate XI, Fig. 2, Text-Fig. 14

Material: One large fragment of a leaf from layers VII of zone C and two small fragments from layer III and IV and of zone C.

Description: The leaf is larger and more dissected than that of *Flabellofolium* sp. 1. It is fan-shaped, more than 12 cm long and broad (in its broadest part), Sinus coinciding with the vertical axis of the leaf is at least two thirds the length of the leaf and up to 4 cm wide. The other sinuses are somewhat shorter and more narrow. Like in *Flabellofolium* sp. 1, the leaf lamina is dissected into four major lobes, approximately of the equal width. Further, a more narrow marginal lobe is present at the left portion of the leaf. One of the four major lobes (the right central) is dissected into two additional lobes by a rather deep sinus reaching half the length of the axial sinus. Possibly other lobes are also more or less deeply dissected. This cannot be established, however, due to a very abrupt and uneven rupture.

The veins visible at the base of the leaf are noticeable, their density being about 8 per 0.5 cm with additional strands being sometimes visible. Higher up, the venation is dense (15 to 16 veins per 0.5 cm) and even. Within the exposed part of the leaf the veins appear to dichotomize not less than four to six times.

Remarks: Both types of leaves described here show sufficient morphological variation to be separated into different species. *F.* sp. 2 differs from *F.* sp. 1 by its larger size, more open angle between the leaf margins, deeper dissection of the leaf and different shape and size of the segments. However, both types of leaves have very small marginal segments near the leaf bases which distinguish them from other species of *Flabellofolium* and it cannot be excluded that they represent morphological varieties of the same species. The small marginal segments resemble those of *Rhipidopsis* but the triangular shape of the two *Flabellofolium* leaves described above distinguishes them from *Rhipidopsis* that are characterized by rounded or oval leaves.

Genus *Plagiozamites* Zeiller 1894

Plagiozamites ? sp.

Plate IX, Fig. 1, Text-Fig. 15

Material: One fragment of a pinna from layer III of zone C.

Description: The fragment of the upper part of the pinna is about 9 cm long. The rachis is smooth, up to 2 mm wide at the base of the fragment, narrowing up to 1 mm, and then grades into a midrib of the apical segment. The rachis is dissected by a series of transverse fissures, rather regularly associated to the bases of pinnules. The pinnules, 1.5 to 2 cm long and 0.5 to 0.8 cm wide, are generally elongated-oval with smooth-margin and diminishing in size from the exposed base towards the apex of the pinna. Pinnules are arranged in two rows closely spaced and overlapping each other by their margins. They are attached to the rachis by wide decurrent and perhaps amplexicaul bases. It may be assumed that transverse fissures on the rachis associated with the bases of pinnules, correspond to absent amplexicaul parts.

The pinnules are markedly curved. Their basal parts are almost pressed to the rachis. Higher up they unroll and widen. The bend is distinct in the catadromal parts of pinnules (especially lower), being frequently emphasized by a fissure cutting across a pinnule lamina. The existence of such a fissure, as well as the fact that the higher and lower parts of the pinnule lamina are generally arranged in somewhat different planes, indicate an oblique attachment of pinnules to the rachis and certain deformation in the process of burial and flattening out in the plane of the rachis.

The lanceolate apical segment is characterized by lobed margins (relics of accrete pinnules), reaching 4 cm in length. In pinnules near the base of the fragment the veins radiate slightly, while towards the apex they are almost parallel. The veins in the central sectors of the lower pinnules appear to dichotomize at least four times. However, the exact number of dichotomies cannot be established due to poor preservation.

Remarks: The genus *Plagiozamites* was established by Zeiller (1894) for pinnate (mostly bipinnate) leaves with pinnules attached obliquely to the rachis and having more or less amplexicaul basements. Halle (1927) interpreted *Plagiozamites*, as well as the similar *Noeggerathia*, as shoots bearing simple leaves, not dissected fronds. This was based on the similarity of these genera to *Tingia* which according to Halle are shoots with leaves arranged in four rows.

The peculiar attachment of the pinnules to the rachis observed in the fragment described here is comparable to that of the genus *Plagiozamites*. The fragmentary and unique character of the impression along with its poor preservation, however, prevent a more detailed comparison. If this fragment really belongs to *Plagiozamites*, it supports Zeillers interpretation of leaf organization since the apical fragment is distinct and cannot be confused with the pinnules arranged down the axis.

SYSTEMATIC COMPOSITION, BIOGEOGRAPHICAL POSITION AND AGE OF THE FLORA

Systematic composition and quantitative ratios of the various plants of the flora of zone C are presented in Table I. The flora of zone C is highly diverse regarding its systematic composition. Pteridosperms are clearly predominant and the flora may be referred to as pteridospermalean, or, more accurately as a flora of peltaspermalean pteridosperms, as plants that are included in, or affiliated with the family Peltaspermaceae are dominant among the pteridosperms.

As mentioned earlier the flora has been collected in a region situated near the boundary of the two major palaeophytogeographical units: The Angaran and the Cathaysian kingdoms. Thus, the flora should be compared to both the Cathaysian and the Angaran Upper Palaeozoic floras.

Zone C is according to information from Bexell (1935) and confirmed by Chinese geologists (Shi & Liu, 1981) stratigraphically younger than the two other plant-bearing zones (A and B), considered by Halle (1935, 1937) as typically Cathaysian. Halle ascribed the assemblage of zone A to the uppermost Carboniferous – lowermost Permian, while the assemblage of the lowermost parts of zone B was considered as Lower Permian and that of the uppermost parts of zone B as Upper Permian. Halle regarded the assemblage of zone C as typical Angaran and did not identify any Cathaysian elements among its plants. Recently Chinese palaeobotanists have expressed a somewhat different view (Li & Yao 1979, 1980) and consider the flora of the zone C of the Nan-shan Range and synchronous assemblages of adjacent regions not purely Angaran, but mixed, containing both Angaran and Cathaysian elements. Regarding the Bexell section, they state (Li & Yao 1980, page 5): "The Angara flora was not wholly located above the Cathaysia flora but was in fact contemporaneous in the same bed during the period of Late Permian, i.e. the former was mixed with many typical elements of the Cathaysia flora of the Upper Shihhotse formation in North China, such as *Lobatannularia lingulata* (Halle), *Pecopteris anderssonii* Halle and *Rhipidopsis lobata* Halle".

From the present study it may be concluded that the Nan-shan zone C flora is of the same type as the latest Permian (Tatarian) of the Russian Platform (Durante 1980, 1983; Gomankov & Meyen 1986). This view has not previously been expressed in palaeobotanical papers (Wang Dexii et al. 1984; Zhang Hong & Shen Guanglong 1987) regarding the Nanshan flora, and will be further developed below.

Undisputable Cathaysian plants in the zone C collection studied here are not numerous. They are represented by a single fern pinna referred to as *Pecopteris* cf. *anderssonii* and a fragment of a pinna (leaf?) of a fern-like plant with reticulate venation that also appears to be a Cathaysian element (Pl. III, Fig. 5). The Cathaysian origin of some pteridosperms cannot be excluded either, particularly for the forms identified as *Compsopteris* cf. *contracta*. At the same time these forms may be close to *Rhaphidopteris* described by Meyen (1979) from the Upper Permian deposits of the Russian platform. Regarding *Compsopteris*, in general, it should be noted that Chinese palaeobotanists have recently attributed the widely distributed Cathaysian species of the Upper Shihhotze formation "*Protoblechnum*" *wongii* Halle to this genus. They followed Zalessky (1934b) and Meyen (Meyen & Migdisova 1969). This attribution, however, requires confirmation by epidermal studies, since *Compsopteris* has a distinct epidermal characteristic, and has so far been known with certainty only in the Angaran palaeofloristic area. As to the genus *Callipteris*, the Euramerian species *Callipteris conferta* (Sternb.) Brongniart was described by Sze from the Upper Shihhotse formation of the Shansi province (Sze 1935). The same author identified a new peculiar species of *Callipteris*: *C. changii* Sze (Gu & Zhi 1974, pl. 92). The Cathaysian flora incorporates plants with foliage close to *Comia*: *C. yichunensis* Huang (Gu & Zhi 1974, pl. 93) and *Jidopteris satohotoi* Kon'no

Table 1. Distribution of plants species in the zone C beds.

Zone C Plants	Number of specimens in individual beds										Specimens of unknown location	Total number
	III	IV	V	VI	VII	VIII	XIV	XV	XVI	XVII		
Annularia sp.	9											9
Phyllotheca ? sp.	1					1						2
Paracalamites sp.	4											4
Cladophlebis sp. 1	5				1							6
Cladophlebis sp. 2	1				1							2
Katasiopteris cf. *lata*					1							1
Pecopteris cf. *anderssonii*	1											1
Pecopteris ex gr. *anthriscifolia*	2										1	3
Pecopteris sp.	7	4									1	12
Sphenopteris cf. *tajuanensis*	1											1
Sphenopteris sp.	9											9
Callipteris bexellii						11	2					13
Callipteris ex gr. *bexellii*					5							5
Callipteris sp.	20				2		9				1	32
Callipteris vel *Compsopteris*	4				1							5
Comia sp. 1	10											10
Comia (?) sp.	1											1
Compsopteris cf. *adzvensis*	1											1
Compsopteris ? *contracta*	2											2
Compsopteris ? sp. 1	1											1
Compsopteris ? sp. 2	3											3
Compsopteris ? sp. 3	3											3
Compsopteris ? sp. 4	10											10
Peltaspermum nanshanense	about 30 peltoids											about 30 peltoids
Peltaspermum sp.	1 shoot											1 shoot
Pursongia elegans	20											20
Pursongia serrata	11											11
Pursongia ex gr. *amalitzkii*	2											2
Pursongia cf. *angustifolia*											1	1
Pursongia sp.	82	2				1	8				4	97
Phylladoderma (?) sp.	21											21
cf. *Anomozamites* sp.									7			7
Cardioneura (?) sp.	1											1
Cordaites sp.	1									2	1	4
cf. *Sashinia* sp.	1											1
Geinitzia sp.	35–40	2					1					about 40
Walchia (?) sp.	1											1
Coniferous shoots incertae sedis	2											2
Coniferous male strobili	4											4
Coniferous strobili incertae sedis	1											1
Psygmophyllum sp.		2										2
cf. *Psygmophyllum demetrianum*							1					1
Psygmophyllopsis norinii	1				5							6

Zone C Plants	Number of specimens in individual beds										Specimens of unknown location	Total number
	III	IV	V	VI	VII	VIII	XIV	XV	XVI	XVII		
Rhipidopsis aff. *palmata*		5									1	6
Rhipidopsis cf. *palmata*							2					2
Rhipidopsis sp. 1		3										3
Rhipidopsis sp. 2			5									5
Flabellofolium sp. 1	1	5										6
Flabellofolium sp. 2	1	1			1							3
Plagiozamites ? sp.	1											1
Taeniopteris sp.	1	3										4
Part of leaf with reticulate venation											1	1
Sylvella sp.	2											2
Samaropsis sp.	5											5
Carpolithes sp.	10											10

(1968). Thus foliage of the callipteroid type has been identified in the Cathaysian Upper Permian floras. However, according to the cited works, callipterids neither dominate anywhere, nor form any appreciable accumulations.

The genus *Psygmophyllum* is frequently recognized in the Upper Permian of Cathaysia (Asama 1967; Kon'no 1968). However, the Cathaysian representatives of this genus known in the literature noticeably differ from the Nan-shan ones. Leaves of this type are described in the present work as *Flabellofolium*. It appears to be a genus known in the boundary regions of both Angaraland and Cathaysia.

Conifers of the genera *Walchia* and *Ullmannia* were identified from the Permian of Cathaysia. However, illustrations available in the literature either do not show sufficient details for comparison or demonstrate plants differing from those in the Nan-shan section.

The rare cordaiteans present in the flora of zone C are similar in shape to the leaves of *Cordaites schenkii* Halle from the Upper Carboniferous-Permian deposits of the Shansi province. At the same time the Nan-shan cordaiteans are in general similar to the "sulcial" Cordaites group characteristic of the Upper Permian deposits of Angaraland.

Regarding the most abundant plant fossils of the Upper Permian flora of zone C the association of *Pursongia* leaves with fructifications of *Peltaspermum* has not previously been identified from the Permian of Cathaysia.

Thus, unequivocal Cathaysian plants from zone C were observed mainly among ferns. No exclusively Cathaysian forms have been identified for other plant groups. It is noteworthy that Chinese palaeobotanists, though speaking of the mixed character of the Upper Permian flora of Nan-shan and adjacent regions, mentioned the equistetopsids and ferns only among Cathaysian elements. However, the flora of the zone C is mostly pteridospermous and has an admixture of Cathaysian elements only.

As mentioned earlier, Halle (1935, 1937) compared the flora of the zone C to that of "suite II" (after Neuburg) of the Kuznetsk basin. Neuburg (1956) established that "suite II" corresponds to the Upper Permian (Kolchuginskaya series). The flora of the zone C contains no plants that could be compared to those of the Lower Balakhonskaya subseries of Kuznetsk basin dated at present as Middle-Late Carboniferous. Nevertheless, the repeatedly cited list of Halle (1935, 1937) does contain lower Balakhonskaya plants, viz. "*Callipteris murenensis*" (= *Paragondwanidium sibiricum*) and *Noeggerathiopsis scalprata*. Under the former name Halle appears to have denoted leaves presently identified as *Comia*? sp., under the latter – *Cordaites*, which, if they are similar to the Angaran forms, belong to Upper Permian species. In Halle's list there is also a species characteristic of the Lower Permian Upper Balakhonskaya subseries, *Zamiopteris glossopteroides*, i.e. evidently *Pursongia elegans* sp. nov. widely distributed in the zone C.

The flora of the zone C has much more in common with the flora of the Upper Permian Kolchuginskaya series of the Kuznetsk basin. Both floras have abundant callipterids, one of the most characteristic elements of the Upper Permian floras of the Angaraland (except for the Tungusso-Verkhoyanie province). Distribution of *Psygmophyllum* leaves incorporating the representative Kolchuginskaya species *Iniopteris sibirica* is common to both floras as well. The fragmentary nature of the present material did not allow a reliable establishment of this species in the zone C. Seeds of the genus *Sylvella* are also a distinct Angaran Upper Permian element in zone C.

Despite the presence of some common elements, the flora of zone C differs substantially from the Kolchuginskaya flora in the following:

1) wide distribution of a *Pursongia-Peltaspermum* association in zone C (leaves of *Pursongia*, as well as fructifications of *Peltaspermum* are absent or rare in the Kolchuginskaya flora and only some specimens referred to *Zamiopteris tailuganensis* Radcz. may belong to *Pursongia*);

2) presence of conifers in zone C (conifers if any, were recognized in the Kolchuginskaya flora as single specimens);

3) cordaites rare in zone C (predominant in the Kolchuginskaya flora).

Thus the floristic assemblages of the Kolchuginskaya series cannot be directly identified with the flora of zone C.

As mentioned above, Meyen (1970) and the present author (Durante 1971) previously draw a parallel between the flora of zone C and the Upper Permian flora of a Far-Eastern province, particularly with the flora of the Tavan-Tologoi coal field of South-Eastern Mongolia. The flora of the Tavan-Tologoi differs from that of the Kolchuginskaya of Kuznetsk Basin in a certain endemism and presence of few Cathaysian elements (Durante 1971, 1976). It has, however, a typically Kolchuginskaya character and differs from that of zone C in the same way.

The flora of zone C is much more similar to the Far-Eastern Upper Permian floras, namely those of the Vladivostokskaya, Barabashskaya and Sitsinskaya suites of the southern Primorie that were studied by Burago (Burago et al. 1974, Burago 1976, 1977, 1982) and Zimina (1977). In addition to the wide distribution of callipterids, the following characteristics unite these Far-Eastern floras to that of zone C:

1) abundance of plants with fernlike foliage (mostly pteridosperms) over cordaites;

2) larger number of common, frequently at a specific level, plants than in the floras of the central part of Angaraland.

These are ferns with lobatopteroid venation of pinnules, representatives of the genera *Flabellofolium*, *Psygmophyllum*, *Phylladoderma*, and perhaps, some of the callipterids. In the Far-Eastern Late Permian floras, conifers are more abundant compared to the rest of the Kuznetsk basin, although less important than in zone C.

Despite these common features, differences of the flora of zone C from the Far-Eastern Upper Permian floras are still substantial. The latter floras lack one of the dominant elements of the flora of zone C, namely foliage of the *Pursongia* type. *Peltaspermum*-like fructifications are known in the Primorie area but associated with callipterids. It is noteworthy that the Far-Eastern floras differ from that of zone C not only in geographical position but also in age being usually compared to the Upper Shihhotse suite. The analogues of zone C in South Primorie are possibly represented by marine deposits of the Lyudyanzinskaya suite (the *Colaniella parva* zone).

While comparing the zone C flora with the Upper Permian floras of North Eurasia, the so-called Korvunchana flora of the Tunguska basin must also be considered. The flora was compared by Vakhrameev et al. (1978) to the flora of zone C and the age of the flora ranges within the latest Permian-Triassic (Sadovnikov 1981a, 1981b). The Korvunchana flora contains both the *Tatarina-Peltaspermum* association (Meyen & Migdisova 1969; Gomankov & Meyen 1979; and conifers, including the genus *Quadrocladus* (Meyen 1981a) which is probably also present in zone C. Ferns of the genus *Katasiopteris* are widely distributed in the Korvunchana flora, especially in its lower assemblage. The Korvunchana flora is not identical to the flora of zone C due to a predominance of true ferns and its different stratigraphic position. Both in the Tunguska basin and in the other regions of North Asia the Korvunchana flora is distributed in the strata overlying horizons with cordaites and rare callipterids. But it contains neither of them. For this reason the flora of the zone C is regarded as contemporary with floras older than the Korvunchana flora. Yet, the different composition prevents a direct comparison of these floras.

In summary, the flora of zone C is analogous to none of these floras of the central and southern parts of the Angaraland. The flora of zone C is more comparable to the Upper Permian floras of the Russian platform situated on the western periphery of the Angara kingdom and distinguished as the East-European or Subangaran area (Meyen 1970, 1980; Vachrameev et al. 1978).

In the Upper Tatarian flora of the Russian platform, the dominating element is the Peltaspermaceae genus

Tatarina. Therefore, Gomankov and Meyen (1986) have suggested the term *Tatarina* flora. The genus was established by Meyen (1969) for leaves with gross morphology indistinguishable from *Pursongia*, but with epidermal characteristics present. The affinity between *Tatarina* and leaves of *Pursongia* from zone C is indicated by their morphological identity and association with comparable *Peltaspermum*-like fructifications. In the *Tatarina* flora the original association of leaves and fructifications was established on common epidermal features. *Peltaspermum nanshanense* associated with *Pursongia* in the zone C is extremely similar to *Peltaspermum buevichae* Gomankov and Meyen (1979, 1986) of the *Tatarina* flora. These species constitute a unique group within this complex and Gomankov and Meyen (1986) therefore placed them in a separate genus *Peltaspermopsis*. *P. nanshanense* (Gomankov personal communication) is also recorded in some localities of the Russian platform. In this area other species of *Peltaspermum* are associated with foliage of *Lepidopteris*.

The association of *Tatarina* (al. *Pursongia*) leaves with fructifications of *Peltaspermum* (al. *Peltaspermopsis*) gives an idea of a quite specific group of peltaspermalean pteridosperms dominating both in the *Tatarina* flora of the Russian platform and the flora of zone C. Thus, the Upper Tatarian flora of the Russian platform is the only one among all Angaran floras that resembles that of zone C by prevalence of the same unique group of plants.

Another common feature of the zone C flora and the *Tatarina* flora is the presence of conifers. This plant group is absent or very rare in other Angaran floras. The conifers in both floras exhibit some common characters, especially in the structure of vegetative shoots and to some extent female fructifications. This allows us to assume that they belong to the same group of conifers. Those of the *Tatarina* flora (Gomankov & Meyen 1986) are represented by vegetative shoots of *Quadrocladus* associated with the female fructifications *Sashinia* and the male fructifications *Dvinostrobus*. *Dvinostrobus* can be compared with voltzitalean male fructifications, and *Sashinia* is very primitive in structure represented by a bundle of seed-bearing stalks with subapical abaxial ovules. The female conifer fructifications from zone C described as cf. *Sashinia* differ from typical *Sashinia* by having seed-bearing stalks scattered along the shoot and not forming a compact bundle. *Quadrocladus* from the *Tatarina*-flora differs from Zechstein representatives of the genus by distinct heterophylly. The Nan-shan vegetative coniferalean shoots show even more distinct heterophylly. In zone C no dispersed fertile shoots similar to *Dvinostrobus* have been recorded, only rare and poorly preserved microstrobili. Detached compact microstrobili were also found by Meyen and Gomankov in the *Tatarina* flora, their detailed structure is, however, not clearly understood.

Despite the uncertain systematic position of the conifers collected in zone C they differ considerably (possibly at generic level) from the Upper Tatarian *Quadrocladus-Sashinia-Dvinostrobus* complex, but at the same time they are also related to this complex by the peculiar female fructifications and the structure of the vegetative shoot.

Amongst other plants from zone C particular emphasis should be placed on the leaves of *Phylladoderma* (?) sp. Their small dimensions and predominantly linear shape indicate that they are possibly related to *Phylladoderma* subgen. *Aequistomia*, another constituent of the *Tatarina* flora. However, both the absence of cuticules in the Nan-shan leaves and insufficient information on the morphology of *Aequistomia* (absence of data on leaf base structure) prevent reliable comparison between the plants.

To summarize it can be emphasized that analogues of all the main components of the *Tatarina* flora to a certain extent may be recognized in the zone C assemblage, viz. peculiar peltaspermaceous pteridosperms with *Pursongia* leaves and female *Peltaspermum*-like fructifications, conifers, possibly allied to the *Quadrocladus-Sashinia* plant as well as *Phylladoderma*-like leaves, distinctly differing from *Phylladoderma* subgen. *Phylladoderma* from the Kazanian of the Russian platform and the Upper Permian of the Pechora basin.

The flora from zone C differs, however, from the *Tatarina* flora in several respects. The most striking difference is the presence of callipterids and *Psygmophyllum* in zone C, forms that are completely absent from the *Tatarina* flora of the Russian platform, but are known in the older Kazanian flora. In the Euramerian area callipterids appear in the Stephanian and do not pass into the Upper Permian. In the Fore-Urals they are known in the Upper Artinskian-Kungurian floras. In other parts of Angaraland they appear near the Early/Late Permian boundary and survive throughout (or almost throughout) the Late Permian. It was previously believed that the leaves of the Euramerian and Angaran callipterids belonged to different groups of pteridosperms (Meyen & Migdisova 1969), but information accumulated over the last few years indicate that they are all closely related to the peltaspermaceous pteridosperms. The heterochroneity of their appearance may be a result of a gradual dispersal from the Euramerian area into the peripheral parts of Angaraland. Thus, the callipterids of the zone C flora may be regarded as Angaran elements. Their presence may indicate a slightly higher latitudinal position of the zone C flora compared to the *Tatarina* flora of the Russian platform. The presence of callipterids in zone C could also be explained by a more eastern longitudinal position of the flora and less arid conditions.

In addition to the plants mentioned above seeds of *Sylvella* have also been discovered in zone C (Pl. IX, Fig. 7). They occur in the Permian throughout Angaraland but are absent in the *Tatarina* flora that also lacks leaves of *Cordaites* that are commonly associated with *Sylvella* (Meyen 1982). *Pecopteris* ex gr. *anthriscifolia* (Goepp.) Zal. (Pl. VI, Fig. 1) is possibly also an Angaran form, though similar ferns (Halle 1927) were found in the Upper Permian of Cathaysia.

As for the genera *Rhipidopsis*, *Flabellofolium* and *Psygmophyllopsis*, they are found in the Permian both of Angaraland and Cathaysia, the foliage of the *Rhipidopsis* type being the geographically most widespread. The two other genera more likely occur along the boundaries of Angaraland and Cathaysia.

The phytogeographic relation of the plant described here as cf. *Anomozamites* sp. is uncertain. It may be regarded as a zone C endemic or possibly an Angaran rarity. Gorelova (1984) described a similar plant from the Kuznetzk basin as *Odontopteris*.

Plagiozamites (?) sp. belongs either to problematic Cathaysian elements or is endemic.

Katasiopteris-like ferns are evidently Angaran plants. Ferns of this type are certainly characteristic of the Triassic of Angaraland and Cathaysia, but during the Late Permian they occurred along the periphery of the Siberian province. The same patterns are also evident from the other fern-like plants of zone C. The poorly preserved remains of equisetopsids provide neither stratigraphic nor phytogeographic information.

Summarizing the phytogeographical observations the flora from zone C may be considered as a deviating East-Asiatic analogue of the *Tatarina* flora of the Russian platform. The latter belongs to the group of Angaran floras that constitute the youngest Permian flora of the East-European area on the western margin of Angaraland. Thus, the view that the flora of zone C is of mixed Cathaysian-Angaran type as advocated by Li and Yao (1979, 1980) and by Shi and Liu (1981) is not absolutely correct. The available Cathaysian elements in the collection (including problematic ones) are very rare and the flora may be regarded as analogue to the *Tatarina* flora, but with a small admixture of Cathaysian plants. The zone C flora should therefore probably be referred to the Upper Tatarian substage that contains the Tatarian flora of the Russian platform. One should bear in mind, however, that the upper part of the Lower Tatarian substage has no unique palaeobotanical characteristics. Hence, the exact position of the *Tatarina* flora within the Tatarian stage cannot be established and the zone C flora can only be referred to the Tatarian stage in general.

The presence of an Upper Permian flora in North China similar to the Tatarian flora of the Russian platform and different from contemporary floras of Siberia and Mongolia permits reconstruction (for the Tatarian age) of the extensive belt, embracing the internal regions of Angaraland by its huge arch (Text-Fig. 16). The association of both floras in a single belt is indicated by their similarity and their identical peripheral position in the North Hemisphere phytochoria. Both floras considered border on one side the floras of the equatorial belt (Atlantic and Cathaysian) and, on the other Angaran floras (those of the Pechora and Far-Eastern provinces, in particular) with many common elements (Meyen 1970; Burago 1976; Zimina 1977).

It was previously believed that the Permian flora of the West-Angaran type was confined to the Cis-Ural and the Russian platform, and to Kazakhstan, during some epochs. Accordingly, the Kama-Urals (Radczenko and Rosenkrantz 1961) or Ural-Kazakhstan palaeofloristic provinces (Kumpan 1963) were recognized. Meyen (1970; Vakhrameev et al. 1978) believed that the Ural-Kazakhstan province existed at the end of the Early Permian only and that in the Late Permian the West-Angaran flora type was distributed to the west of Ural, in what he called the East-European area.

The discovery of West-Angaran characteristics of the Upper Permian Nan-shan flora has revealed that the area of distribution of this flora type does not diminish during the Late Permian as previously thought but expands to form an extended belt. This tendency during the Late Permian has been confirmed by finds of typical Angaran plants in Afghanistan (Meyen 1981b) and West Tien-Shan (Meyen 1982).

The exact timing of this floristic expansion is uncertain. It is only possible to say that it took place during the Late Permian. The age of the upper part of zone B, underlaying the red plant–bearing beds of zone C (see Text-Fig. 1) is evidently late Early Permian or early Late Permian (Bexell 1935). The plant-bearing zone C was dated as Tatarian and thus the replacement of the Cathaysian flora by the Angaran flora in Nan-shan has possibly taken place during the Ufimian or Kazanian.

The possibility of a penetration of Angaran plants to South Asia during the first part of the Late Permian is supported indirectly by the presence of Angaran Upper Permian plants in Afghanistan. There, near Kabul, Meyen (1981a) identified and figured a plant assemblage consisting of several Cathaysian species and *Phylladoderma* leaves comparable to those from the Ufimian and Kazanian of the Russian platform and the Pechora basin. Meyen (1980) indicated that the genus *Yuania* described by Sze (1953) from north western Shansi may be a synonym of *Phylladoderma.* Sze believed that it belonged to the Shihchienfeng series, but Gu and Zhi (1974) showed it to be older. *Yuania* may mark the beginning of the penetration of Angaran plants into the North of Cathaysia.

The boundaries of the Late Permian flora of East-European type in the territory of China remain uncertain. The northern boundary of this flora was established somewhere between Nan-shan and the frontier between China and Mongolia. Directly to the north of this boundary, in the outskirts of Somon Noyan, Durante (1976) described the typical locality of the youngest Angaran plant assemblage with "sulcial" cordaites, approximately synchronous to the flora of zone C.

In the more eastern regions of North China (Shansi province) the lower part of the red bed of the Shihchienfeng Series is regarded as an analogue to the Sunan Formation. The name "Shihchienfeng Series" was suggested by Norin (1922) for a sequence of red-brown terrigenous rocks (with thickness exceeding 700 m) overlaying the coal-bearing Upper Shihhotse Series (Formation). In the 1960's the Shihchienfeng Series has been divided into three formations: Sunchiakou, Liuchiakou and Hoshankou of which only the first is of Permian age. Li Xing-xue and Yao Zhao-qi (1982) suggested that the name "Sunchiakou" should be changed to "Shihchienfeng", as this formation corresponds to the stratotype section of the "Shihchienfeng" Series. Therefore the name "Shihchienfeng Series (Formation)" has presently two different contents: sensu lato – for all three formations mentioned above and sensu stricto – for the lowermost formation.

Small assemblages of plants, consisting predominantly of Cathaysian species with a small Angaran admixture were described from the Shihchiengfeng Series and its analogues (Stockmans & Mathieu 1939; Lee 1964). Li Xing-xue and Yao Zhao-qi (1979) pointed out that the Shihchienfeng Series (s.s.) stratotype contains neither mega- nor microfossils, but that in NW Shansi this series yielded a pareiasaurian fauna of vertebrates, i.e. the fauna associated with the *Tatarina* flora of the Russian platform. Sheng and Li (1974) identified several Cathaysian (*Lobatannularia* cf. *heianesis* Kod., *Fascipteris* cf. *hallei* (Kaw.) and Angaran species (*Callipteris* cf. *zeilleri* Zal.) in the analogues of the Shihchienfeng Series. All these facts do not seem to contradict the idea that the Shihchienfeng Series was formed contemporary with the *Tatarina* flora.

Another view on the phytogeographic position of the Shihchienfeng flora was expressed by Wang Ziqiang (1985). On the base of a limited plant assemblage he identified *Ullmannia bronnii* Goepp., *Pseudovoltzia liebeane* (Gein.) Florin, cf. *Callipteris martinsii* (Kurtze) Zeil., *Platyspiroxylon* cf. *heteroparenchimatosum* Greguss and attributed the flora to the Zechstein-type. As a result of these identifications North China was included in the "Eurasian arid province" (Wang Ziqiang 1985).

Thus, currently two different views on the phytogeographical position of North China during the Late Permian have been expressed. One is based on the present analysis of the Nan-shan flora and suggests a connection between part of North China (at least the Nan-shan region) and the Cis-Urals as well as some regions of the Russian platform. During most of the Permian these regions were situated at the periphery of Angaraland. The other suggestion by Wang Ziqiang (1985) that North China belonged to the Euramerian floral province, however, is not well-documented and based on rather limited fossil material.

The problem of the phytogeographical position of North China on the whole is not possible to solve without considering the data on the Subangaran outline of the Nan-shan zone C flora coeval with the Shihchienfeng flora. As it has been demonstrated above the zone C flora can be attributed neither to the Euramerian nor to the central Angaran types. Most likely it belongs to the belt of transitional floras (Subangaran area), that during most of the Permian was more closely connected with Angaraland than with the Euramerian area (Meyen 1980). Certainly the possibility of Zechstein-type plant associations in some parts of this belt cannot be ruled out.

The southern boundary of Angaraland is identified by Chinese palaeobotanists more or less traditionally (Li & Yao 1979) and is obviously considered constant all through the Late Palaeozoic. This is, however, contradicted by the ratio between Cathaysian and Angaran plants in the floras along the northern slopes of Nan-shan, as well as the presence of Angaran elements both among mega- and microfossils far south of this boundary. Thus, at the end of the Permian, the boundary between Angaraland and Cathaysia was apparently located further south than in the previous epochs; however, its position cannot be determined using the data available at present.

The formation of the Subangaran area was possibly accompanied by the final closing of the Inner-Mongolian geosyncline, considered by some geologists (Mossakovsky 1975) as a northern branch of the Palaeotethys ocean, separating North Cathaysia from more northern regions. The high independence in development of the Angaran and Cathaysian floras is possibly a result of the existence of a similar large barrier at the boundary between these phytochorias during the major part of the Upper Palaeozoic.

In the second half of the Late Permian, no traces of the barrier, separating the Angaraland floras from those of Cathaysia are perceptible, indicated by the extension of the Russian platform flora into North China and the establishment of the phytogeographical zonation of the Angaran type over the whole North Eurasian territory (Durante, Dmitriev & Pavlova 1985).

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PLATES

Explanation of plates

Plate I

Annularia sp.
Fig. 1 – N Bex 165 (× 2)
Katasiopteris cf. *lata* Radczenko
Figs 2, 3 – N Bex 300 (× 3). Rachis of penultimate order and parts of two pinnae of ultimate order.
Cladophlebis sp. 1
Fig. 4 – N Bex 52 (× 3)
Fig. 5 – N Bex 59-2 (× 3)
Fig. 6 – N Bex 193a (× 2)
Pecopteris cf. *anderssonii* Halle
Fig. 7 – N Bex 194 (× 3)
Cladophlebis sp. 2
Fig. 8 – N Bex 317 (× 2)

Plate II

Annularia sp.
Fig. 1 – N Bex 127-1 (× 2)
Fig. 2 – N H sh p sh H:III (× 2)
Callipteris bexellii sp. nov.
Fig. 3 – N H sh p H:III (× 1)
Fig. 4 – N Bex 295-3 (× 3); the thin border at the pinnule margin is visible.

Plate III

Callipteris bexellii sp. nov.
Fig. 1 – N H sh p sh H:VII:8 (× 1)
Fig. 2 – N Bex 296-2 (× 2)
Callipteris ex gr. *bexellii* sp. nov.
Fig. 3 – N H sh p sh H:VII:14 (× 1)
Geinitzia sp.
Fig. 4 – N Bex 46 (× 1)
Part of a leaf (pinnae?) with a reticulate venation.
Fig. 5 – N H sh p sh H (× 1)

Plate IV

Callipteris ex gr. *bexellii* sp. nov.
Fig. 1 – N Bex 313 (× 1)
Fig. 2 – N H sh p sh H:XIV:15 (× 1)
Compsopteris (?) cf. *contracta* Gu and Zhi
Fig. 3 – N H sh p sh H:III (× 1)
Rhipidopsis cf. *palmata* Zalessky
Fig. 4 – N Bex 412 (× 1)

Plate V

Callipteris sp. vel *Compsopteris* sp.
Fig. 1 – N H sh p sh H (× 2)
Geinitzia sp.
Fig. 2 – N Bex 45-1 (× 3)
Compsopteris (?) sp. 2
Fig. 3 – N H sh p sh H:III (× 1); counterpart of Bex 219
Fig. 4 – N Bex 171 (× 1)
Compsopteris (?) *contracta* Gu and Zhi
Fig. 5 – N Bex 218 (× 1)
Compsopteris cf. *adzvensis* Zalessky
Fig. 6 – N Bex 163 (× 1)

Plate VI

Pecopteris ex gr. *anthriscifolia* (Goepp.) Zal.
Fig. 1 – N H sh p sh H:VI:10 (× 3)
Pursongia elegans sp. nov.
Fig. 2 – N H sh p sh H:III:110 (× 1)
Fig. 3 – N H sh p sh H (× 1)
Fig. 4 – N H sh p sh H (× 1)
Pecopteris sp.
Fig. 5 – N Bex 192 (× 3)
Katasiopteris cf. *lata* Moguch.
Fig. 6 – N H sh p sh H (× 3)
Peltaspermum nanshanense sp. nov.
Fig. 7 – N Bex 141-2 (× 5) (photographed in alcohol)
Cordaites sp.
Fig. 8 – N Bex 439 (× 2)

Plate VII

Pursongia amalitzkii Zalessky
Fig. 1 – N Bex 116-1 (× 1)
cf. *Psygmophyllum demetrianum* Zalessky
Fig. 2 – N H sh p sh H:XIV:17 (× 1)
Pursongia elegans sp. nov.
Fig. 3 – N Bex 83 (× 1)
Fig. 4 – N H sh p sh H:III (× 1)
Carpolithes sp.
Fig. 5 – N Bex 48-2 (× 5)
Rhipidopsis aff. *palmata* Zalessky
Fig. 6 – N H sh p sh H:IV:8 (× 1)
Peltaspermum nanshanense sp. nov.
Fig. 7 – N Bex 134 (× 5)
Fig. 8 – N Bex 153 (× 3)
Pursongia serrata (Srebrodolskaya) Meyen
Fig. 9 – N H sh p sh H:III:112 (× 1)

Plate VIII

Pursongia elegans sp. nov.
Fig. 1 – N H sh p sh H:III:13, shoot
Pursongia cf. *angustifolia* Zalessky
Fig. 2 – N H sh p sh H:III (× 1)
Pursongia elegans sp. nov.
Fig. 3 – N Bex 124-1 (× 1) (photographed in alcohol), holotype
Fig. 4 – N The same as in Fig. 3 (photographed without alcohol)
Peltaspermum nanshanense sp. nov.
Fig. 5 – N Bex 75-1 (× 3); spherical aggregation ("head") of peltoids, holotype
Fig. 6 – N Bex 139-1 (× 5), single peltoid (upper side)
Fig. 7 – N Bex 214 (× 4); head of peltoids
Peltaspermum sp.
Fig. 8 – N Bex 154 (× 2); shoot with spherical aggregations ("heads") of peltoids
Fig. 9 – N Left lower "head" of the same shoot (× 5)

Plate IX

Plagiozamites (?) sp.
Fig. 1 – N Bex 164 (× 1)
Pursongia sp.
Fig. 2 – N Bex 93 (× 1)
Pursongia serrata (Srebrodolskaya) Meyen
Fig. 3 – N Bex 85 (× 3)
Fig. 4 – N Bex 77 (× 1)
Rhipidopsis sp. 1
Fig. 5 – N H sh p sh H:IV:15 (× 1.25)
Rhipidopsis aff. *palmata* Zalessky
Fig. 6 – N H sh p sh H (× 2)
Sylvella sp.
Fig. 7 – N Bex 75-2 (× 2)

Plate X

cf. *Anomozamites* sp.
Fig. 1 – N H sh p sh H:XII:2 (× 3)
Fig. 2 – N Bex 441 (× 1) (photographed in alcohol)
Fig. 3 – N H sh p sh H (× 3)
Fig. 4 – N H sh p sh (× 3)
Fig. 5 – N Bex 390-1 (× 3)
Fig. 6 – N Bex 390-2 (× 3)
Pursongia elegans sp. nov.
Fig. 7 – N Bex 91-2 (× 1)
Fig. 8 – N Bex 67-1 (× 1)
Peltaspermum nanshanense sp. nov.
Fig. 9 – N H sh p sh H:III:117 (× 3)
Fig. 10 – N Bex 141-1 (× 3)
Callipteris bexellii sp. nov.
Fig. 11 – Bex 302 (× 1) – holotype

Plate XI

Psygmophyllum sp.
Fig. 1 – N H sh p sh H:IV:3 (× 1)
Flabellofolium sp. 2
Fig. 2 – N Bex 295 (× 1)
Flabellofolium sp. 1
Fig. 3 – N Bex 244-2 (× 2)
Callipteris bexellii sp. nov.
Fig. 4 – N Bex 307 (× 1)
Psygmophyllum sp.
Fig. 5 – N Bex 263 (× 1)

Plate XII

Compsopteris (?) sp. 3
Fig. 1 – N Bex 114 (× 1)
Phylladoderma (?) sp.
Fig. 2 – N H sh p sh H:III (× 2)
Fig. 3 – N Bex 166 (× 1)
Geinitzia sp.
Fig. 4 – N Bex 46 (same as in Plate III, Fig. 4) (× 2)
Phylladoderma (?) sp.
Fig. 5 – N Bex 167 (× 2)
Fig. 6 – N Bex 116-2 (× 1)
Male coniferous strobili
Fig. 7 – N Bex 29 (× 3)
Fig. 8 – N Bex 104 (× 3)
Fig. 9 – Same as Fig. 8 (× 5)
Psygmophyllopsis norinii gen. et sp. nov.
Fig. 10 – N Bex 310 (× 1)
Fig. 11 – N Bex 296-1, holotype
Comia (?) sp.
Fig. 12 – N Bex 432 (× 2)

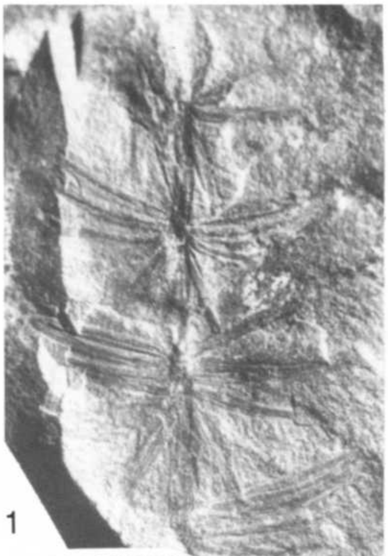
Plate XIII

Ginkgophyllum (?) sp. 1
Fig. 1 – N H sh p sh H III:55
Compsopteris (?) sp. 1
Fig. 2 – N Bex 220 (× 1)
Rhipidopsis cf. *palmata* Zalessky
Fig. 3 – N H sh p sh H XIV:102 (× 1)
Psygmophyllopsis norinii gen. et sp. nov.
Fig. 4 – N H sh p sh H IV (× 2) counterpart of N Bex 250
Fig. 5 – N Bex 314 (× 1)
Flabellofolium sp. 1
Fig. 6 – N Bex 244-1 (× 1)

Plate XIV

Geinitzia sp.
Fig. 1 – N H sh p sh H-III (× 3)
Fig. 2 – N Bex 32 (× 3)
Fig. 3 – N Bex 100 (× 2)
Walchia (?) sp.
Fig. 4 – N Bex 189 (× 3)
Coniferous shoots of uncertain affinity
Fig. 5 – N Bex 73 (× 2)
Fig. 6 – N Bex 99 (× 2)
Geinitzia sp.
Fig. 7 – N Bex 72 (× 1.76)
cf. *Sashinia* sp.
Fig. 8 – N Bex 48 (× 2)
Peltaspermum nanshanense sp. nov.
Fig. 9 – N Bex 139-1 (× 3)

Plate I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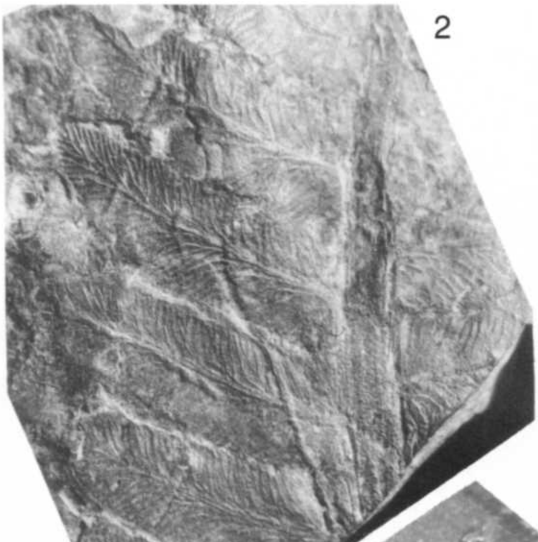
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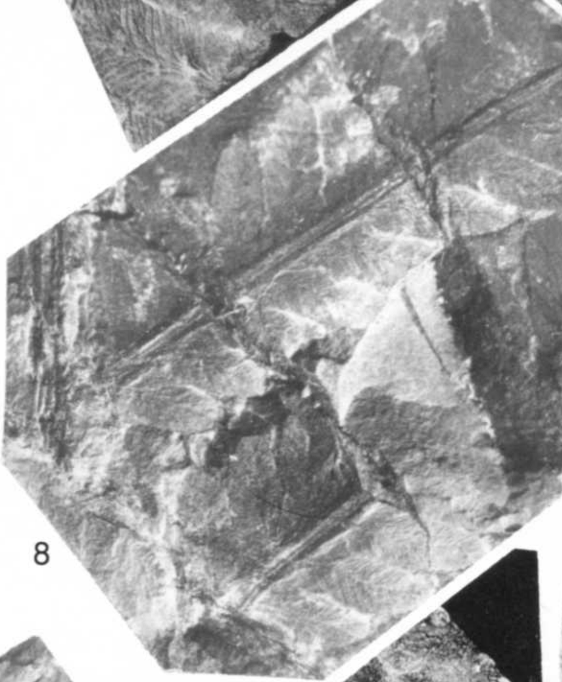
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Plate II

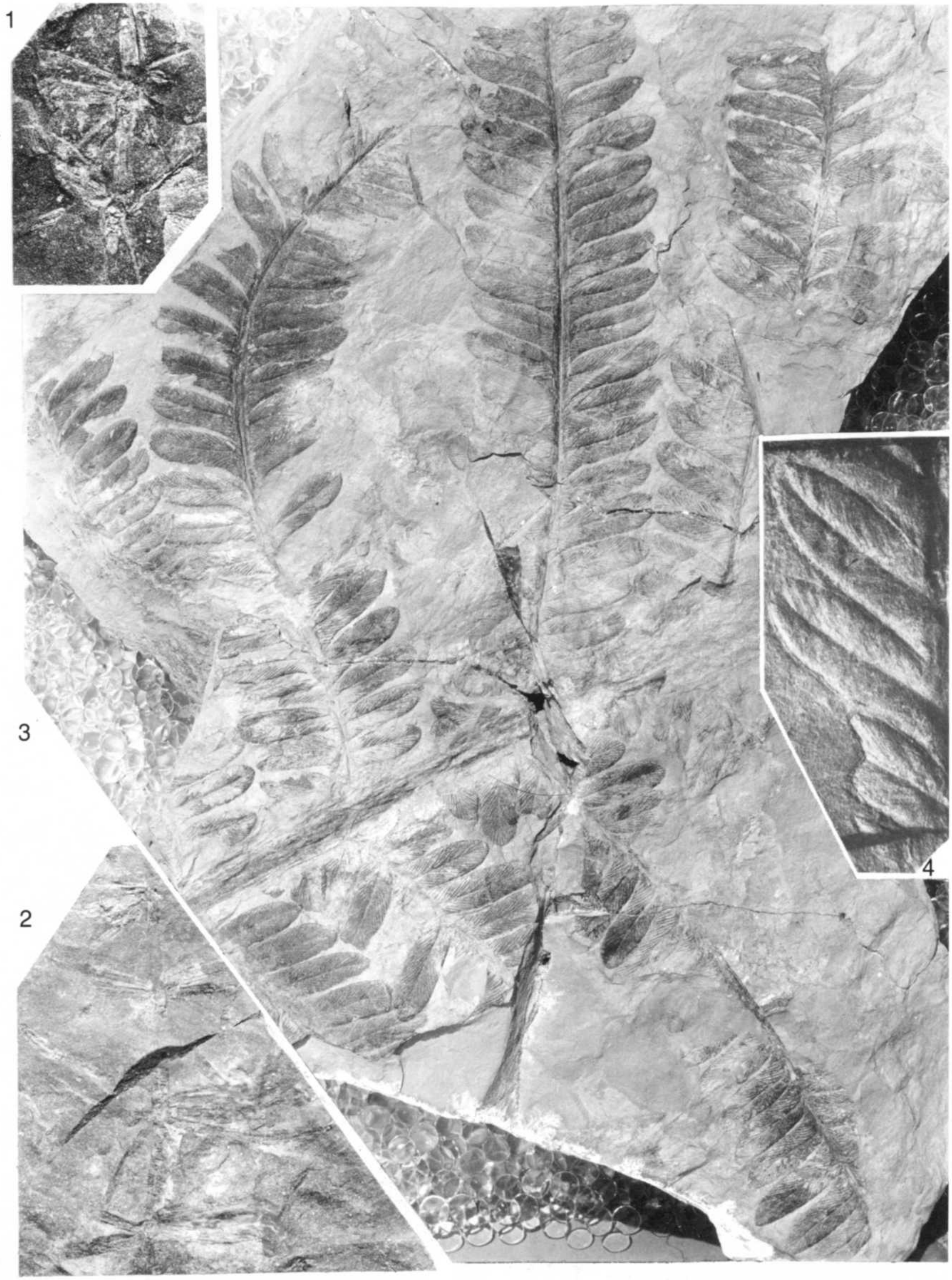

Plate III


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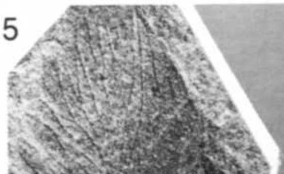
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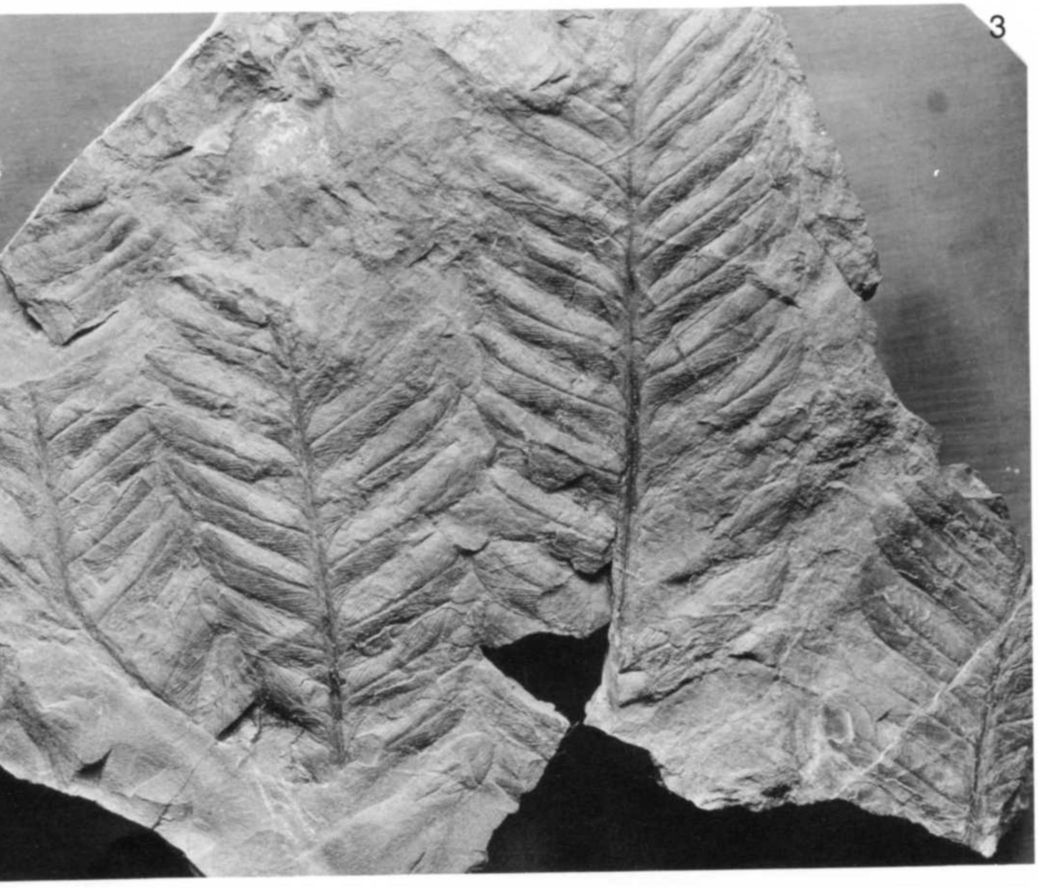
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Plate IV


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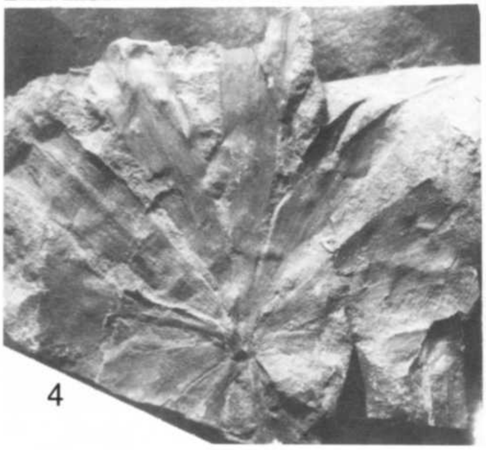
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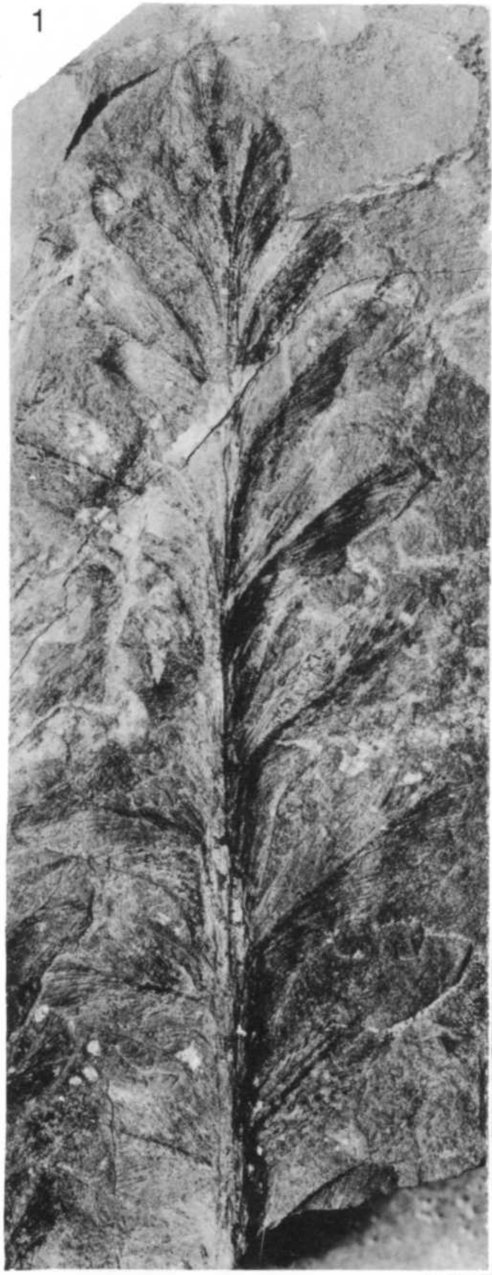
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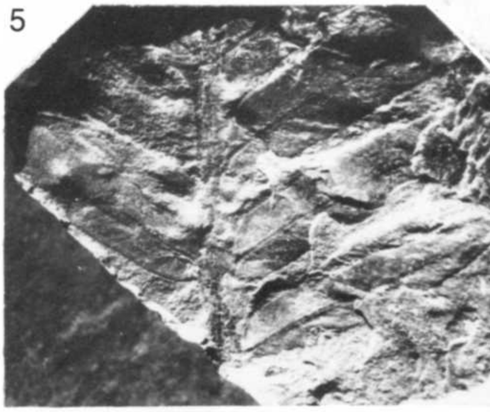
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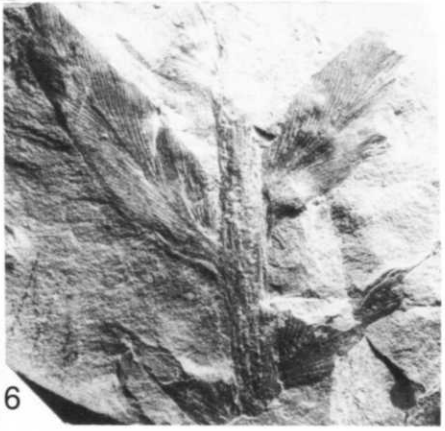
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Plate VI


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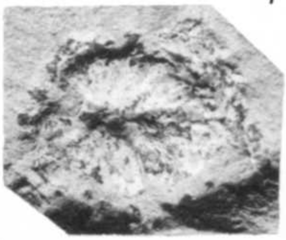
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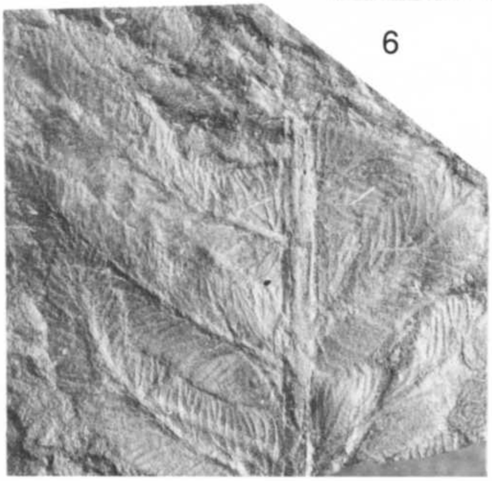
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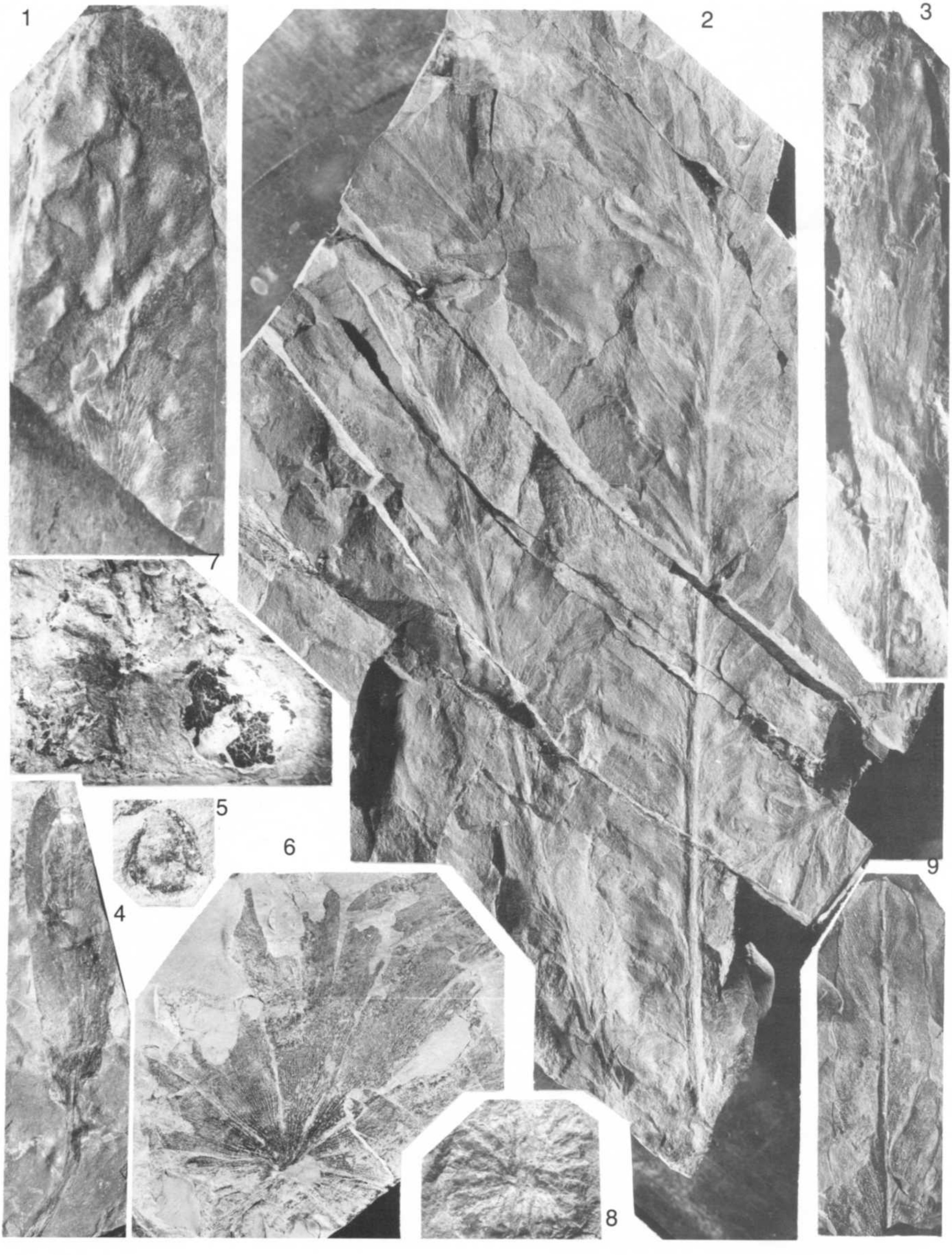
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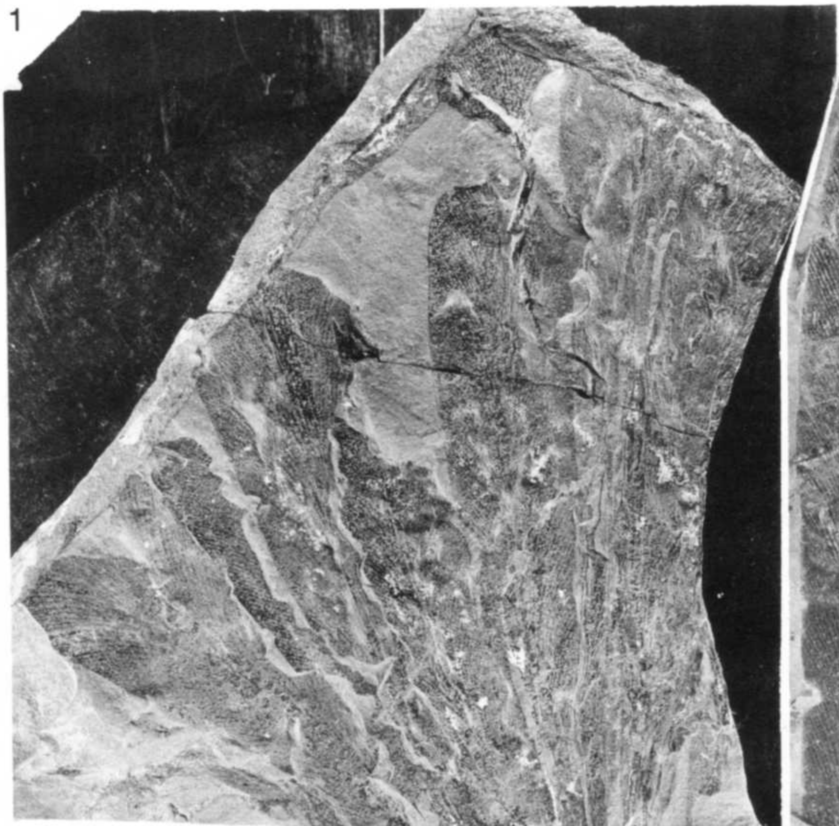
Plate VIII

1



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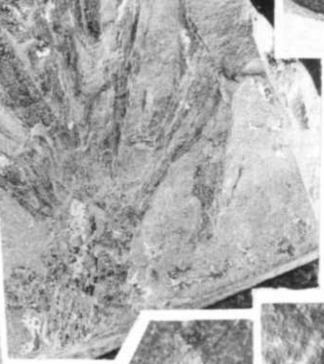

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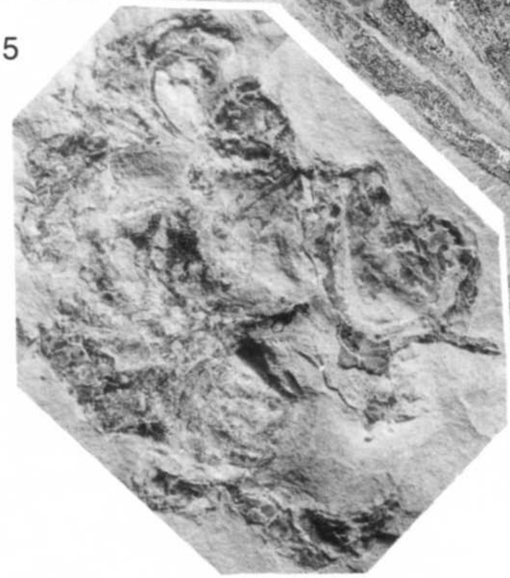

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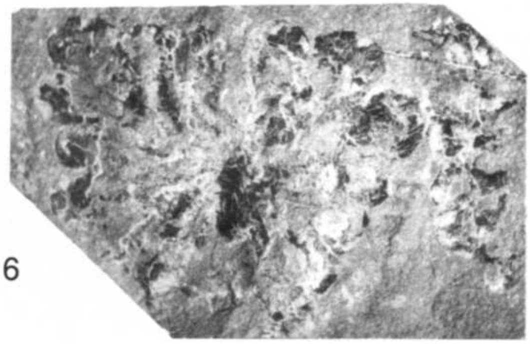

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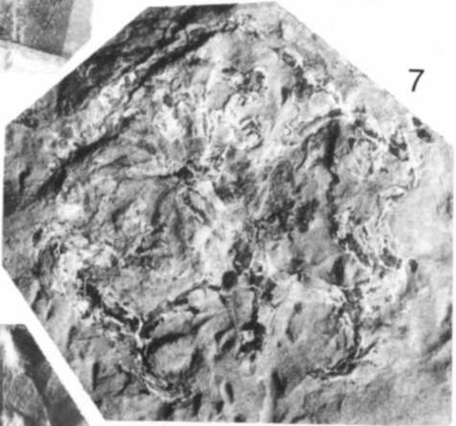

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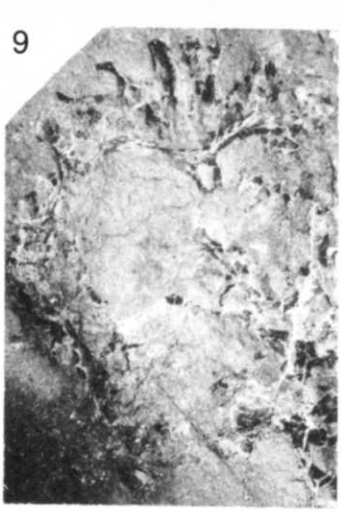

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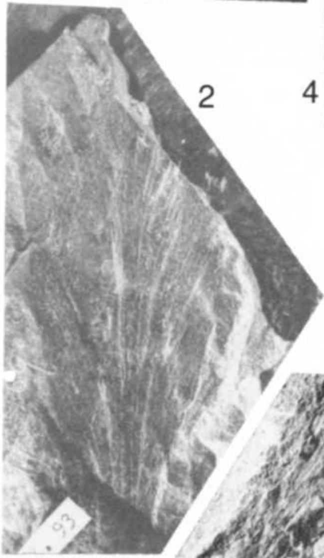

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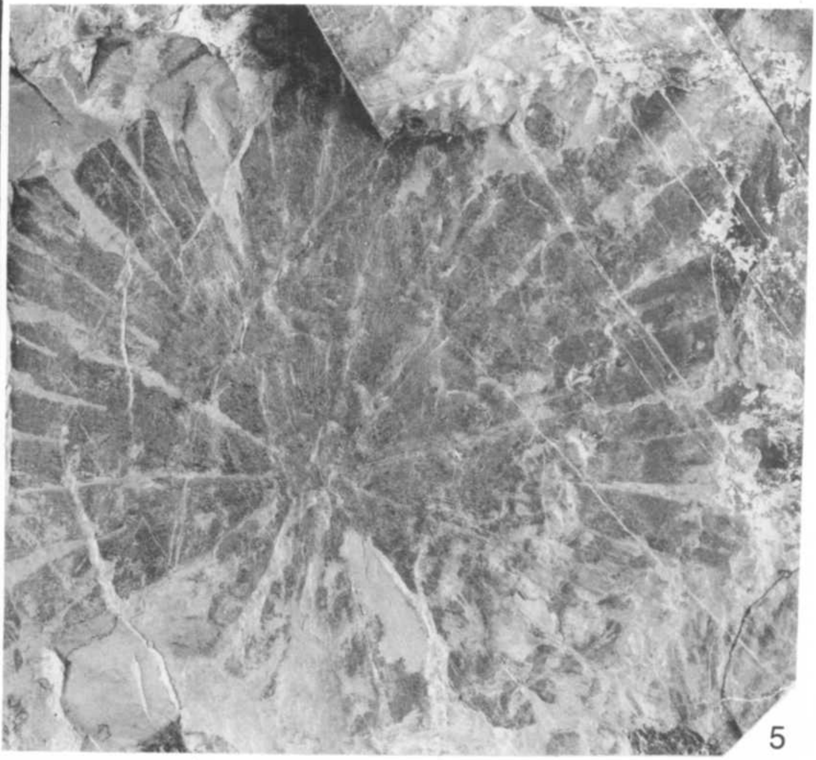

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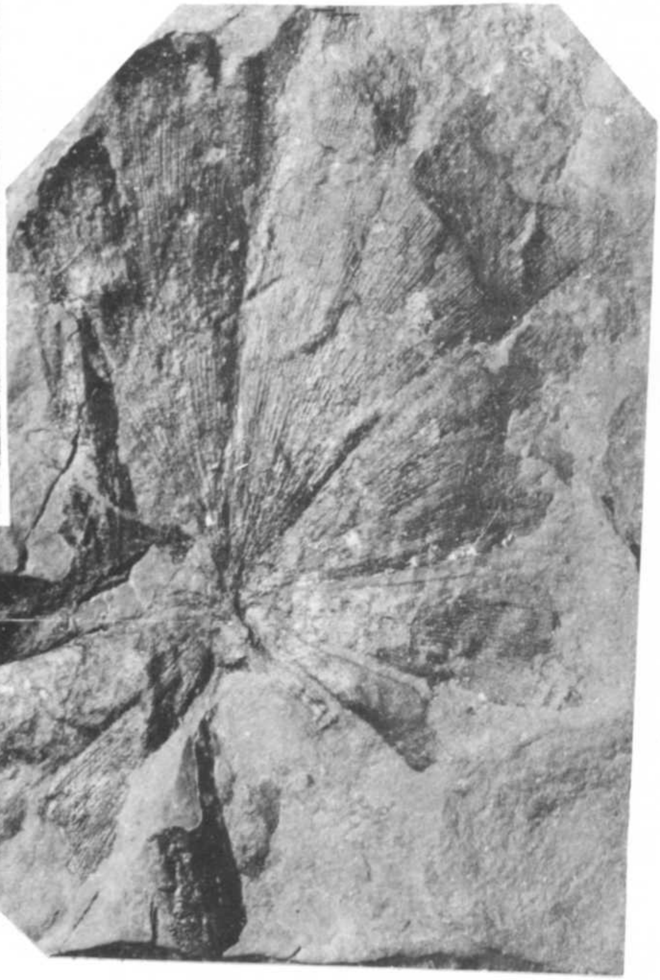

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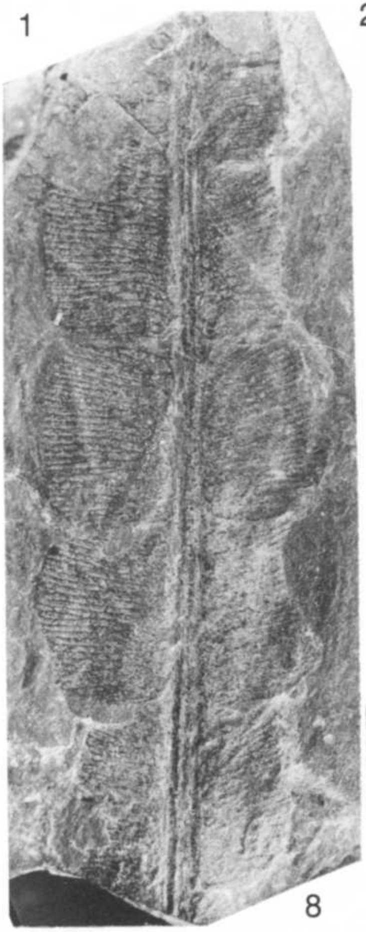

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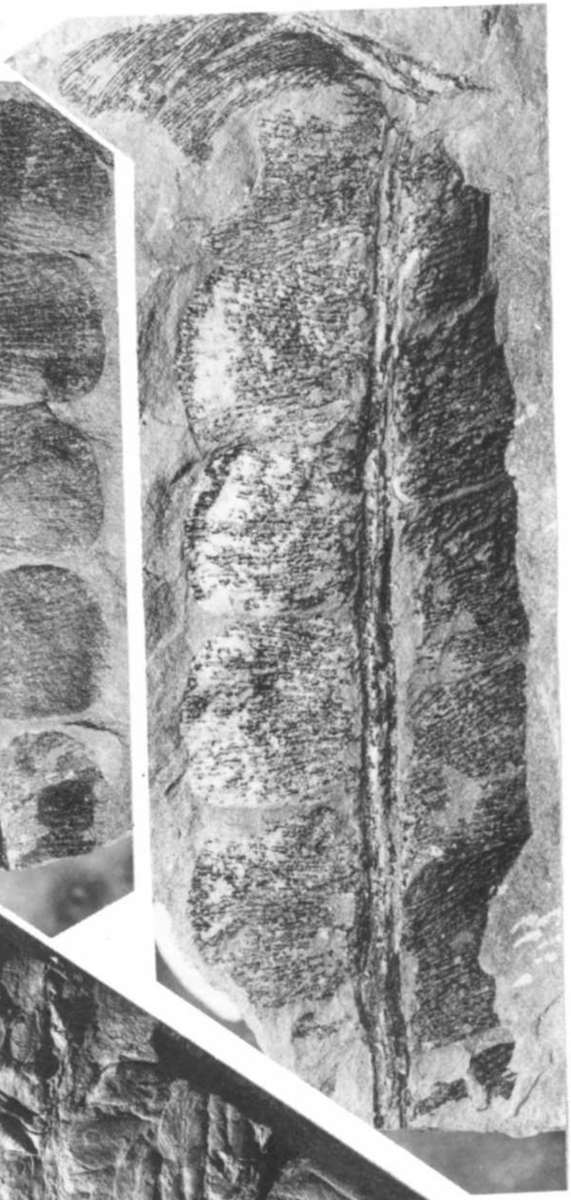

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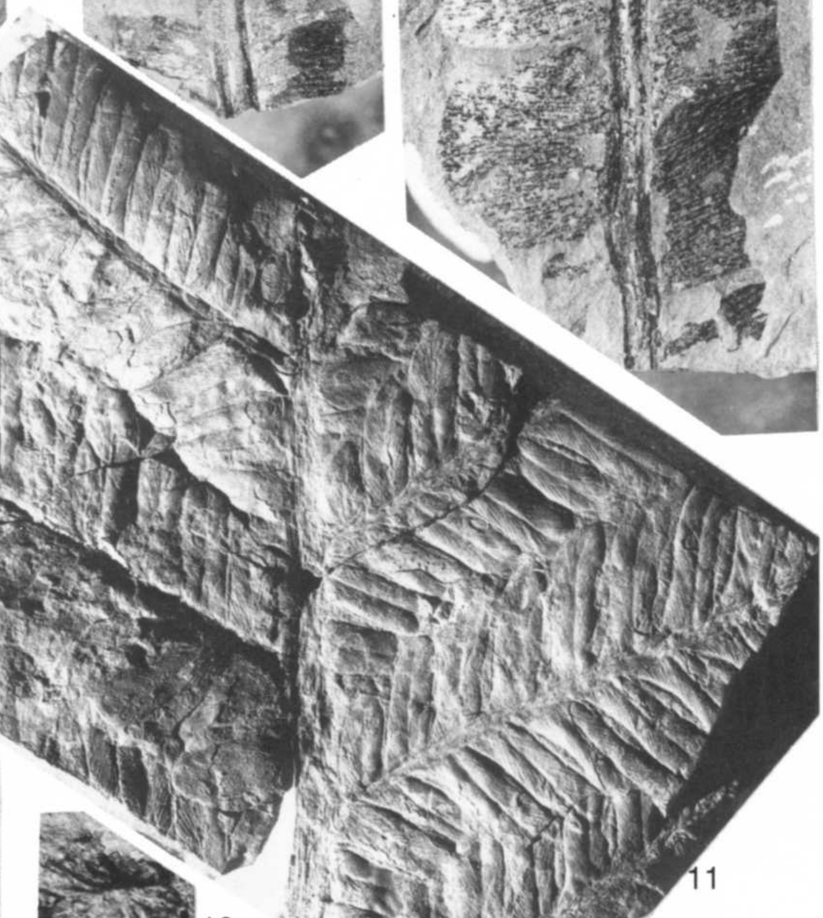

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Plate XI


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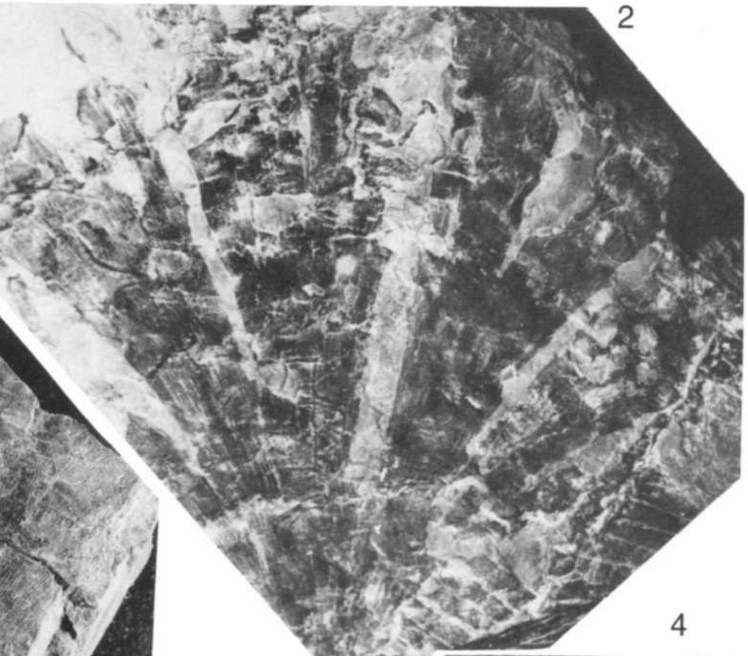
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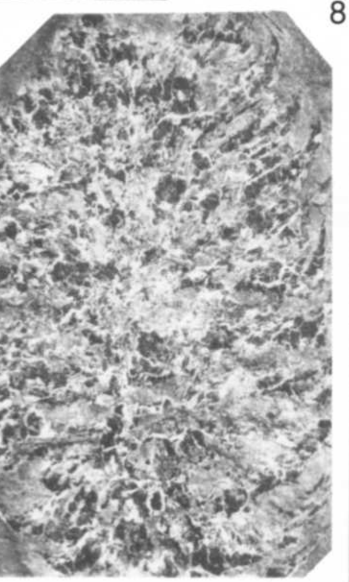
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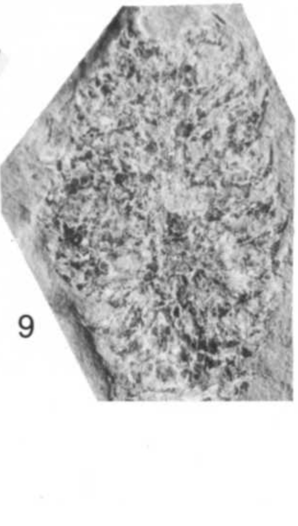
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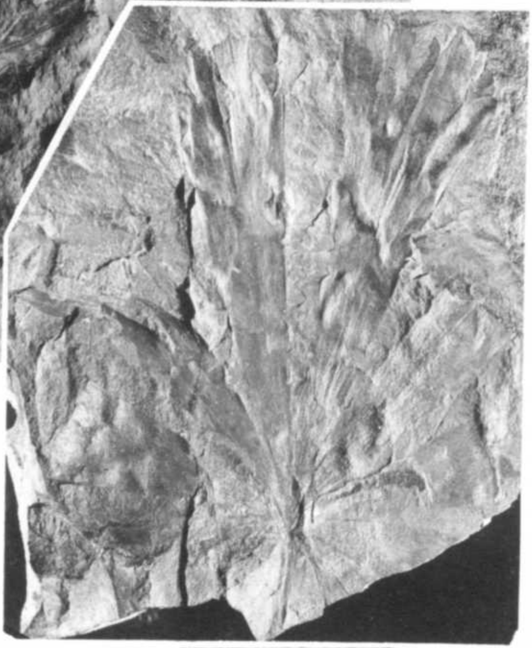
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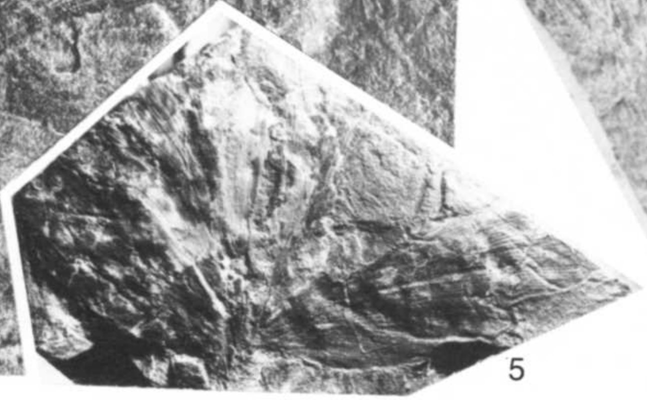
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Plate XIV


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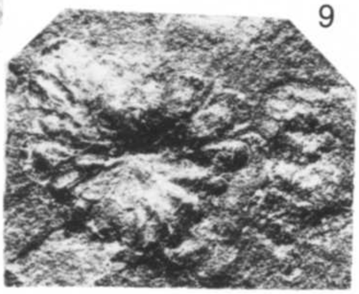
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TEXT-FIGURE CAPTIONS

Fig. 1
Location and section of Upper Paleozoic deposits of the Nan-shan northern slope compiled by Bexell.

Fig. 2
Callipteris bexellii sp. nov., N Bex 302 (× 1) (same as Pl. X, Fig. 11).

Fig. 3
Callipteris bexellii sp. nov., a: N Bex 307-1 (× 1, 7) (same as Pl. XI, Fig. 4), b: N Bex 296-1 (× 2) (same as Pl. III, Fig. 2); c: *Callipteris* ex gr. *bexellii*, N Bex 313 (× 2) (same as Pl. IV, Fig. 1).

Fig. 4
a:*Compsopteris* cf. *adzvensis* Zal., N Bex 163 (× 1) (same as Pl. V, Fig. 6), b: *Compsopteris* (?) sp. 2, N Bex 171 (× 1) (same as Pl, V, Fig. 4).

Fig. 5
Peltaspermum nanshanensis sp. nov., a: N Bex 139 (× 5), upper side of a peltoid (same as Pl. VIII, Fig. 6 and Pl XIV, Fig. 9); c: N Bex 75-I (× 3), holotype, part of aggregation of peltoids attached to the axis (same as Pl VIII, Fig. 5); b: N Bex 134 (× 5), imprint of lower side of peltoid with scars of seeds (same as Pl. VII, Fig. 7).

Fig. 6
Pursongia elegans sp. nov., N Bex 124-1 (× 1) (same as pl. VIII, Fig. 3, 4).

Fig. 7
Phylladoderma (?) sp., N Bex 166 (× 1.5) (same as Pl. XII, Fig. 3).

Fig. 8
cf. *Anomozamites* sp., N Bex 441 (× 2) (same as Pl. X, Fig. 2).

Fig. 9
cf. *Sashinia* sp., N Bex 48 (× 2) (same as Pl. XIV, Fig. 8).

Fig. 10
Geinitzia sp. 1, N Bex 72 (× 1.76) (same as Pl. XIV, Fig. 7).

Fig. 11
Psygmophyllum sp., N Bex 263 (× 1) (same as Pl. XII, Fig. 5).

Fig. 12
Psygmophyllopsis norinii gen. et sp. nov., a: N Bex 296 (× 1), holotype (same as Pl. XII, Fig. 11); b: N Bex 310 (× 1) (same as Pl. XII, Fig. 10).

Fig. 13
Flabellofolium sp. 1, N Bex 244-2 (× 1) (same as Pl. XIII, Fig. 6).

Fig. 14
Flabellofolium sp. 2, N Bex 295 (× 1) (same as Pl. XI, Fig. 2).

Fig. 15
Plagiozamites (?) sp., N Bex 164 (× 1.5) (same as Pl. IX, Fig. 1).

Fig. 16
Phytogeographical zonation of Central and Northern Asia at the end of the Late Permian. 1: Angaran kingdom; a Siberian area, central part; b, Siberian area, periferal part; c, Subangaran area. 2: Cathaysian kingdom. 3: Boundary between Atlantic and Angaran kingdoms. 4: Boundaries between different areas. 5: State boundaries.

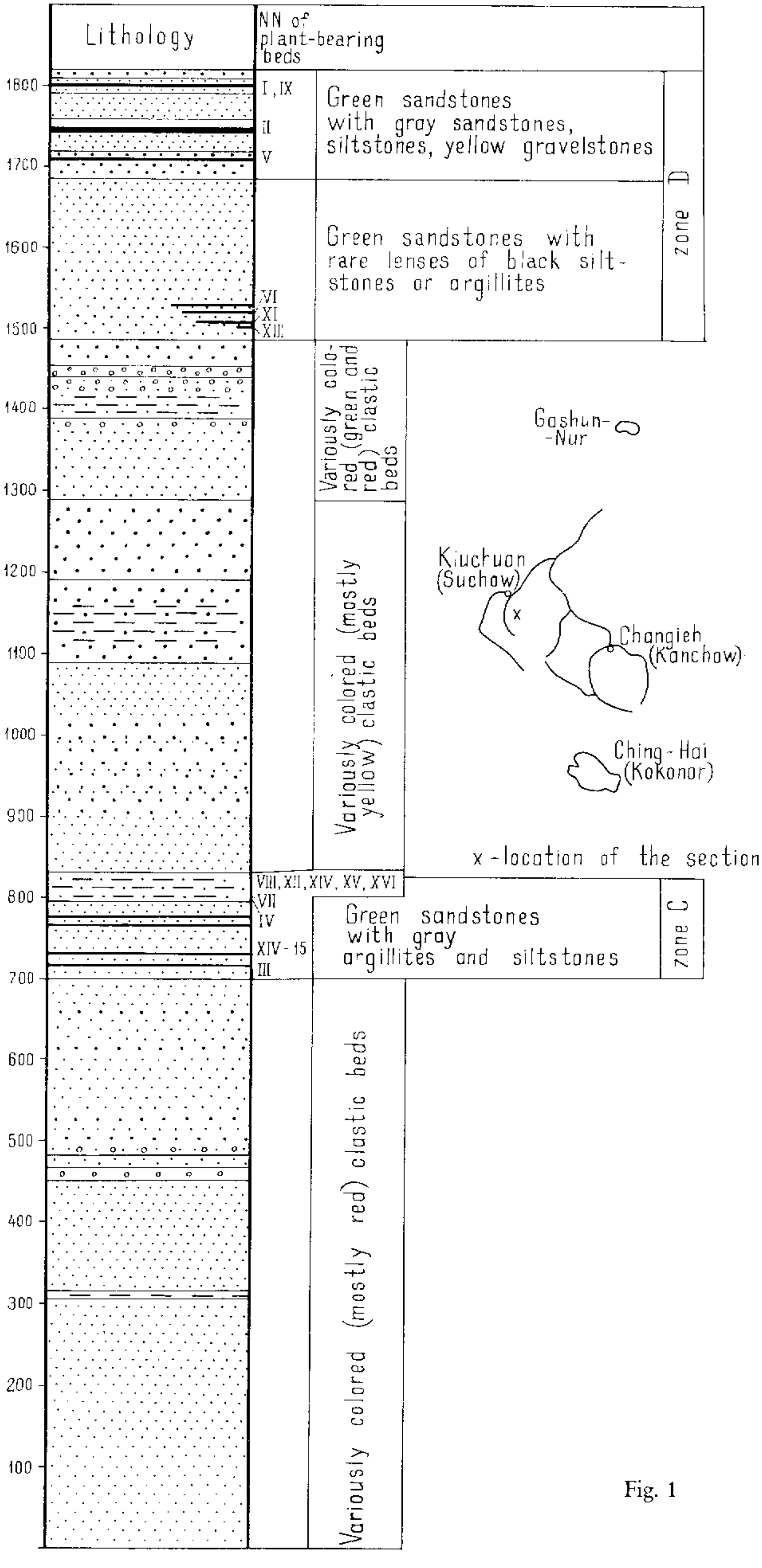

Lithology
NN of plant-bearing beds
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
I, IX
II
V
VI
XI
XIII
VIII, XII, XIV, XV, XVI
VII
IV
XIV-15
III
Green sandstones with gray sandstones, siltstones, yellow gravelstones
Green sandstones with rare lenses of black siltstones or argillites
zone D
Variously colored (green and red) clastic beds
Variously colored (mostly yellow) clastic beds
Green sandstones with gray argillites and siltstones
zone C
Variously colored (mostly red) clastic beds
Goshun-Nur
Kiuchuan (Suchow)
x
Changieh (Kanchow)
Ching-Hai (Kokonor)
x - location of the section

Fig. 1

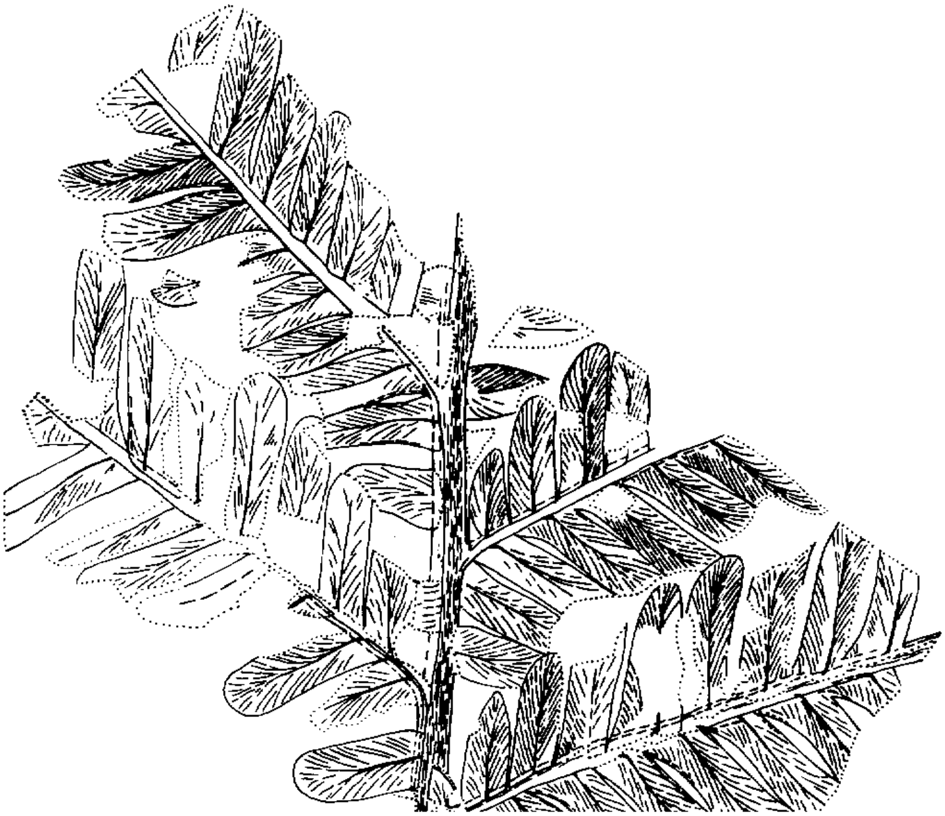


Fig. 2

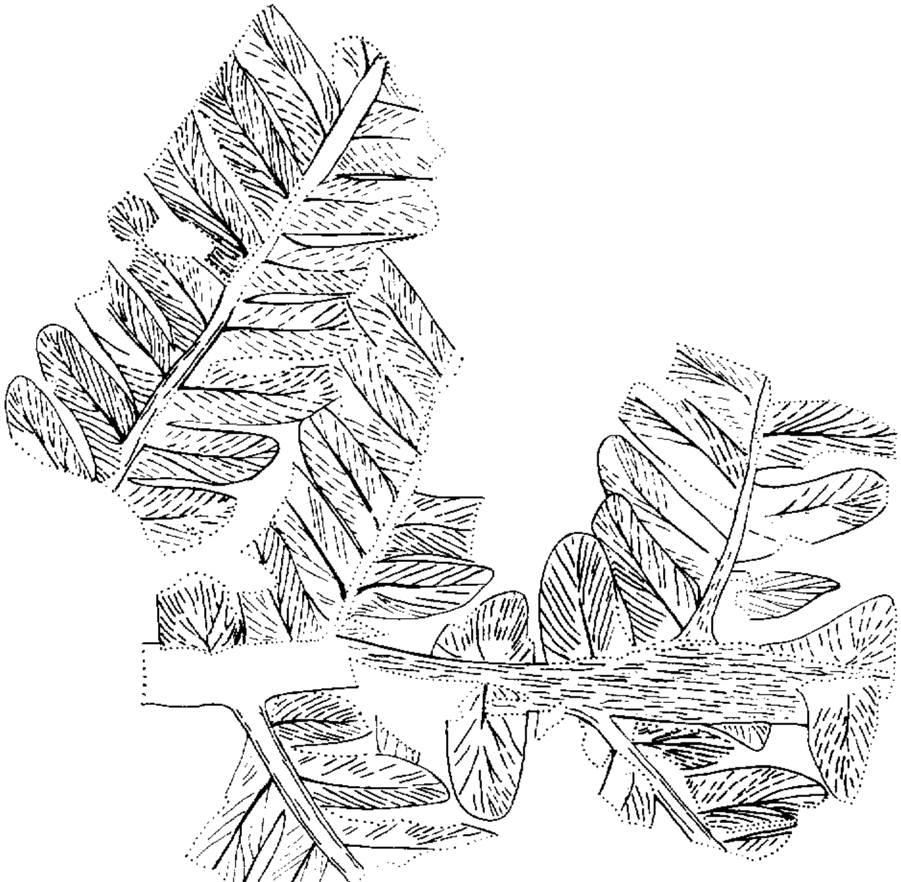
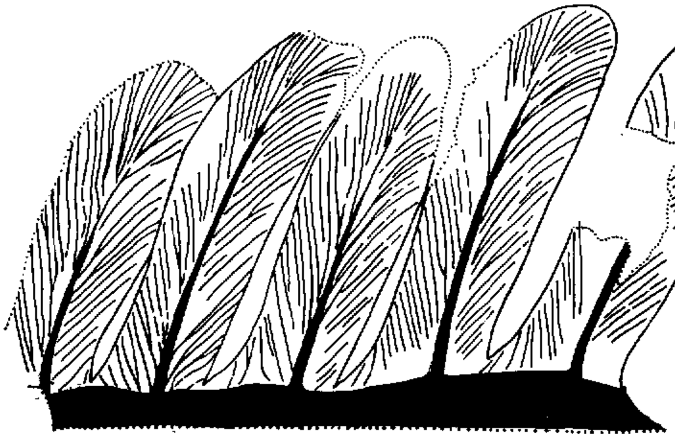


Fig. 3 a


Fig. 3 b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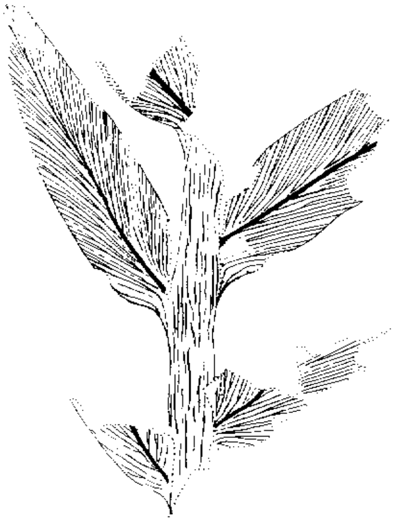


Fig. 4 a


Fig. 4 b

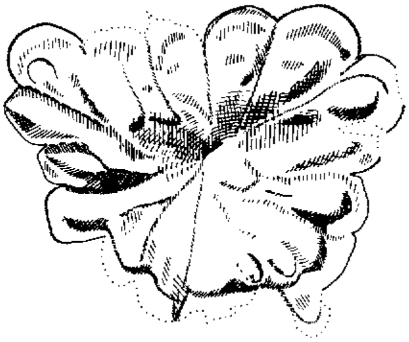


Fig. 5 a

Fig. 5 b

Fig. 5 c

Fig. 6

Fig. 7

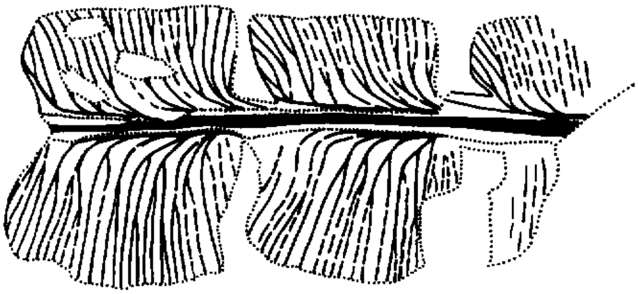


Fig. 8

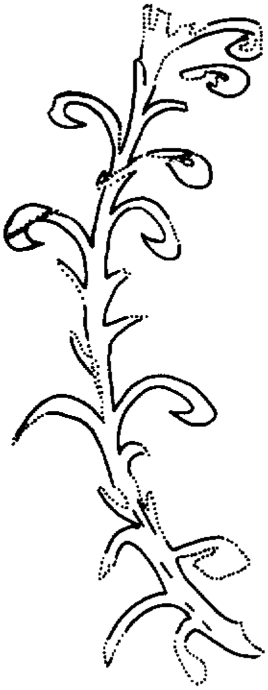


Fig. 9

Fig. 10

Fig. 11

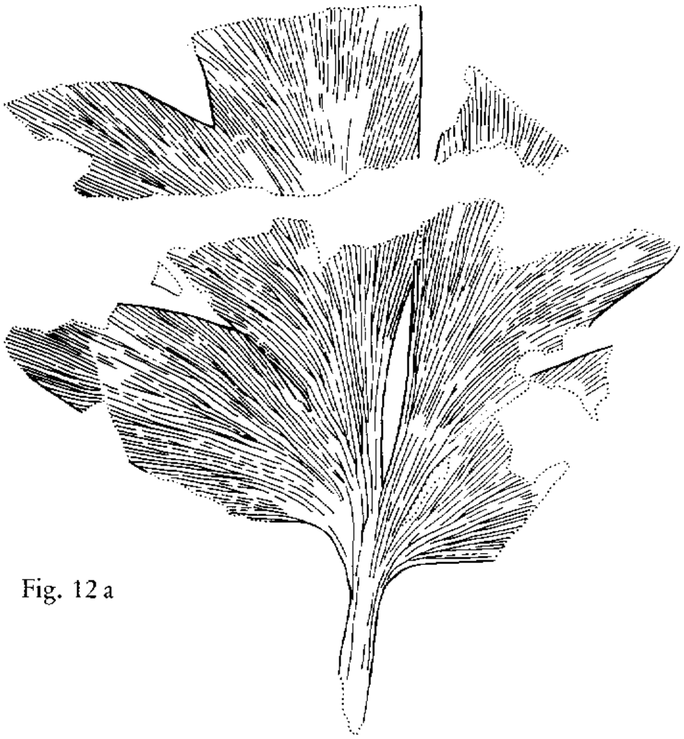
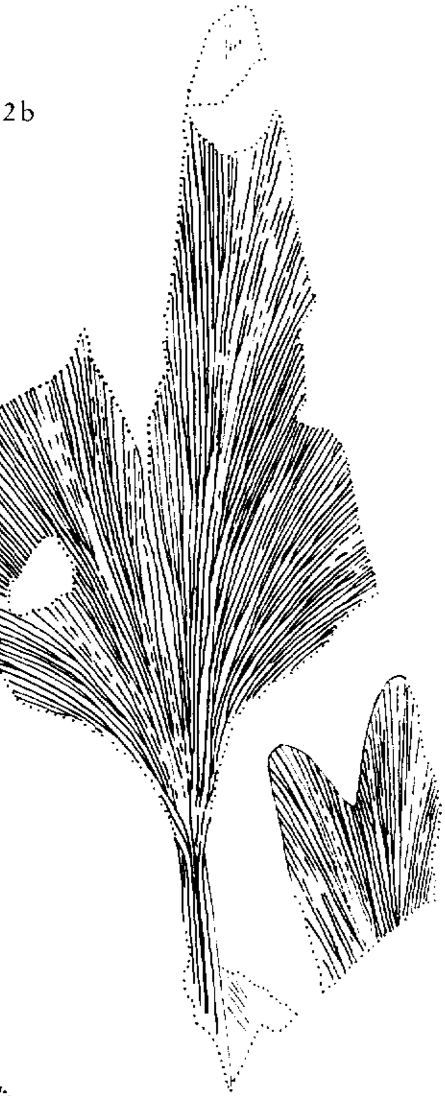


Fig. 12 a

Fig. 12 b



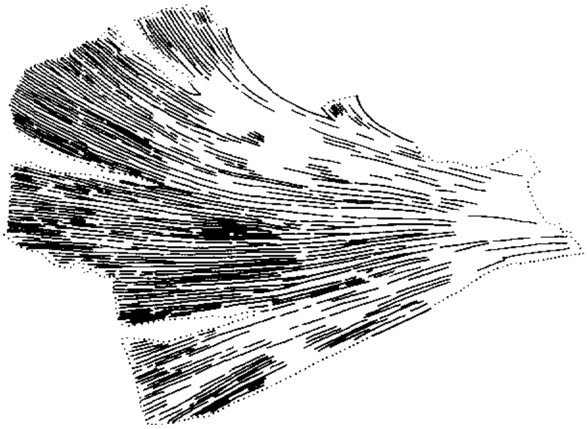


Fig. 13

Fig. 14

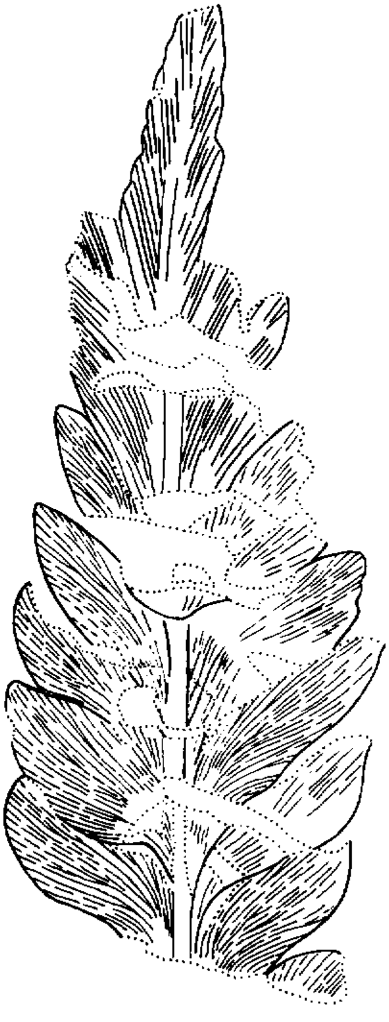


Fig. 15

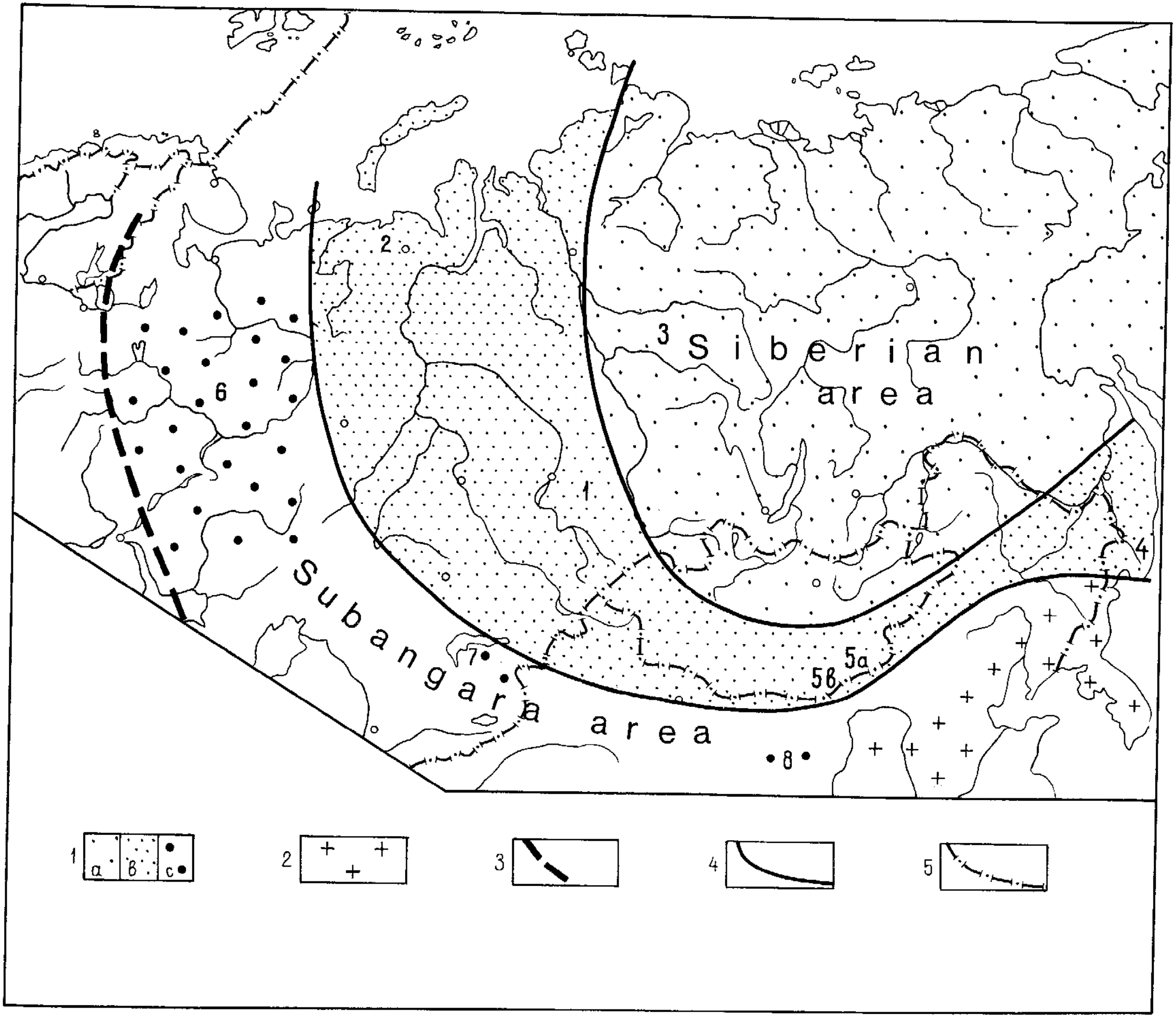


Fig. 16

Appendix

Stockholm, November 10, 1951

Dear Halle,

I am herewith sending the deciphering of the designations of the rock specimens / . . . . /.

The designation K.t'Ch is thus an abbreviation of Kou-t'ou ch'uan (or ch'uan-tze) (= the bone spring). No regard need be paid to the W.T.Sh. which is often present on the same rock specimens. The region corresponding to this designation is situated at the northern margin of the Richthofen Mountains, on the eastern side of the emergence of the Pei-t'a ho from the mountains, and covers an area of about 6 × 4 km. T.H.K. = Tai-huang-kou (the rhubarb spring) represents the corresponding part on the western side of the river, and Y.Ch. = Yao-ch'uan its (i. e. Tai-huang-kou's) westernmost part, 8–9 km to the west of Pei-t'a ho.

K.L.K. = Ka-la-tze-kou, a small area on the northern side of the mountain Hsi-shan-hu-ti-shan (or Hei Shan; named Po-shan = Pei-shan in the older literature) is an isolated part of the northern foothills of Nan-shan (in its entirely designated Lung-shan) and is situated about 50 km to the north of the preceding area, or 40 km to the north-west of Suchow.

The rock specimens marked T.T.T. = Ta-tsao-t'an (S of the oasis Chin-fo-tzu at the foot of the mountain) were derived from a small coal basin within the more northerly parts of the Richthofen Mountains 50 km to the SSO of Suchow. Hs.H.Y. = Hsi-ho-yen 7 km to the SE of the preceding, T.H.Sh.Sh.T = Tung-hui-shirk-shan-t'ang 2 km ESE of the preceding, I.t.Sh. = Yin-Chung-shan 3 km ESE of the preceding one, Sh.ch.H. = Shirk-chi-ho another 3 km towards SE (from here are only available calcareous tufas with impressions from the Quaternary, however).

H.Sh.p.Sh.H. = Hung-Shui-pa-Shang-ho, the name of a tributary of the Hung-shui-pa-ho (sometimes designated Ling-Shui on the maps), which departs from the mountains E. of the Pei-ta-ho. The sediments which appear around this tributary, actually represent a direct continuation within the mountains towards the SE of the sediments exposed along Pei-ta-ho. The principal occurrence is situated about 50 km SE of the mouth of the Pei-ta-ho and about as far SSE of Suchow.

Palaeozoic plant fossils were thus found within a very limited part of the area investigated (contrary to the Jurassic ones), which is partly due to the tectonic conditions, partly to the change of character to which the sediments are subjected towards the interior of the mountains.

Generally, the sections had to be synthesized from a large number of partial profiles from the same area. It was possible to measure the section at Hung-shui-pa-Shang-ho in one continuous outcrop, however, but some of the fossiliferous horizons indicated have been transferred from (nearby) parallel profiles / . /.

In the sections, P.I designates the equivalent to the part with the last marine horizons, earlier designated as the "Shansi series". From this it is immediately apparent that P. II corresponds to Norin's Shihhotze series, which was divided into the subdivisions a and b. The former consists chiefly of dark greyish-green marsh deposits near the borderlands of the regressing sea, division b of more strongly washed sandy deltaic deposits, since a translocation evidently took place even of the marshy areas and the places of deposition of the finer material. This division was, in a younger phase, and with continuous drying, more and more subjected to lateritic weathering or addition of red material to areas outside the depressions saturated with water, where the formation of red earth was enabled considerably earlier. (There are cases, where this weathering has affected P. I and P. IIa at suitable localitites).

The sedimentation of subdivision P. II was interrupted in connection with minor tectonic adjustments followed by volcanic activity. Beds of tuff and lava are therefore present, in particular in the lower part of the following division P. III. This division consists in its remaining part of rapidly changing beds of often strange light red, yellow, orange-coloured and greyish or green beds, of which many show a striking similarity in colour to reworked products formed in the present tropics from a substratum, which was earlier subjected to laterization or in any case tropical weathering. Fragments of volcanogenic rocks occur as reminiscences of the past throughout the whole following series.

The red sandstones and shales with numerous limestone concretions of P. IV a have obviously been deposited during chiefly semiarid conditions. The greyish violet unsorted conglomerate beds 38–52 within division P. IV c may correspond to maximally arid conditions during this phase. The darker brownish red to brownish black beds of division P. V, rich in limestone concretions and silica, must as far as I can see, mark a return to semiarid conditions (approximately, steppe), and an introduction to the moister phase P. VI, which begins with the only really characteristic river-bed gravel (bed 90), and is followed by the sandstones and shales containing the Angara flora. In the following, there are first grey and later variegated sandstones that correspond to the Shichienfeng Series, of which the main part has the same ??? formation as the Bunter of Middle Europe, in middle and southern Nanshan also containing a Lower Triassic fauna. To the north follows thin-banked greyish green sandstone (J. II) with some plant-bearing horizons, followed by the Jurassic coal-bearing series (J.)
/................../

Greetings,
Bexell

Translation from Swedish by Britta Lundblad

Pinyuin transliteration of the geographical names mentioned in Bexell's letter to Halle:

	Pinyuin letters
Kou-t'ou-ch'uan	Kou-tou-quan
Ch'uan-tze	Quan-zi
Pei-t'a-ho	Bai-ta-he
Tai-huang-kon	Da-huang-gou
Yao-ch'uan	Yao-quan
Ka-la-tze-kou	Ka-la-zi-gou
Hsi-shan-hu-ti-shan	Xi-shan-hu-di-shan
Hei-shan	Hei-shan
Po-shan = Pei-shan	Bai-shan (Bei-shan)
Nan-shan	Nan-shan
Lung-shan	Long-shan
Su-chow	Su-zhou
Ta-tsao-t'an	Da-cao-tan
Chin-fo-tzu	Qing-fo-zu
Hei-ho-yen	Hei-he-yan
Tung-hui-shirk-shan-t'ang	Dong-hui-she-er-ke-shan-tang
Yin-chung-shan	Yin-zhong-shan
Shirk-chi-ho	She-er-ke-qi-he
Hung-shui-pa-shang-ho	Hong-shui-ba-shang-he
Hung-shui-pa-ho	Hong-shui-ba-he
Ling-shui	Ling-shui
Shansi	Shanxi
Shihhotze	Shihezi