SOME CONNECTION BETWEEN THE CATHAYSIAN FLORA AND THE GLOSSOPTERIS FLORA IN INDIA DURING THE LATER PERMIAN AGE

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ABSTRACT

The Taiyuan ($C_3 + P_0$), the Shansi ($P_1^1 + P_1^2$), and the Shihhotse (P_2^1) including the Shihchienfeng (P_2^2) series are roughly correlated to the Talchir (including the Boulder Bed), the Barakar (including the Karharbari and possibly the Barren Measure), and the Raniganj series in India, respectively. The respective floras of each series of Cathaysia and India are compared with each other epoch by epoch. It is concluded that the Cathaysian flora had almost nothing to do with the Glossopteris flora in India during the age ranging from the Taiyuan to the Shansi epoch, while during the mid-Permian crustal movements some elements of the Glossopteris flora as *Schizoneura*, *Rhipidopsis*, *Glossopteris*, and possibly *Palaeovittaria* came into contact and mixed with the Upper Permian Cathaysian flora.

INTRODUCTION

IN 1927a, *Rhipidopsis lobata* Halle, an element of the Glossopteris flora was first recorded in the Far East by the late Professor T. G. Halle from the Shihhotse series in Central Shansi in North China. Since then *Schizoneura* and another species of *Rhipidopsis* were described by Kawasaki & Kon'no in 1932. Kawasaki expressed (1934, p. 265-266) that "In the Jido flora no characteristically Gondwana species is known, which is a remarkable contrast to the superposing Kobosan Series.— the Kobosan flora has a number of Gondwanan elements." Against Kawasaki's view, Jongmans (1937, p. 359-360) stated: "So far as we know at present there is no proof of any mixing of these floras (the Gondwana and the Cathaysian). So we can conclude that the Cathaysia (*Gigantopteris*)-flora has no relation with the real Gondwana flora of the southern hemisphere, —." Since then more than quarter a century has elapsed, and here I wish to express my opinion on this subject.

COMPARISONS OF THE CATHAYSIAN FLORA WITH THE GLOSSOPTERIS FLORA IN INDIA

In the northern half of the Cathaysian floral province, where the records of the Cathaysian flora are known to be better preserved, four or five later Palaeozoic plant-bearing formations are almost consecutive from the Middle Carboniferous to the Upper Permian. They are in ascending order: the Penchi (C_2), the Taiyuan (C_3+P_0), the Shansi ($P_1^1+P_1^2$), the Shihhotse (P_2^1), and the Shihchienfeng (P_2^2), including their respective equivalents in South China and Korea.

(1) The Cathaysian flora in the Penchi epoch, approximately Moscovian (C_2).

Excluding the detached seed fossils, about 40 species have so far been described from the Penchi series, of which *Lepidodendron*, *Sphenopteris*, *Linopteris brongniarti* (Gutdier), *Neuropteris gigantea* Sternb., *N. scheuchzeri* Hoffm., etc. are most important. In the northern part of Cathaysia the Penchi series always accompanies a rich fusulinid fauna of the *Fusulina-Fusulinella* Zone, and therefore its Moscovian age is without doubt. In India the Moscovian beds have not been discovered yet.

(2) The Cathaysian flora and the Glossopteris flora in India in the Taiyuan epoch, approximately Uralian (C_3) and Sakmarian (P_0) combined.

About 80 species in 25 genera of plants (seed fossils excluded) have been described, of which *Cathaysiodendron*, *Lepidodendron oculus felis* Abbado, *Sphenophyllum*, *Annularia*, *Tingia* (with 4 spp.), *Pecopteris* (13 spp.), *Cordaites*, etc. are the most important members of this flora. The Taiyuan series and its equivalents in Korea usually contain limestones and other marine fossil-bearing beds, yielding brachiopods, advanced forms of fusulinids, etc. It is certain that the Taiyuan epoch includes the Uralian (C_3) and the Sakmarian (P_0). In the Salt Range in India, the marine *Conularia* beds, according to Jacob (1952, p. 156), of the Olive series has yielded *Schizoneura*, *Glossopteris*, *Gangamopteris*, *Vertebraria*, *Noeggerathiopsis*, *Ottokaria*, etc. This *Conularia* beds and the equivalent Talchir beds in peninsular India are shown in Jacob's correlation table of the Gondwana System in India (*l.c.*, p. 154-155) to be correlative to the Sakmarian, and the underlying Boulder Beds to the Uralian. If it is so, then these Boulder Bed and the Talchir series should be approximately homotaxial to the Taiyuan series (C_3+P_0) in Cathaysia. As mentioned above, the Taiyuan flora contains some endemics as *Lepidodendron oculus felis*, *Tingia*, etc., but the vegetation as a whole continued to retain largely the aspect of the later Carboniferous coal-measure flora in Eurameria. In India, on the contrary, the vegetation had completed its transformation into the Glossopteris flora by the opening of the Talchir epoch, which should have taken place in connection with the climatic and edaphic conditions of the later Carboniferous ice age.

(3) The Cathaysian and the Glossopteris flora in India during the Shansi epoch, approximately Artinskian (P_1^1) and Kungurian (P_1^2) combined.

The Lower Shansi series (P_1^1) consists of dark-coloured rocks of various lithology as coals, black shales, etc. containing a few marine fauna-bearing beds, while the Upper Shansi series (P_1^2, synonymous with Lower Shihhotse Series of NORIN, 1922) is composed of rocks of limnic facies as variegated shales, sandstones, red shales, and fire clay beds. From both the Lower and the Upper Shansi series as many as 170 species of plants have so far been described, of which the most dominant genera are: *Lepidodendron* and its allies (14 spp.), *Sphenophyllum* (14 spp.), *Tingia* (4 spp.), *Pecopteris* (20 spp.), *Sphenopteris* (10 spp.), *Neuropteris* (4 spp.), *Taeniopteris* (12 spp.), etc. Differing from the preceding Taiyuan epoch, the vegetation in the Shansi epoch made a remarkable advancement by the addition of abundant vigorous new comers of both Euramerian and indigenous genera and species. They are, e.g. *Sphenophyllum thonii*, *Taeniopteris* including *T. multinervis*, *Callipteris*, *Protoblechnum*, *Plagiozamites*, *Nilssonia*, *Pterophyllum*; *Lobatannularia*, *Cathysiopteris*, *Gothanopteris*, *Palaeogoniopteris*, *Gigantopteris* (*see* ASAMA, 1959), etc. Above all, it is noteworthy that many plants with large tongue-shaped leaves or pinnae as *Gigantopteris* and *Taeniopteris* made their first appearance. However, *Glossopteris*, *Gangamopteris* or other Gondwanaland plants with similar large tongue-shaped leaves are not found in the Cathaysian flora in the Shansi epoch. The Lower Shansi series (P_1^1) in the northern Cathaysia has often yielded marine fossils, but they are too insufficient to determine the age of that series. Fortunately, contemporaneous series in the southern half of Cathaysia contains fusulinid and other marine fossils in abundance, which indicate that the Shansi epoch represents the time span of the Artinskian (P_1^1) to the Kungurian (P_1^2) (*see* H. H. LEE, 1963).

Jongmans & Gothan (1935) described an important flora from Djambi in Sumatra, which is of particular interest, because it represents a far distant southward outpost of the Cathaysian flora. Jongmans (1937) considered the age of the Djambi flora as pre-Permian Westphalian E of his sense and correlated it with the *Taeniopteris*-bearing division of his " middle part of the Cathaysian flora ", which includes the Taiyuan and the Shansi flora. The Taiyuan flora is, as mentioned above, destitute of *Taeniopteris*, while the Shansi contains as many as 12 species and the Djambi flora bears nine species of the same genus, of which six are common to these two floras. In the Djambi district, the plant-bearing beds are some hundred meters above the limestone bed, which by yielding *Productus sumatrensis*, *Pseudoschwagerina princeps*, etc. proves it to be Sakmarian in age (OZAWA, 1929). These evidences indicate that the Djambi flora-bearing beds are almost equivalent in age to the Lower Shansi series (P_1^1) in northern Cathaysia. According to Jongmans & Gothan (1935), the Djambi flora (Aphlebia and seed fossils excluded) contains about 63 species of plants, of which seven species belong to Lycopsida, five to *Sphenophyllum*, 15 to *Pecopteris*, three to *Callipteridium*, nine to *Taeniopteris*, two to the so-called *Gigantopteris*, and four to *Cordaites*. Thus the composition of the Djambi flora resembles that of the Shansi flora, which is believed to have flourished under warm and humid climatic conditions. As will be seen below, the Djambi flora is approximately contemporaneous with those in the Karharbari and Barakar beds in India. It is therefore quite surprising to find, as previously pointed out by Sahni (1935), Jongmans (1937) and Jongmans & Gothan (1935) that the luxuriant Djambi flora appears to have had almost nothing to do with its contemporaneous Glossopteris flora in India, despite their geographical nearness. Thus it has become certain that in the early Lower Permian age (P_1^1) the vegetation in Cathaysia was sharply separated even in its southern marginal regions as Djambi by an impenetrable barrier from Gondwanaland around India. In Kashimir, according to Jacob (1952, p. 155-156), the *Gangamopteris* beds, which have yielded *Gangamopteris kashmirensis, Glossopteris indica, Noeggerathipsis hislopi*, and *Psygmophyllum haydeni*, are considered as homotaxial equivalents to the Karharbari beds, and the plant-bearing beds underlie the marine Zewan beds of the Middle Permian age. In peninsular India, the Karharbari beds overlie with unconformity the Talchir and underlie with conformity the Barakar. Thus Jacob's corelation table shows that the Karharbari and the Barakar beds are collectively of Lower Permian or Artinskian in age. These two Lower Permian beds in India, therfore, are approximately contemporaneous with the Lower Shansi series (P_1^1) in northern Cathaysia. The Karharbari and the Barakar series have yielded, according to Sahni (1922), Jacob (1952), and others, *Schizoneura* (2 spp.), *Phyllotheca* (1 sp.), *Sphenophyllum* (1 sp.), *Gangamopteris* (3 spp.), *Glossopteris* (7 spp.), *Vertebraria* (1 sp.), *Gondwanidium* (1 sp.), *Pseudoctenis* (1 sp.), *Taeniopteris* (3 spp.), *Noeggerathiopsis* (2 spp.), *Dadoxylon* (3 spp.), Conifers (3 spp.), *Rhipidopsis* (1 sp.), *Psygmophyllum* (2 spp.), etc. Thus the flora of these Lower Permian beds in India appears to show no direct connection with its contemporaneous flora in Cathaysia.

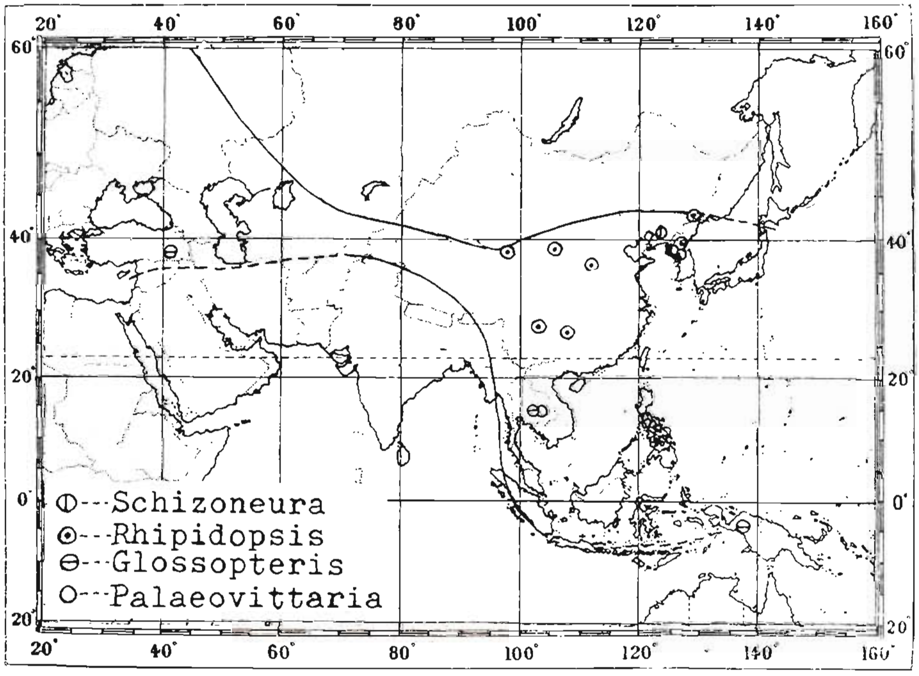
(4) The Cathaysian and the Glossopteris flora in India in the Shihhotse and the Shihchienfeng epochs, approximately Kazanian (P_2^1) and Tartarian (P_2^2), respectively.

The Shihhotse series is defined here as synonymous with the Upper Shihhotse Series of Norin (1922), containing the *Gigantopteris nicotianaefolia*-bearing flora or simply the Gigantopteris flora, which was often mistaken for the whole Cathaysian flora during the later Palaeozoic era. The succeeding Shihchienfeng series in North China is mainly composed of red beds of various lithology, and usually poor in plant records, but they are sufficient to justify that the Shihchienfeng flora is a direct prolongation of the preceding Shihhotse flora. In the Shihhotse epoch (P_2^1), various rocks of facies of inland limnic basins were deposited extensively in northern Cathaysia, while in southern Cathaysia numerous paralic or lagoonal basins were introduced, in which the so-called "*Gigantopteris* Coal Series" was laid down. From both northern and southern Cathaysia more than 140 species of plants have been described, of which the Euramerian floral elements are: *Annularia* (10 spp.), *Sphenophyllum* (9 spp.), *Pecopteris* (15 spp.), *Desmopteris* (3 spp.), *Callipteris* (1 sp.), *Alethopteris* (1 sp.), *Odontopteris* (3 spp.), *Cordaites* (2 spp.), *Walchia* (1 sp.), and *Ullmannia* (1 sp.); the Cathaysian elements are: *Tingia* (3 spp.), *Lobatannularia* (6 spp.), *Gigantopteris* of *nicotianaefolia*-type (6 spp.); the forerunners of the Mesozoic plants are: *Chiropteris* (2 spp.), *Ctenopteris* (1 sp.), *Neuropteridium* (2 spp.), *Pelourdea* (1 sp.), and *Sphenobaiera* (1 sp.). Differing from all the preceding floras in Cathaysia, the Shihhotse flora (P_2^1) contains numerous exotic elements, of which the Angara floral elements are *Pecopteris anthriscifolia* (Goepp.), *Psygmophyllum multipartitum* Halle, *Callipteris changi* Sze, *Brongniartites* sp.; the elements of the Glossopteris flora are: *Schizoneura* (*Manchurostachys*) *manchuriensis* Kon'no, *S. striata* Kawasaki & Kon'no, *Rhipidopsis baieroides* Kawasaki & Kon'no, *R. densinervis* Feistm., *R. gondwanensis* Seward, *R. lobata* Halle, *Glossopteris* cf. *angustifolia* Brongn., *G.* cf. *stricta* Bunb., *Palaeovittaria? koreanica* Oishi, and *P. parvifolia* Kon'no, all of which will be discussed in detail in the next chapter. So far as the present knowledge goes, such admixture of these exotic elements of the Angara and the Gondwanaland floras into the Cathaysian commenced during the mid-Permian interval between the Upper Shansi (P_1^2) and the Shihhotse (P_2^1) epochs in Cathaysia.

The age of the Gigantopteris flora (*s. str.*) has long been the subject of controversy. In South China the Gigantopteris flora-bearing coal series — the Lungtan series — is underlain by the Maokou Limestone series with a rich fusulinid fauna of the *Neoschwagerina-Verbeekina* Zone, and overlain by the Changhsing Limestone series which yielded the *Reichelina-Palaeofusulina* fauna of the *Palaeofusulina* Zone. The *Neoschwagerina-Verbeekina* Zone and *Palaeofusulina* Zone in Asia are assigned to the Socio (Kungurian) and the Chideru (Tartarian) epochs, respectively (see HANZAWA & MURATA, 1963, p. 15-16). Moreover the Lungtan series itself has often yielded marine fossils as *Leptodus*, *Codonofusiella*, *Reichelina*, *Nankinella*, etc., which indicate as a whole the early Upper Permian age. Therefore the Gigantopteris flora (*s. str.*) in both northern and southern Cathaysia is evidently of the early Upper Permain (Kazanian) in age.

The Upper Permian beds in India are represented by the Raniganj series, which is, according to Jacob (1952, p. 154-155), corelated with the Thuringian in West Europe, and if so then the Raniganj is approximately contemporaneous with the Shihhotse (P_2^1) and the Shihchienfeng (P_2^2) series combined. The Raniganj series has yielded a rich flora containing such plants (according to SAHNI, 1922, JACOB, 1952; SURANGE, 1955, and others) as: *Phyllotheca* (2 spp.), *Schizoneura gondwanensis* Feistm., *Actinopteris* (1 sp.), Equisetalean cone, *Sphenophyllum speciosum* (Royle), *Belemnopteris* (1 sp.), *Cladophlebis roylei* Arber, *Dictyopteridium* (1 sp.), *Gangamopteris whittiana* Feistm., *Glossopteris angustifolia* Brongn., *G. browniana* Brongn., *G. communis* Feistm., *G. conspicua* Feistm., *G. indica* Schimper, *G. retifera* Feistm., *G. ampla* Dana, *G. stricta* Bunb., *G. tortuosa* Zeill., *Palaeovittaria kurzi* Feistm., *Vertebraria indica* Royle, *Pecopteris* (2 spp.), *Sphenopteris* (2 spp.), *Taeniopteris danaeoides* (Royle), *T. feddeni* (Feistm.), *T. macclellandi* (Feistm.), *Pterophyllum* (1 sp.), *Noeggerathiopsis hislopi* (Bunb.), *Dadoxylon parbeliense* Rao, *D. zalesskyi* Sahni, *Rhipidopsis densinervis* Feistm., etc. (seed fossils excluded). Of them, 12 genera are in common with the Shihhotse flora in Cathaysia as: *Schizoneura*, *Phyllotheca?*, *Sphenophyllum*, *Cladophlebis*, *Glossopteris*, *Palaeovittaria*, *Pecopteris*, *Sphenopteris*, *Taeniopteris*, *Cordaites* (*Noeggerathiopsis*), and *Rhipidopsis*. Thus the admixture of some elements of the Glossopteris flora in the Cathaysian has been proved, but we have no reliable criteria to determine through which passage-way their migration took place.

Recently Wagner (1962) reported the Hazro flora from SE. Anatolia (Turkey) which, according to him (*l. c.*, p. 748), "represents the westernmost occurrence of the Cathaysian provice in Asia." The Hazro flora contains (detached fructifications ex-



TEXT-FIG. 1 — Distribution of localities of *Schizoneura*, *Rhipidopsis*, *Glossopteris* and *Palaeovittaria* found in the Permian beds in Cathaysia.

cluded), about 18 species, of which the Cathaysian floral elements are *Lobatannularia heianensis* (Kodaira), *Gigantopteris* of *nicotianaefolia* type, *Pecopteris tenuicostata* Halle, *P.* cf. *wongii* Halle; the Gondwanaland elements are *Glossopteris* cf. *stricta* Bunb., *Cladophlebis roylei* Arber, and *Pecopteris phegopteroides* (Feistm.). The predominance of *Pecopteris* (with 8-9 spp.), the absence or extreme rarity of either *Walchia* or *Callipteris*, etc. indicate that the Hazro flora has much more in common with the Cathaysian flora than either the Gondwanaland or the Euramerian. On the age of the Hazro flora, Wagner (*l. c.* p. 749) states as: " Combining the evidence from both the upper Shihhotse (synonymous with Shihhotse in the present paper) and the Raniganj flora in China and India, it seems that the Hazro flora in SE. Anatolia should be considered as either middle Permian or middle to upper Permian in age." As mentioned above, the Shihhotse flora in Central Shansi is now proved to be of the early Upper Permian age, and the Raniganj has also been referred by Jacob (1952) to the Upper Permian. Therefore the Hazro flora would be more preferably regarded as Upper Permian, instead of middle or middle to upper Permian. Thus it has become certain that in SE. Anatolia, too, the migration of the Gondwanaland elements into Cathaysia took place mainly in the Upper Permian age as in China and Korea. However, SE. Anatolia seems to be too remote from the main habitat of the Cathaysian flora to have been in the main routes, through which some members of the Glossopteris flora might have invaded deep into Cathaysia proper.

In Yunnan and Thailand there have been found several localities of the Upper Permian Cathaysian flora, which are situated relatively near the realm of the Glossopteris flora in India. Of them, the Hsianwei coal series has yielded, according to Yokoyama (1906) and Halle (1927b), such plants as: *Annularia* (2 spp.), *Sigillaria* (1 sp.), *Pecopteris* (5 spp.), *Gigantopteris hallei* Asama, *G. nicotianaefolia* Schenk, *Glossopteris*? (1 sp.), *Taeniopteris* (4 spp.), *Rhipidopsis* (1 sp., originally described by Yokoyama as *Phoenicopsis*?), etc. Thus the Hsianwei flora is undoubtedly equivalent in either composition or age to the Gigantopteris flora (*s. str.*) in the Shihhotse epoch (P_2^1), and further they are common in having some Gondwanaland elements as *Rhipidopsis*. In Thailand, the Phetchabun flora consists of, according to the writer (KON'NO, 1963), *Bowmanites* sp., *Sphenophyllum trapaefolium* Stockm. & Math., *Alethopteris* (1 sp.), *Taeniopteris* (2 spp.), *Glossopteris* cf. *angustifolia* Brongn., *Palaeovittaria parvifolia* Kon'no, and *Poacordaites* (1 sp.). To see as a whole, these two floras are mainly composed of the pure Cathaysian elements, and besides contain a few members of the Glossopteris flora. Southwestern China and Thailand containing these localities lie within the realm of the Permian fusulinid fauna, and accordingly belong to the pure Cathaysian terrain. As is well known, during or immediately after the mid-Permian phase of the crustal movements, intensive outflows of plateau or submarine basaltic lavas broke out over extensive areas covering southwestern China, Thailand, and possibly part of Malaya. It seems, therefore, probable to assume that these volcanism and uplifting of the sea-bottom in or around the Tethys orogen produced some direct routes of eastward migration of those elements of the Glossopteris flora from some areas, lying probably to the west of Yunnan and Thailand.

(5) The Permian flora in West New Guinea. Jongmans (1940) reported a small but important flora from two localities near the south coast of West New Guinea. The one locality has yielded a flora, according to him, of decidedly Cathaysian affinity, consisting of *Sphenophyllum verticillatum* Schloth., *Pecopteris unita* Brongn., *P.* cf. *arcuata* Halle, *P.* cf. *paucinervis* Jongm., *P.* cf. *orientalis* Schenk, *Taeniopteris* cf. *multinervis* Weiss, and *T.* cf. *taiyuanensis* Halle; he considered it as contemporaneous with the Djambi flora in Sumatra. The other locality is situated at about 10 km. distance from the former; it yielded some splendid specimens of *Vertebraria* sp., which he considered as belonging to the flora from the other locality. Recently Visser & Hermes (1962, p. 54, encl. 17, FIGS. 1-10, specific names were determined by C. A. HOPPING & R. H. WAGNER) added some nine species of plants from other localities in West New Guinea. They are, according to Hopping and Wagner, *Glossopteris* cf. *browniana* Brongn., *G.* cf. *indica* Schimper, *G.* aff. *retifera* Feistm., *Vertebraria* sp., *Taeniopteris* cf. *hallei* Kawasaki, *Cladophlebis* cf. *australis* (Morris), *Pecopteris monyi* Zeill., *Validopteris* sp., *Pecopteris unita* Brongn., and *Sphenophyllum* cf. *speciosum* Royle. There is no doubt that

the mentioned plants belong, as pointed out by Hopping and Wagner, to the Permian flora. However, we are not acquainted with further information to know the more detailed classification of all the plant-bearing beds so far known in West New Guinea into respective series, each representing one stratigraphic epoch. It seems here porbable to assume that there are two alternatives to explain such curious occurrence of elements of essentially different floras in proximity. The one is to assume that the Lower Permian beds, which include the flora of the Cathaysian affinity and referred by Jongmans (1940) to the Djambi flora, are overlain and overlapped by the Upper Permian beds yielding *Glossopteris* and other Gondwanaland elements. The other is to interprete that all of these reported plants are to be lumped together into a single group, which may represent one large mixed flora as the Wankie flora in Southeastern Rhodesia (WALTON, 1929[2]). The writer is now inclined to believe that the first explanation is more probable than the second.

SOME ELEMENTS OF THE GLOSSOPTERIS FLORA COMMON TO INDIA AND CATHAYSIA

Genus *Schizoneura* Schimper & Mougeot

Schizoneura contains several well-defined species as: *S. africana* Feistm., *S. gondwanensis* Feistm., *S.* (*Manchurostachys*) *manchuriensis* Kon'no, *S. striata* Kawasaki & Kon'no, *S. wardi* Zeill., etc. On the origin of *Schizoneura*, Arber (1905, p. 13-14) states as: "— in the rocks of Gondwana land the genus *Calamites* is unknown. We have in its place two other representatives of the same group, *Schizoneura* and *Phyllotheca* —. In *Schizoneura* we have a more distinct type and one almost entirely confined to India during the Permo-Carboniferous period—. We may regard *Schizoneura*, unlike *Phyllotheca*, as essentially of Indian origin, where it first appeared in the earlier *Glossopteris*-bearing series, and later spread to more distant regions." (*see* also K. R. SURANGE, 1955, p. 83).

In Cathaysia, *Schizoneura* has been known by two species as: *S. striata* Kawasaki & Kon'no (1932) and *S.* (*Manchurostachys*) *manchuriensis* Kon'no (1960), both from the Shihhotse series (P_2^1) in NE. China and its equivalent in North Korea. These Cathaysian species resemble very closely *S. gondwanensis* Feistm. which appeared first in the Karharbari epoch and flourished in the Raniganj. The main distinctions between them lie in the maximum number of leaves in a whorl, i.e. in *S. gondwanensis* it is usually 22 rarely 28, while in *S. manchuriensis* 14-16, and in *S. striata* 12. *Manchurostachys* (*Schizoneura*) *manchuriensis* (*see* PL. 1) is represented by a long loose spike being built up by regular alternations of numerous whorls of simple peltate sporangiophores and a magnificient coherent sterile leaf-sheath; the sporangiophore consists of a simple axis and hexasporangiferous polygonal peltate disc bearing ovoid sporangia containing numerous spores of 10-14 μ in diameter. Thus in having regular alternations of numberless whorls of sporangiophores and a large coherent sterile leaf-sheath, *Manchurostachys* (*Sch.*) *manchuriensis* is common with either *Phyllotheca deliquescens* (Goepp.) from the Permian beds in the Lower Tsungusca in Siberia (SCHMALHAUSEN, 1879; SOMLS-LAUBACH, 1891, p. 181, FIG. 17), *P. uluguruana* Gothan (1927, p. 150, PL. 18, FIGS. 6-8) from the Ecca Series in East Africa, or *P.* (*Tschernovia*) *striata* Neuburg (1964, p. 73-75, PL. 42, FIGS. 2-11; PL. 43, FIGS. 1-9) from the Permian beds in the Petchora basin in U.S.S.R. Its main distinction from these fructifications of *Phyllotheca* appears to lie only in the difference in degree of fusion of the sterile leaves in a whorl. In the vegetative shoot, too, *Schizoneura* and *Phyllotheca* are common in having the ridges and furrows on the internodes of the stem being not alternate but continuous at node from one internode to the next, and their leaves in a whorl being united into a coherent sheath. Moreover, according to Surange (1955, p. 83), "In the Glossopteris flora of the southern hemisphere Equisetales is represented by two genera, *Schizoneura* and *Phyllotheca*, against *Calamites* and allied genera in the northern hemisphere." Thus *Schizoneura* (*Manchurostachys*) *manchuriensis* appears to be quite reasonably entitled to be included in the family Phyllothecaceae with its type-genus, *Phyllotheca*, characterized by both vegetative and reproductive features as mentioned above.

As said above, *S. manchuriensis* resembles very closely *S. gondwanensis*, but their fructifications appear to differ considerably from each other. The strobilus of *S. gondwanensis* was first reported by Etheridge (Jun.) from the New Castle Series in Australia under the name *S. australis* Etheridge. This specific name was later merged into *S. gondwanensis* by Arber in 1905, when he described it as: "In one of the specimens figured the leaf-bearing axis is terminated by a pair of compact strobili of 2-2·5 cm. in length (TEXT-FIG. 4). Unfortunately, however, the preservation is not sufficiently good to afford any details as to the morphological structure of the cone." To see his Text-fig. 4, the terminal cone appears to be entirely devoid of any sterile leaf, and if so then they appear to differ essentially from *Manchurostachys*. A similar isolated Equisetalean cone was reported by Srivastava (1952, p. 98; 1954, p. 76-77, FIGS. 22-25) from the Raniganj series in India, which he considered as "a cone probably belonging to *Schizoneura gondwanensis*." After comparing his cone with that of Etheridge's, he concluded: "in my specimen there is no indication of the presence of sterile bracts; —, cones of the *Schizoneura* type are much close to *Equisetum* group than the *Phyllotheca* type." Another similar Equisetalean cone was described by Surange (1955, p. 87, FIG. 11) also from the Raniganj series, which according to him, "resembles very much to that described by Srivastava (1954) which he had ascribed to *Schizoneura*." Thus just contrary to the above-cited conclusion of Srivastava (1954, p. 76-77) with regard to the cone of *S. gondwanensis*? from the Raniganj series, *Manchurostachys manchuriensis* shows a much closer resemblance to the fructification of *Phyllotheca* than that of *Equisetum*. It is, therefore, certain that despite their close resemblance in vegetative features, *S. manchuriensis* differs in fructification considerably from *S. gondwanensis*, at least in the age of the Raniganj and New Castle series. The absence of the insertion of sterile leaves in the cone is generally considered as an essential characteristic of *Equisetum* or *Equisetites*. However, in some fertile shoots either of the Recent *Equisetum* (POTONIÉ, 1921; GOTHAN & WEYLAND, 1954, p. 188, FIG. 171) or of the Upper Triassic *Equisetites* (KON'NO, 1962, p. 30-31, PL. 13, FIGS. 4, 5), cluster of sporangiophores occasionally occur above and below the large sterile leaf-sheath, and this alternation of fertile and sterile members seems to suggest a primitive type of the fructifications of the *Equisetum* group. If it is so, then the fructification of *Schizoneura manchuriensis* also may represent a type more primitive than that of *S. gondwanensis* of the age of the Raniganj series among the cones of *Schizoneura*.

Besides the above mentioned, there are other specimens in the Cathaysian flora, which were only tentatively or incorrectly referred to *Schizoneura*. The type-species for example, of *Lobatannularia* Kawasaki (1927) was first described by Kodaira (1924) under the name of *Schizoneura heianensis*, and transferred by Kawasaki (*l. c.* p. 10) into his new genus, for the reason that the two lobes of its leaf-sheath are not amplexicaul but spread out in one plane oblique or nearly parallel to the stem, and its ultimate stem is terminated in a fan-shaped terminal leaf-whorl. *Lobatannularia* is generally conceived to have been originated from some form of *Annularia* as *A. stellata* (Schloth.) by successive fusion of the leaves in a whorl into two lobes, which is also the case with coherent lobes of the leaf-sheath of *Schizoneura*. However, *Annularia* and *Lobatannularia* are assigned to Calamitales, whereas *Phyllotheca* and *Schizoneura* to Equisetales. Thus we come to a conclusion that *Schizoneura* mixed in the Upper Permian Cathaysian flora is to be taken as an exotic element having migrated from Gondwanaland.

Genus *Rhipidopsis* Schmalhausen

The Genus *Rhipidopsis* was established by Schmalhausen (1879) on the basis of the large petiolate *Ginkgo*-like leaf with large oval lamina, which is split into numerous obcuneate segments of markedly different form and size, traversed by very fine veins. This genus was first found from the Upper Permian beds in the Petchora basin in U.S.S.R., but subsequently it was mainly recorded from India and Argentina, and consequently has been considered as one of the important members of the Glossopteris flora. In India, this genus has been known by two species viz. *R. gondwanensis* Seward from the Barakar series and *R. densinervis* Feistm. from the Raniganj. *Rhipidopsis* in Cathaysia contains four species so far known, all of which are restricted to occur in the Shihhotse (P_2^1) and the Shihchienfeng (P_2^2) series. They are *R. lobata* Halle from the Shihhotse and Shihchienfeng series (HALLE, 1927b, 1935; LEE, H. H., 1963; KAWASAKI, 1939); *R. baieroides* Kawasaki & Kon'no from the Shihhotse and its equivalent series in North and South China and Korea (KAWASAKI & KON'NO, 1932; P'AN, 1936), *R.*

densinervis Feistm. (KAWASAKI, 1931, 1934) and *R. gondwanensis* Seward (KAWASAKI, 1931, 1934), both of the latter two from the Kobosan series (P$_2^1$) in North Korea. In the Angara flora, too, *R. ginkgoites* Schmalh. (SCHMALHAUSEN, 1879) occurs in the Upper Permian beds in the Petchora basin and also in the Upper Permian in the Nanshan Range in China (HALLE, 1935), *R. palmata* Zalessky (ZALESSKY, 1932, etc.; NEUBURG, 1948) in the Upper Permian in the Kuznetsk basin. There arises naturally a question whether *Rhipidopsis* in Angara and Cathaysia is an immigrant from the far distant Gondwanaland as has been considered, or this genus is endemic to these provinces in the northern hemishphere. As mentioned above, in both Angara and Cathaysia all the species of *Rhipidopsis* occur exclusively in the Upper Permian beds, whereas in India in beds ranging from the Lower Permian Barakar to the Upper Permian Raniganj. *Rhipidopsis* is generally considered as one of the oldest representatives of the most vigorous Mesozoic Ginkgoales, and thus this genus seems to have first appeared in Gondwanaland in an age of the earlier Gondwana System or immediately after the ice age, and later migrated therefrom into Angara and Cathaysia.

Genera *Gangamopteris*, *Glossopteris* and *Palaeovittaria*

These three genera are the most important representatives of the Glossopteris flora, and are usually distinguished from one another by the presence or absence of the midrib and difference in anastomosing of the secondary veins of the leaf (*see* SURANGE & SRIVASTAVA, 1956, p. 47). These three genera are collectively grouped together into Glossopteridaceae (ZIMMERMANN, 1959, p. 370-371) or Glossopteridales.

The record of Glossopteridales so far known in Cathaysia is quite limited. A specimen from the Kobosan Series (P$_2^1$) in North Korea, which had been referred to *Gangamopteriopsis*? by Kawasaki (1934, p. 177-178, PL. 106, FIG. 19), was proved to represent a mere fragmental piece of a large leaf of *Chiropteris kawasakii* Kon'no (KON'NO, 1939). *Palaeovittaria*? *koreanica* Oishi (1931, p. 117, PL. 36, FIG. 26) from the Kobosan series (P$_2^1$) in Korea was described by Oishi as: " The midrib is comparatively broad, marked as a shallow furrow on the matrix and resolves into the lateral nerves at a short distance below the broken apical end. The lateral nerves, —" never anastomosing." A similar specimen of a small leaf was recorded by the present author (KON'NO, 1963, p. 153-154, PL. 8, FIG. 11) under the name of *Palaeovittaria parvifolia* Kon'no from the Upper Permian beds in Thailand. This Thailand species is also characterized by a leaf of elongate-oblong shape, with the midrib well-defined for about half the length of the lamina, which then abruptly resolves into numerous radiant veins, and the lateral veins arising obliquely from the midrib, parallel and not anastomosing. Unfortunately each of the Korean and the Thailand species was established on a single leaf specimen, which is much smaller in size than the type-specimen of *P. kurzi* Feistm. from the Raniganj series in India. However, a large leaf similar to the typical *P. kurzi* was described from the Upper Triassic beds in Tongking by Zeiller (1903, p. 81, PL. 16, FIG. 1). Thus although the available materials are not sufficient enough to draw a definite conclusion, the presence of *Palaeovittaria* in the Upper Permian Cathaysian flora seems to be highly possible. *Glossopteris* is the most important element of the Glossopteris flora, but it has not so far been recorded from any Permian beds in China and Korea. As mentioned above, Wagner (1962, p. 745-752, PL. 24, FIGS. 2, 3; PL. 25, FIGS. 5-8) reported from the Upper Permian beds in SE. Anatolia several specimens of typical *Glossopteris* under the name of *G.* cf. *stricta* Bunb. It occurs in close association with *Gigantopteris* of the *nicotianaefolia* type, *Lobatannularia heianensis*, and other elements of the Cathaysian flora. A single imperfect specimen of a linear lanceolate leaf named *G.* cf. *angustifolia* Brongn. was recorded also from the Upper Permian in Thailand by the writer (KON'NO, 1963, p. 152-153, PL. 8, FIG. 12, TEXT-FIG. 2).

SUMMARY

In northern Cathaysia, the main habitat of the Cathaysian flora, several coal-bearing beds containing a rich coal-measure flora were almost consecutively laid down in paralic or lagoonal basins during the age ranging from the Upper Carboniferous (C_3) to the Middle Permian (P_1), under subtropical and humid climatic conditions. Since the mid-Permian crustal movement

(Tungwu Revolution of LEE, J. S., 1939), the northern half of the Cathaysia land began to have dry seasons, and the characteristic Gigantopteris flora was introduced, and rapidly spread over almost the whole surface of Cathaysia. It was in the age of this mid-Permian crustal movement that several elements of the Glossopteris flora as *Schizoneura*, *Rhipidopsis*, *Glossopteris*, and possibly *Palaeovittaria* succeeded in their eastward migration deep into Cathaysia across the Tethys Sea, possibly from near India. However, these stray Gondwanaland genera are only four in number, which constitute only less than 10 per cent of the total genera of the Cathaysian flora in the Upper Permian age ($P_2^1+P_2^2$). Although *Rhipidopsis* shows more or less wide distribution, *Schizoneura*, *Palaeovittaria*, etc. have so far been known to occur in beds as very rare fossils and in very limited localities. These stray Gondwanaland elements seem to have merely played a very minor role in the Cathaysian vegetation in the Upper Permian age. Excepting the Hazro flora in SE. Anatolia, such a mixed flora as having the Gondwanaland elements dominating the Cathaysian has not been detected, even in regions as southwestern China, Thailand, Sumatra, etc. lying relatively near India.

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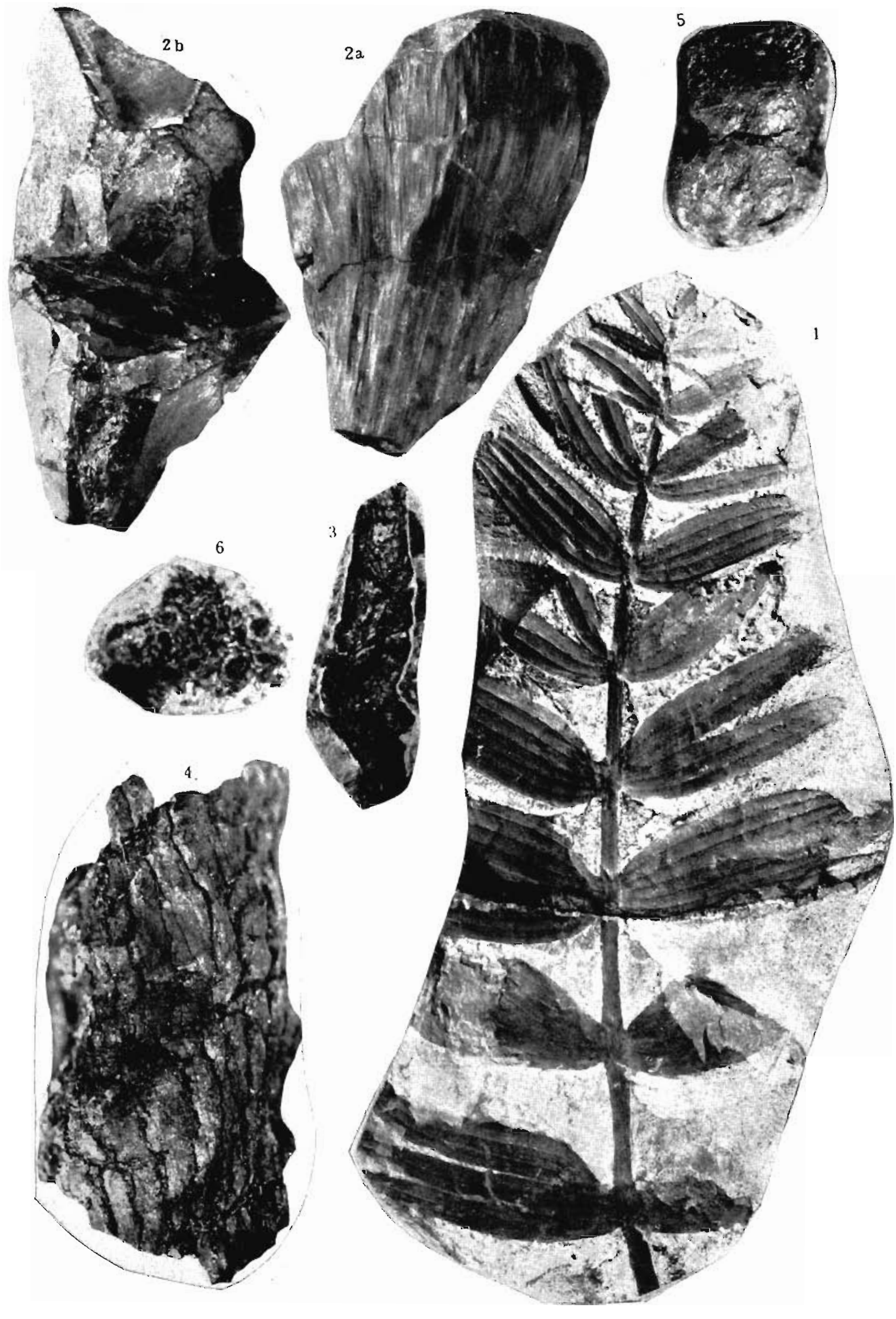
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EXPLANATION OF PLATE

PLATE 1

1. *Schizoneura manchuriensis* Kon'no. Type specimen, showing middle and apical parts of a main foliage stem. × 1.

2a. *Manchurostachys* (*Schizoneura*) *manchuriensis* Kon'no. Back view of a cone, showing a large coherent sterile leaf-sheath composed by complete fusion of all sterile leaf-segments along sutural lines. × 1.

2b. The same specimen, showing front view; fertile axis is seen on lower part, being covered by cluster of sporangiophores; on middle part several whorls of coherent sterile leaf-sheaths are seen. × 1.

3. Type specimen of *Manchurostachys* (*Schizoneura*) *manchuriensis*. Central fertile axis of 55 mm. in length are inserted by six whorls of coherent sterile leaf-sheaths preserved in rock-matrix (not figured here). × 1.

4. Enlarged view of a cylinder of a fertile axis, separated from the upper part of the specimen shown in Fig. 3. × 5.

5. Two sporangiophores showing upper view of peltate disc, about six sporangiophores are radially arranged around central circular depression. × 15.

6. Mass of spores of 11-13μ in diameter. × 760.

(Figs. 1, 2, 3, 4, and 6 are reproduced from paper of Kon'no 1960); all specimens collected from the Upper Permian beds in Penchihu coalfield N.E. China, by E. Kon'no.