Further contributions to the study of the Qubu Flora from southern Xizang (Tibet)

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The taxonomy of *Glossopteris* species occurring in the Qubu Formation is reviewed; *G. xizangensis* is proposed. *Samaropsis xizangensis* is proposed for seeds found attached to *G. xizangensis*. An affiliation with the *Glossopteris* Flora of the Mamal Formation, Kashmir appears valid although the number of distinctive species in common is reduced to *Glossopteris dingriensis*.

Aspects of sporophyte taxa are reviewed in the light of doubts concerning affiliations proposed previously. Additional specimens are needed before problems can be resolved concerning species of *Sphenophyllum* or *Trizygia*, *Austroannularia*, *Cladophlebis* and *Pecopteris*. Scale leaf remains have not been named.

Key-words— Palaeobotany, Glossopteris Flora, Permian, Xizang (Tibet).

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साराँश

दक्षिणी जिजाँग (तिब्बत) से क्यूबु वनस्पतिजात के अध्ययन में और योगदान

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क्यूबु शैल-समूह से प्राप्त *ग्लॉसॉप्टेरिस* की जातियों के वर्गिकीय अध्ययन की विवेचना की गई है; *ग्लॉ. जिजाँगेन्सिस* प्रस्तावित की गई है तथा *ग्लॉसॉप्टेरिस जिजाँगेन्सिस* से संलग्न बीजों के लिए *समारोप्सिस जिजाँगेन्सिस* नामक नाम प्रस्तावित किया गया है। उपलब्ध वनस्पतिजात काश्मीर के मामल शैल-समूह के *ग्लॉसॉप्टेरिस* वनस्पतिजात से सजातीयता व्यक्त करता है, यद्यपि इनमें *ग्लॉसॉप्टेरिस डिंगरियेन्सिस* ही एक अन्तरात्मक सामान्य जाति है।

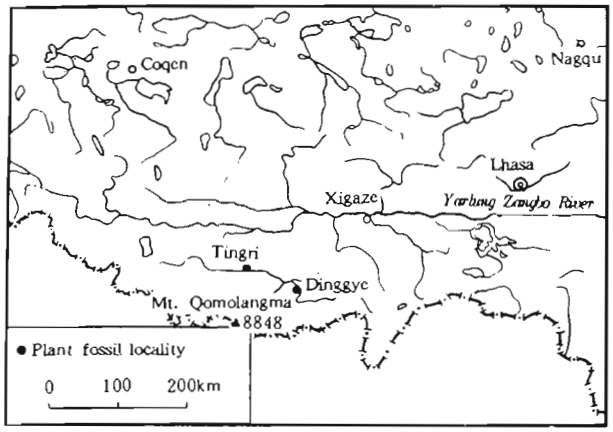
बीजाणु उत्पादक वर्गकों की भी विवेचना की गई है। *स्फीनोफिल्लम्* अथवा *ट्राइजीजिआ, ऑस्ट्रोएनुलेरिया, क्लेडोफ्लेबिस* एवं *पीकोप्टेरिस* जातियों की समस्या का निदान और प्रादर्श उपलब्ध होने पर सम्भव है। शल्क पत्रों के अवशेषों को कोई नाम नहीं दिया गया है।

A Permian Gondwana or Glossopteris Flora from the Qubu region of southern Xizang (Tibet) has been described in the past, based entirely on two collections housed in the Institute of Botany, Academia Sinica, Beijing (Specimen nos. 4737-4783; Hsü, 1975, 1976; Li, 1983; Hsü *et al.*, 1990; Rigby, 1991, Specimen nos. TB 6551 - TB 6571: Hsü, 1973).

A Third collection which has not been described taxonomically, is housed at the Nanjing Institute of Geology and Palaeontology, Academia Sinica. The first and third collections were considered by Li *et al.* (1991) in a paper discussing the biostratigraphical aspects of these floras.

We have re-examined all three collections, and have reclassified some specimens and taxa as a result. Throughout the text, all specimens held by the Nanjing Institute of Geology and Palaeontology, Academia Sinica, are prefixed by NIGPAS, and by the Institute of Botany, Academia Sinica, in Beijing by IBAS. Wang *et al.* (1984) have described the stratigraphy of the area, and given detailed sections at the collecting sites: Tingri, pp. 39-40, fig. 1$_1$-12; Dingjye, p. 44. Localities are shown herein on Text-figure 1.

Q is pronounced as CH in English, and X as SH. Tingri and Dingri are alternative transliterations, other alternative spellings are listed by Mercier & Li (1984, pp. 429-430).



Text-figure 1 — Map showing plant fossil localities described herein.

TAXONOMY

Sphenophylls—General discussion

Specimens previously identified as *Sphenophyllum minor* (Sterzel) Gu & Zhi 1974 are incomplete and not entirely clear. With so little evidence it might be advisable to use a less emphatically Cathaysian name in a flora that otherwise is strongly Gondwanan.

There is also a problem with specimens included in *Sphenophyllum speciosum/Trizygia speciosa.* Our specimens are not particularly good, so we are going to avoid controversy by not naming these specimens at this stage. Some of the problems are: (1) Whether the specimens should be included in *Sphenophyllum* or *Trizygia.* (2) The same species name has been used for what seem to be two distinctive populations, Cathaysian leaf whorls have the ratio between the shortest and longest leaves as 1 to 2 or $1^1/2$, and Gondwanan as 1 to 3. This difference may be of specific rank. (3) The specimens from the Qubu Formation appear to have a Cathaysian morphological ratio.

Austroannularia Rigby 1989

Austroannularia (?) *qubuensis* (Hsü) Rigby 1989

This recombination was made for sphenopsid leaf whorls originally included as *Raniganjia qubuensis* Hsü 1976. Since the recombination was published (Rigby, 1989), doubt has been expressed as to its correctness, hence we question it.

The holotype, IBAS 4738a, is refigured herein (Pl. 1, fig.1). These are the largest leaf whorls of this species found in the Qubu Formation, the smallest is 9 mm in diameter perpendicular to the plane of symmetry, and had 14 leaves estimated from the slightly more than half whorl preserved (specimen IBAS 4775; Pl.1, fig. 2).

Paracalamites Zalessky 1927

Paracalamites australis Rigby 1966

These very common sphenopsid trunks occur in the Qubu Formation. All specimens are narrow, 20 mm diameter or less (Pl. 1, fig. 5, left side). They may have been the trunk of any Gondwanan sphenopsid so could have belonged to any of the sphenopsid leaf species occurring here.

Ferns—General discussion

The fern species *Pecopteris qubuensis* (Hsü) Li 1983 and *Cladophlebis qubuensis* (Hsü) Li 1983 are known only from the Qubu Formation. One or other genus is quite common in many of the palaeogeographically warmer parts of the Carboniferous to Mesozoic land masses, including the Permian of Gondwanaland.

The most widespread fern genus in the Permian of Gondwanaland, *Neomariopteris*, has neither been found in the Qubu Formation nor in the most closely correlatable Mamal and Nishatbagh formations of Kashmir

PLATE 1

Austroannularia (?) qubuensis (Hsü) Rigby 1989

1. Holotype, IBAS 4738a, x 3.
2. Paratype, IBAS 4775, nat. size.

Cladophlebis qubuensis (Hsü) Li 1983

3. Holotype, IBAS 4744, nat. size.
6,7. NIGPAS 8492-130. 6, nat. size. 7 x 3, to show pinna venation.

Pecopteris qubuensis (Hsü) Li 1983

4. NIGPAS 8492-171a, showing pinnule venation, x 3.
5. Right side. Lectotype, IBAS 4742, nat. size.

Paracalamites australis Rigby 1966.

5, left side. Poorly preserved specimen, IBAS 4742, nat. size.

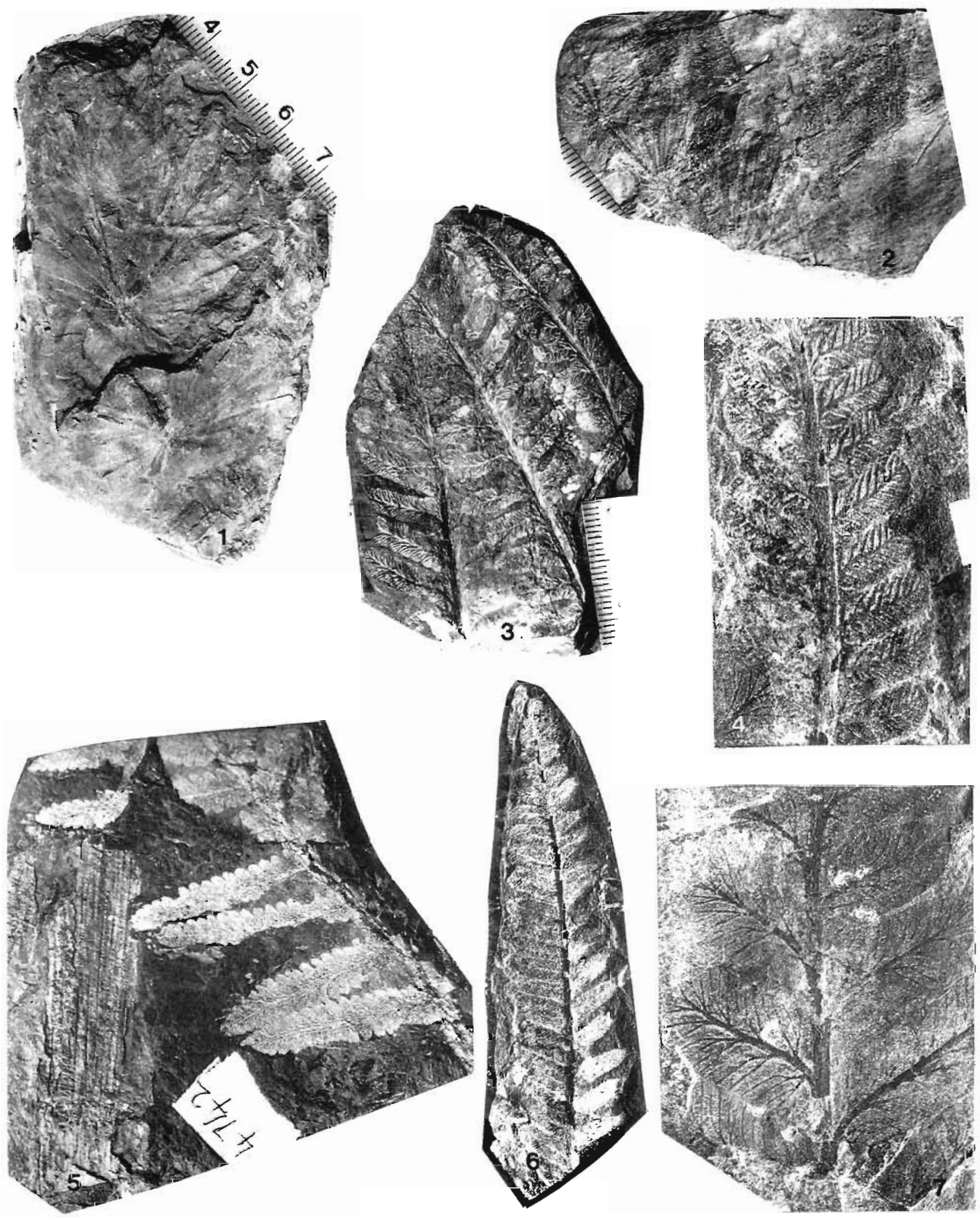


PLATE 1

(see Li *et al.*, 1991; Li & Wu, 1994). This may not have any significance because of the smallness of the available collections examined so far. *Neomariopteris* was a fern that grew in all but apparently the coldest and hottest parts of Gondwanaland. Formerly its Gondwanan species were included in the nonGondwanan genus *Sphenopteris*, which Maithy (1974) explained was inappropriate. Some other fern genera do occur particularly in India, their distribution is not widespread.

A specimen reported by Hsü (1973) as *Sphenopteris* cf. *hughesii* was disregarded in later papers by Hsü, and by others. We consider this specimen to be unidentifiable.

Pecopteris Brongniart 1822

Pecopteris qubuensis (Hsü) Li 1983

In order to validate this species, we select specimen IBAS 4742 as lectotype (Pl. 1, fig. 5) from Hsü's original material. Specimen NIGPAS 8496-17la (Pl. 1, fig. 4) shows the pinna venation clearly.

Asterotheca (?) sp. has been reported from the Qubu Formation (Hsü, 1976; Hsü *et al.*, 1990). Undoubted sori occur on a number of fronds, however, none show an structure whatsoever. We consider the use of this generic attribution to be inappropriate so record them as "fertile fern fronds". They are probably confined to *Pecopteris qubuensis* based on the general frond morphology, but this supposition need not be correct.

Cladophlebis Brongniart 1849

Cladophlebis qubuensis (Hsü) Li 1983

Hsü (1976) described a single specimen by this name, however, he did not nominate it as the holotype. We nominate his specimen, IBAS 4744 (Pl. 1, fig. 3) as lectotype.

The secondary venation of this species is diagnostic (Pl. 1, fig. 7). Most pinnae veins branch dichotomously, and have a second dichotomous branching on one arm of the first branching. This has the appearance of sympodial branching. Sometimes both arms of the first dichotomy are branched, sometimes, neither, and sometimes there is no dichotomous branching at all. Specimen NIGPAS 8492- 130 (Pl. 1, fig. 6) shows all of these variations.

It is interesting to note that *Palasthalia indica* Srivastava 1992 from the Barakar Formation of India has identical venation within individual pinnae but its pinnules are auriculate and the frond is unipinnate, whereas in our specimens the frond is bipinnate and pinnae are decidedly adnate along the stem. The specimen from Xiagangjiang identified in Li *et al.* (1985) as *Pecopteris* aff. *arcuata* also has similar venation. Li and Wu (1994) are of the opinion that the total flora from this site is a "mixed Permian Cathaysian Gondwana flora". The presence of ferns south and north of the Indus Yarlung Zangbo Suture and in the Peninsular India with this distinctive venation may indicate some palaeogeographical connection between these areas, even though the pinnule attachment is different, adnate as against auriculate.

Glossopteris Brongniart 1828

Glossopteris dingriensis Ribgy, in Hsü, Rigby & Duan 1990

Diagnosis (Slightly amended from Hsü *et al.*, 1990, pp. 237, 242) — Long narrow leaf, parallel sided for much of its length, tapering very gradually towards the apex over a distance of about four times the maximum leaf width, apex very acute, coming to a rounded tip; base also gradually tapering; secondary venation moderately arched, parallel, of the *communis* type; one or two dichotomies and up to three anastomoses along each

PLATE 2 ⟶

Glossopteris dingriensis Ribgy, in Hsü, Rigby & Duan 1990

1. Typical middle region of leaf, from Tingri, IBAS 4750, nat size.
2. Leaf, basal region, NIGPAS 8492-105, nat. size.
3. Holotype, middle region of leaf, from Dingjye, IBAS 4758b, nat. size.
4. Leaf narrowing towards apex, NIGPAS 8492-1, nat. size.
5. Paratype, leaf apex, from Dingjye, IBAS 4759, nat. size.
6. Less acute apex, showing venation, NIGPAS 8496-18, x 3.
   Glossopteris sp. cf. *G. communis* Feistmantel 1876
7. Largest of the doubtful leaf fragments, NIGPAS 8492-98, x 3.

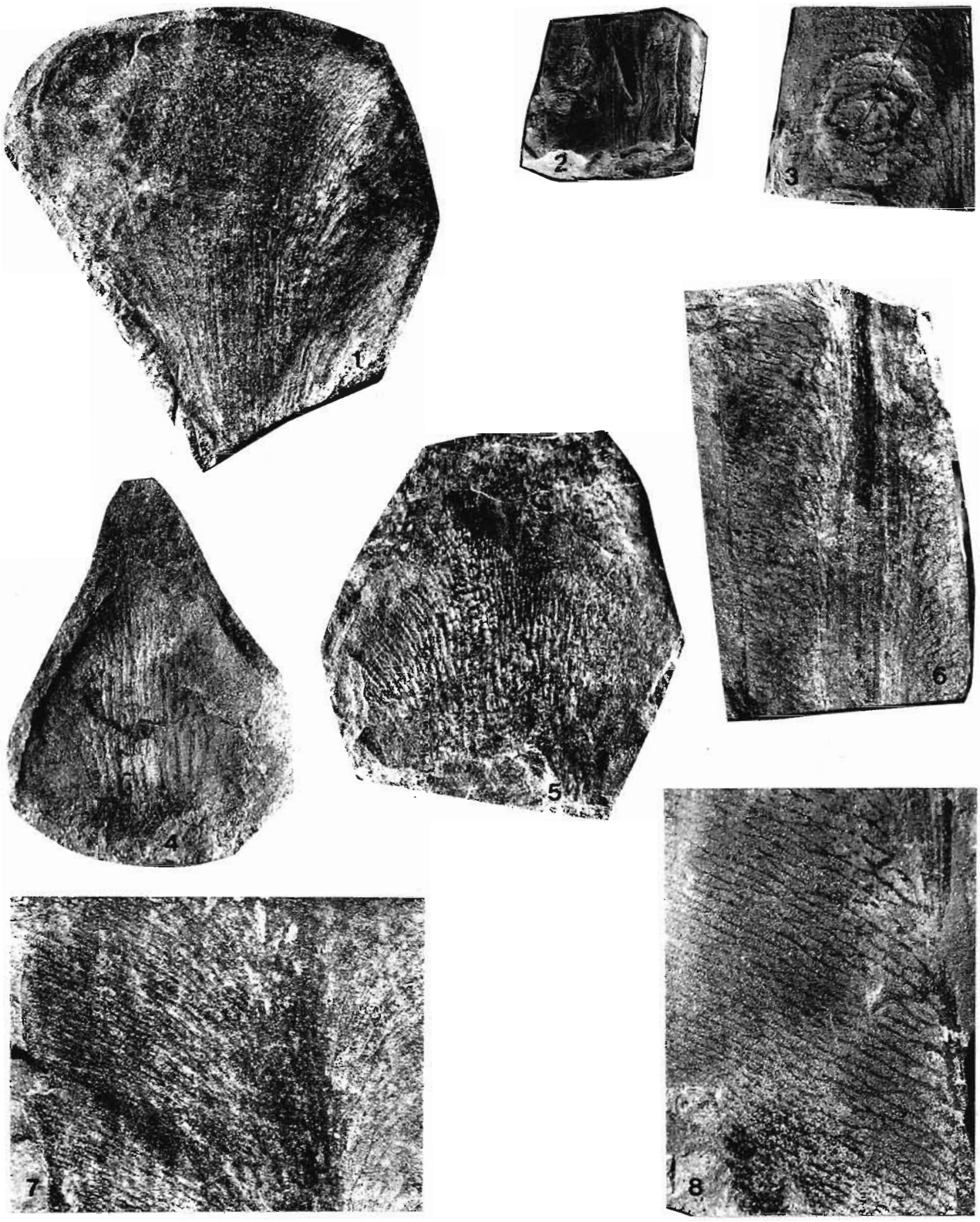


PLATE 2

vein; cross veins not seen. Epidermal structure and fructifications unknown.

Description and comparison — No complete leaves of *Glossopteris dingriensis* are known. The majority of specimens are parallel-sided middle part of leaves. These have a similar venation pattern to *Glossopteris communis* Feistmantel 1876, from the Early Permian of India, however, our leaves are distinguished by having parallel sides compared with gently curved sides in *G. communis*. The apical and basal portions of the leaves are quite distinct from those of all other species because of their narrowly acute shape, and the curved apex. The midrib is comparatively slender with a maximum known width of about 2 mm at the base; it extends almost to the apex. The secondary venation branches at an acute angle from the midrib, then curves parabolically to the margin, marginal angle averaging 52° (range 45°-60°), degree of arching averaging 16° (10°-20°). A small number of leaves have a more or less uniform vein spacing across the blade width (15-25/cm), but most have more widely spaced veins near the midrib (15 - 25/cm) than near the margin (25-30/cm). In all cases the density of the venation is measured parallel to the midrib. All known basal and apical regions have the same density as the second group. Leaves with almost uniform density throughout may prove to belong to some new species if further, better specimens are found.

The largest sized specimens are: apical region — 55 mm long; mid portion - length 93 mm, maximum width 40 mm (average 25 mm); basal region - 82 mm long. A leaf restoration based on these dimensions would be at least 200 mm long. Specimen NIGPAS 8496-18 (Pl.2, fig. 7) is a much more distinctive apical specimen than the paratype IBAS 4759, although somewhat less acute than usual.

The narrow leaf with a very acute apex is not common within *Glossopteris* species. It occurs in some smaller leaves including *G. angustifolia* and *G. linearis* but these species have a different secondary venation. *Glossopteris arberii* Srivastava 1956 from the Raniganj Stage, India, is similar in size and shape to what we envisage *G. dingriensis* would have been except it had a less acute, more rounded apex, was not as strikingly parallel sided and had less arched venation. We do not know of leaves from elsewhere in Gondwanaland having a similar shape and a *communis* type of venation. We consider the leaves from this locality identified as *G. communis, G. intermittens* and *G. indica* usually belong to *G. dingriensis*, although we have compared one fragment with *G. communis* (Pl. 2, fig. 6) implying by this only that it has a *communis* type venation and differs from our concept of *G. dingriensis*.

Type specimens (nominated in Hsü *et al.*, 1990) — holotype - IBAS 4738b (Pl. 2, fig. 3); paratypes - IBAS 4759 (Pl. 2, fig. 5), IBAS 4776.

Glossopteris xizangensis Li & Rigby sp. nov.

Diagnosis — Narrow, apparently linear leaf of unknown length, midrib broad compared with leaf width, secondary venation strongly arched near the midrib, then almost straight and parallel to the margin which is intersected at a high angle, veins dichotomizing once or twice, anastomosing up to three times, cross connections common, these branchings giving rise to six or more meshes between the midrib and the margin, meshes up to three times as long as broad. The fertile leaf bears a single row of *Samaropsis xizangensis* sp. nov. along each side of the midrib, number of seeds unknown.

Holotype — NIGPAS 8496-1; (Pl. 3, figs 2, 3.

Other figured specimen — NIGPAS 8496-112; (Pl. 3, fig. 6).

PLATE 3 →

Scale leaves, x 3

1. This specimen has an apical margin, but it may be a severely damaged leaf, NIGPAS 8492-305.
2. NIGPAS 8492-116.
3. Different taxon from the specimen shown on fig. 18, NIGPAS 8492-171c.
   Glossopteris xizangensis Li & Rigby sp. nov.
4. Holotype, NIGPAS 8496-1, nat. size.
5. Portion of fig. 16, x 3.
6. Paratype, showing venation and broad midrib, NIGPAS 8496-117, x 3.
   Glossopteris dingriensis Rigby, in Hsü, Rigby & Duan 1990
7. Typical venation pattern in the mid region of the leaf, NIGPAS 8492-1, x 3.
   Glossopteris sp.
8. Fragment of leaf having a venation similar to that of a number of Indian species, NIGPAS 8492-92, 3.
   Samaropsis xizangensis Li & Rigby sp. nov.

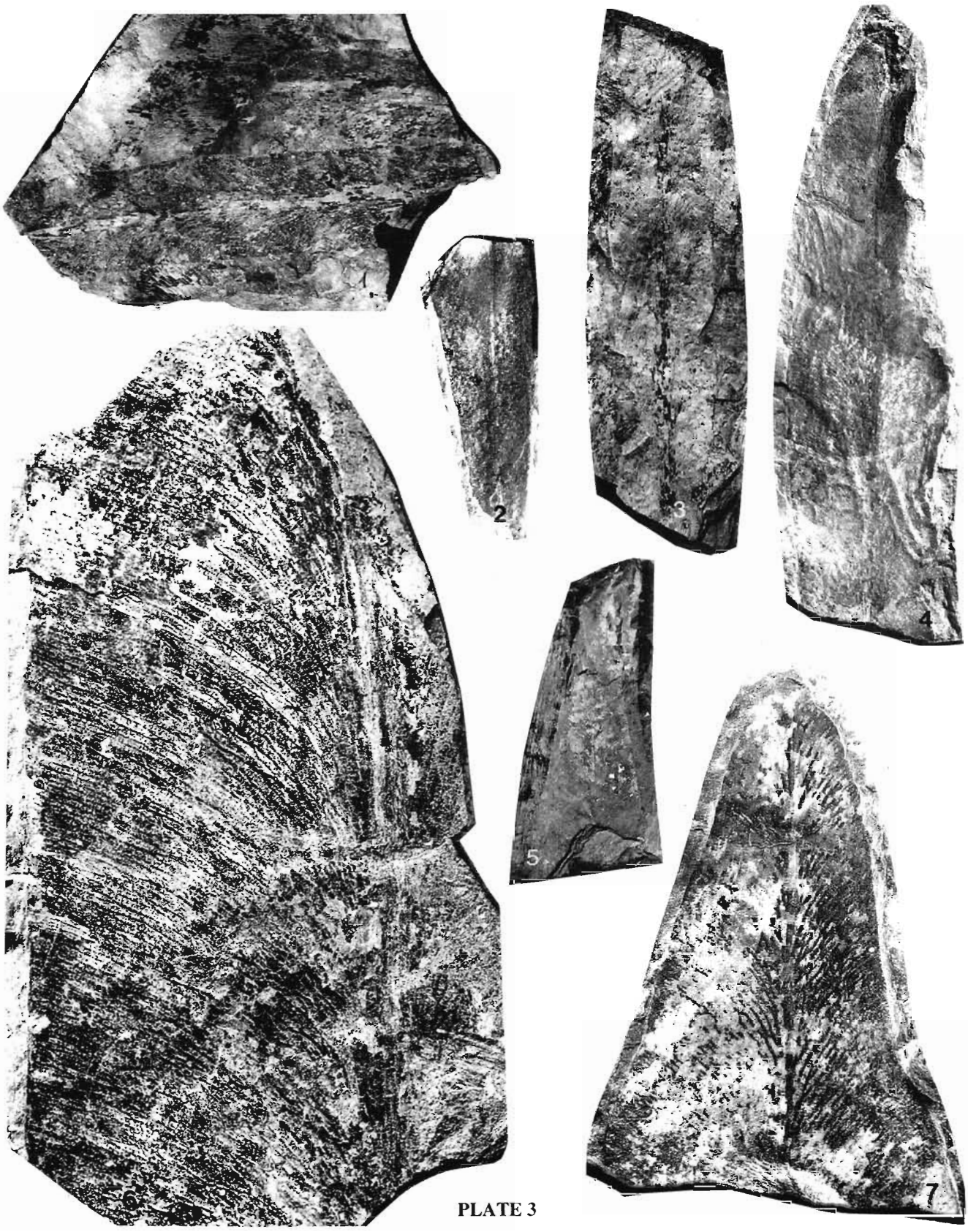


PLATE 3

Type locality — NIGPAS 4896.

Description and comparison — The holotype was selected as it is the only apparently seed-bearing specimen.

Leaf width, midrib to margin: 11 mm; midrib width: 5.5 mm at the level of the seeds; degree of arching: 5°; marginal angle : 85° - 90°. Largest specimen (NIGPAS 8496-112): 36 mm; leaf margin almost parallel to the midrib except for basal 13 mm when the blade narrows and disappears.

This new species is closest morphologically to *G. stricta* Bunbury (1861, pl. 9. fig. 5), whose type specimen is very much larger and more robust, more than twice as large, and has two rows of very pronounced, almost equidimensional polygonal areoles adjacent to the midrib formed by the secondary venation. These are absent in *G. xizangensis*. The Qubu Formation where *G. xizangensis* occurs is of Early Permian age whereas *G. stricta* is found in the Kamthi Formation of Late Permian age.

The seeds are indistinct as they are covered by leaf blade tissue, however, the essential dimensions of the best preserved seed can be observed. This forms the basis of *Samaropsis zizangensis*, described below. It is not possible to name the fructification, but the seeds are arranged in a single row on either side of the leaf midrib rather similar to the arrangement of sporangia clusters found in *Glossotheca* Surange & Maheshwari 1970 in preference to the long stalked, four seeded arrangement found in *Partha* Surange & Chandra 1973.

Glossopteris spp.

There are a number of small fragments of leaves displaying features different from *Glossopteris dingriensis* and *G. xizangensis*. None can be identified, and most appear to be distorted. Specimen NIGPAS 8492-98 (Pl. 2, fig. 6) is the best preserved which we compare with *G. communis* from the Karharbari Formation of India using the description and figures given by Chandra and Surange (1979). The fragment figured on Pl. 3, fig. 8 is similar to a number of Indian species, we call it *Glossopteris* sp.

Samaropsis Göppert 1864

Samaropsis xizangensis Li & Rigby sp. nov.

Diagnosis — Seed almost circular, obovate, body 4 mm long, 3.6 mm wide, slightly cordate at the base, wing broadest laterally, 2 mm wide, narrowing to 0.5 mm at the apex, absent at the base where it is possibly notched. The holotype appears to be attached to a leaf of *Glossopteris xizangensis*.

Holotype — NIGPAS 8492-1 (Pl. 3, figs 2, 3).

Comparison — Very few Lower Gondwanan seed species of any genus have laterally broadened wings, most have wings broadened towards the apex. *Shivacarpus latus* Pant, Nautiyal & Tiwari 1985, which is based on microstructures, is from the Karharbari Formation of India. It has a proportionately narrower central body and a wider lateral wing.

Scale leaves

These scale-like organs have been shown to belong to the pollinate structures of *Glossopteris*-bearing plants (Surange & Chandra, 1974). The three examples figured (Pl. 3, figs 1, 4, 5) all belong in different species, which, at this stage, have not been identified because none is sufficiently complete. One might be a severely damaged leaf base (Pl. 3, fig. 1) although the apical region is bounded by what looks like a margin.

Vertebraria Royle (1839) 1840

Vertebraria indica Royle (1839) 1840

A few poorly preserved specimens having the distinctive segmented structure of this root genus have been found. Specimen, NIGPAS 8496--260 is the only one in the position of growth. It has been distorted when the enclosing mudstone was compressed during burial as it grew across the bedding plane.

Banerjee *et al.* (1991) and Banerjee (1991) has figured some specimens of *Vertebraria* in a growth position attached to an upright stem bearing leaves of *Glossopteris* thus confirming the supposition that both genera may have belonged to the same plant. Not all *Glossopteris*-bearing plants had roots of *Vertebraria* as *Vertebraria* is unknown, or rare in the earliest Permian,

e.g., in India where *Vertebraria* is unknown in most fossiliferous sites in the Talchir Formation (distribution from: Lakhanpal *et al.*, 1976; Chandra & Tewari, 1991).

Roots

A number of root cluster occur in the collections. These have no stratigraphical significance. Biologically they indicate that at least some plants besides *Vertebraria* grew in situ in the, now, fossiliferous mudstone.

DISCUSSION

We include observations based on collections made in the Permian Qubu Formation in southern Xizang housed in the Nanjing Institute of Geology and Palaeontology, Academia Sinica, and the Institute of Botany, Academia Sinica, in Beijing. Li and Wu (1994) have summarized evidence that there are no species in common found between the Nishatbagh Formation (Kashmir) on the one hand and both the Qubu Formation and the Mamal Formation (Kashmir) on the other. A comparison between these latter floras is tabulated below.

SPECIES	Qubu Formation	Mamal Formation
Trizygia speciosa	(1)	x
Sphenophyllum minor	cf	cf
Lobatannularia ensifolia	-	x
L. sinensis var. *curvifolia*	-	x
Austroannularia (?) *qubuensis*	x	-
Paracalamites australis	x	-
Pecopteris qubuensis	x	-
Pecopteris mamalensis	-	x
Cladophlebis qubuensis	x	-
fertile fern fronds	x	-
Glossopteris communis (2)	cf	cf
G. cordatifolia	-	cf
G. dingriensis	x	x
G. intermittens	-	x
G. taeniopteroides	-	x
G. xizangensis	x	-
Samaropsis xizangensis	x	-
Vertebraria indica	x	-
Scale leaves	3 or 2 spp.	-
Ginkgophyllum hydonii	-	x
G. sahnii	-	x

(i) This record may belong in either *Trizygia* or *Sphenophyllum*.

(ii) These two comparisons are not necessarily equivalent.

Other than correlation by means of *Glossopteris dingriensis*, correlation by means of the other species is generalized. We still have a number of problems to solve before the full significance of this flora can be assessed. These problems include the interpretation and identification of fern foliage, and the sphenophylls.

Li and Wu (1994) have discussed relationships of the floras, and Permian palaeogeography of the area. Their final conclusion is also appropriate here. "In conclusion, it must be remarked that while discussing the relationship between a mixed flora and any known flora, the most important problem lies in whether the identification of the diagnostically floristic elements is accurate."

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