ON THE PALAEOBOTANICAL EVIDENCE FOR CONTINENTAL DRIFT AND HIMALAYAN UPLIFT

J. HSÜ

Palaeobotanical Laboratory, Institute of Botany, Academia Sinica, Peking, China

ABSTRACT

This paper provides some recent palaeobotanical evidence from Tibet. The *Glossopteris* flora from the Qubu Formation of Southern Tibet shows no relationship with the *Gigantopteris* flora of Northern Tibet. The fossil localities are only about 600 km apart from each other, yet these two floras are so distinct. They strongly support the view of continental drift that the India block drifted in Cretaceous from the south-eastern corner of Africa and later on in Eocene joined up with Asia to become its subcontinent.

The Cretaceous to Early Eocene flora obtained from Lhasa, Rikaze and Ali of Tibet do not show any relationship with the Deccan Intertrappean flora of India which demonstrates that the initial contact of the drifting India plate and the Eurasia plate began sometime after Early Eocene. The suture of these two plates perhaps lies in the belt of basic to ultrabasic rocks, along the Yalu Tsangpo valleys as suggested by some Chinese geologists.

The writer agrees with the view that the Himalayan uplift is due to the collision of the drifting India plate against the Eurasia plate. The Gandis Mountains may have been uplifted in the Eocene, earlier than the Himalayas. The Himalayan uplift probably began in Miocene, but went on more actively in the Quaternary. The uplift of the Tibetan plateau is also caused by the collision of these two plates, but the upheaval goes on gradually in Miocene.

INTRODUCTION

UPLIFT of the Himalayas is one of the fascinating events happening in the Cenozoic, but the formation of the Himalayas has to be traced back to the Mesozoic, even to the Palaeozoic times.

According to the traditional school, the Himalayan region was a wide geosyncline in the Late Palaeozoic and the Mesozoic, known as the Tethys, which received several thousand metres of marine sediments. These were later folded, faulted and uplifted to form the Himalaya Mountains.

Alfred Wegener (1928) and others (Sahni, 1936; Du Toit, 1937), however, held that in the Late Palaeozoic all the now separate southern continents, together with the India block, were once united as a single land mass, the Gondwanaland. Owing to horizontal movement of the earth crust, the Gondwanaland was fractured into several continents, which subsequently drifted horizontally to their present positions. Since Late Cretaceous the India block drifted northward from the south-eastern corner of Africa and joined up with Asia in the Eocene to become a subcontinent of Asia (Molnar & Tapponnier, 1975). As a consequence of the collision of the drifting India block against Eurasia, the Himalayas came into being.

It is the latter view that has gained wide acceptance among palaeobotanists in the light of the well-known existence, towards the end of Palaeozoic, of four more or less well-defined floras on the earth — the Angara, the Euramerican and the Cathaysian floras in the northern hemisphere and the Gondwana flora in the southern hemisphere (Gothan & Weyland, 1964). The three northern floras have much more elements in common with each other than with those of the Gondwana flora.

The Cathaysian flora predominates in *Calamites*, *Annularia*, *Lobatannularia*, *Tingia*, *Lepidodendron*, *Pecopteris*, *Sphenopteris*, *Alethopteris*, *Neuropteris*, *Gigantopteris*, *Gigantonoclea*, *Cathaysiopteris*, *Taeniopteris* and *Cordaites*. Woods are much unifarm in structure.

The Gondwana flora is characterized by the predominance of *Glossopteris* and *Gangamopteris*, along with *Schizoneura*, *Phyllotheca*, *Stellotheca* (now *Lelstotheca*), *Raniganjia*, *Dizeugotheca*, *Neomariopteris*, *Dichotomopteris* and *Noeggerathiopsis*. Woods are marked with well-defined annual rings.

These two floras being entirely different in composition had developed independently in different geographical environments. The Cathaysian flora must have developed in the region near, or at, the equator, under tropical to subtropical climate analogous to what had produced the European coal measures, while the Gondwana flora flourished in the region much closer to the south pole, probably under a cold temperate climate just emerging from glaciation. Yet China, Thailand, Malayan Peninsula and Sumatra lie at present dovetailed with the Indian subcontinent. Such a situation can only be explained this way. These two provinces originally lay far apart from each other, being situated north and south of a very wide Tethys, but have since drifted towards each other.

Recently, the advent of palaeomagnetic studies as well as sea-floor spreading and plate tectonic concept has strongly supported the view of continental drift. The relative positions of the India plate and the Eurasia plate at various anomalous times since the Late Cretaceous as calculated by many geologists (Molnar & Tapponnier, 1975) show beyond doubt that the India plate moved gradually towards the north, and collided with Eurasia plate in the Eocene. The uplift of the Himalayas is, therefore, a consequence of the India-Eurasia continental collision.

PALAEOBOTANICAL EVIDENCE FOR CONTINENTAL DRIFT

Some years ago, the northern boundary of the Gondwanaland was considered to be at the Himalayan region, because the northern limit of the *Glossopteris* flora was only known from Gulmarg of Kashmir (Seward, 1907) and Sadiya of Assam (Fox, 1934), both of which lie along the south side of the main Himalayas.

However, in the year 1966, the Scientific Expedition Party of Academia Sinica discovered a *Glossopteris* bed from Woluluo (ca 28°15'N; 86°48'E), Quzong (Map 2), of the district Dingri in Southern Tibet which is about 35 km north of the Himalayas. From this bed, *Glossopteris communis* Feistmantel, *Sphenopteris* cf. *hughesi* (Feistm.) Arber and *Pecopteris* sp. were described (Hsü, 1973).

Ten years later, the same party collected some more fossils from Qubu (Map 2), near Woluluo, and Kujian (Map 2, ca 28°15'N; 88°5'E) of the district Dingjie, Southern Tibet, which is about 100 km east of Quzong and about 50 km north of the Himalayas. From Qubu, *Glossopteris communis* (Pl. 1, figs. 1-3), *G. indica* Schimper (Pl. 2, fig. 1), *Sphenophyllum speciosum* (Royle) McClelland, *Raniganjia qubuensis* Hsü (Pl. 2, fig. 2), *Dizeugotheca qubuensis* Hsü (Pl. 2, figs. 3-4, 5-6) and *Dichotomopteris qubuensis* Hsü (Pl. 3, figs. 1-2) were described. From Kujian, *Glossopteris communis* (Pl. 1, fig. 4) and *G. angustifolia* Brongn. (Pl. 1, figs. 5-6) and an unnamed fern were recorded (Hsü, 1976). Under critical survey, all the fossils were actually collected from the same Qubu Formation which is widely distributed in a belt extending from Longda, Selong, Tulong, Qubu to Quzong, about 35-50 km or more, north and roughly parallel to the Himalayas.

In this flora *Glossopteris communis* is the most prominent element. This species is widely distributed in the beds ranging from the Talchir to the Raniganj Series of India and is also known from the Permian of Australia, Antarctica and South Africa. *G. indica* is known from the Lower Gondwana of Kashmir and is widely distributed from the beds ranging from the Talchir to the Panchet of India, and is also known from the Dwyka, the Ecca and the Lower Beaufort of Zäire and other countries in South Africa, the Upper Carboniferous of Brazil, the Lower Gondwana of Argentina. *G. angustifolia* is distributed in the Raniganj Series and the Panchet Series of India, the Lower Gondwana of Antarctica and the Permian of south Africa. *Dizeugotheca* has so far been known only from the Raniganj Series of India and the Permian beds of Argentina and Bolivia of South America. *Dichotomopteris* is restricted to the Raniganj Series of India. *Sphenophyllum speciosum* has been recorded from the Barakar and the Raniganj of India, the Lower Beaufort of south Africa and the Lower Gondwana of Australia, Queensland and Argentina. As *Raniganjia, Dichotomopteris* and *Dizeugotheca* are typical Gondwana plants and restricted to the Raniganj Series of the Indian Subcontinent, and no *Gangamopteris* is found in these collections, the Qubu Formation is considered to be equivalent to the Raniganj Series of India.

The Qubu Formation is mainly composed of quartzite sandstone and carbonaceous shales, with a thickness of only 20 m. The location of the Qubu Formation is only 300-400 km north of the Raniganj Coalfield of West Bengal. Though the Qubu Formation lies on the north side of the Himalayas, it may represent the northern most extention of the Raniganj Series in Southern Tibet.

Furthermore, the Qubu Formation conformably overlies the Jilong Formation which is about 700 m thick and consists of fine to quartzose sandstones intercalated with shales. These sediments are glacial and marine in origin, yielding *Stepanoviella* fauna of Late Sakmarian to Early Artinskian stage, comparable with the Umaria marine beds or *Eurydesma* fauna of the Indian subcontinent (Yin & Guo, 1976).

The Himalayan region is, therefore, a part of the old Gondwanaland, whose northern boundary would be situated somewhere north of the belt of the Qubu Formation.

About 150 km north to the belt of the Qubu Formation lies the Yalu Tsangpo River. Immediately at the southern bank is situated a part the Rikaze Group, which is mainly composed of limestone. Its lower part contains such forms as *Orbitolina concava, O. concava qutarsca* and *Daxia cenomova* of Cenomanian age, and in the middle to upper parts the Turonian ammonites *Mammites* and the Late Cretaceous gastropod *Plesioptymatis* have been obtained. Plant fossils preserved in the shales intercalated in the limestone are apparently of northern hemisphere in affinity. They are *Populus latior* Braun, *Salix* cf. *meekii* Newb., *S. lesquireuxii* Berry, *S.* cf. *flexuosa* Newb., *Juglans sinuatus* Lesq., *Ficus daphnogenoides* (Heer) Berry, *Cercidiphyllum ellipticum* (Newb.) Brown, *Rhamnites eminens* (Bawson) Bell, *Aralia firma* Guo, *Viburnum asperum* Newb., *Cyperacites* cf. *hayeenii* Lesq., *Eucalyptus angusta* Valen., *E. geinitzii* (Heer) Heer, *Cotinus* cf. *coggygria* (L.) Scop., *Tsuga, Euonymus, Typha, Ficus,* and *Leguminosites* (Guo, 1975; Geng, unpublished paper).

In the localities Linbuzong and Niumagou, near Lhasa, a wealden flora has been found in some brownish grey sandstone and dark greyish shales. It is represented by *Weichselia reticulata* (Stokes et Webb.) Ward, *Zamiophyllum buchianum* (Ett.) Nathorst, *Cladophlebis browniana* (Dunker) Seward, *Ptilophyllum, Taeniopteris* and *Onychiopsis* (Tuan, Chen & Geng, 1977). *Zamiophyllum buchianum* has only been found in Europe, North America, Japan and Gansu (=Kansu) of North China. Evidently this flora is closely related to that of Europe and North America and has nothing to do with the Indian flora of the same age. So, if the time of initial contact between India plate and Eurasia plate is really in the Eocene, then the suture would lie south of the *Weichselia* beds and the belt of Rikaze Group.

Immediately south to the Rikaze Group lies a belt of basic to ultrabasic rock complex of Cenozoic age. According to Yin (1973) and Li (1975) the suture of the India plate and the Eurasia plate is probably located there (Zhu *et al.*, 1977). Based upon the data of tectonic geology, Molnar and Tapponnier (1975) also suggested that in part the Indus and Shangpo (=Yalu Tsangpo) valleys mark the precollision boundary of the India and the Eurasia plate. Zhu and others (1977) further stated that magnetic declinations of the remanance measured from the red sandstone of Late Cretaceous-Palaeocene in age at Linzhou (Map 1) (ca 28°30′N; 90°10′E), near Lhasa, differ from those of the Deccan Traps. So they arrived at the conclusion that the suture lies between the Salt Range and the Indus-Yalu-Tsangpo valleys.

According to the report of the Scientific Expedition at the Mt. Jolmo Lungma Region, 1966-1968, geology (1974), the rocks along the south bank of the Yalu-Tsangpo River was extremely fractured. On the southern slope of the Gandis Mountains, the Lower Cretaceous is very complex in its make-up, for some huge erratic blocks are mixed with Cretaceous flysch and ultrabasic rocks. Besides, a gigantic thrust (Map 2) occurs along the belt of basic-ultrabasic rocks parallel to the Himalayas. All these indicate that the line of collision between the India plate and the Eurasia plate most probably would lie along the belt of basic-ultrabasic rocks.

NO RELATIONSHIP BETWEEN CATHAYSIAN & GLOSSOPTERIS FLORA

As pointed out above, the Cathaysian flora and the *Glossopteris* flora are entirely different. Hardly any relationship could be expected between them. This problem was critically discussed by various geologists and palaeobotanists in the Sixth International Botanical Congress held in 1935 and the Second Congress of Carboniferous Stratigraphy of the same year. As far as we know since then most palaeobotanists have held that the Cathaysian flora had nothing to do with the *Glossopteris* flora of the Indian Subcontinent. However, in recent years Kon'no (1965) and Lee (1974) have raised some objections to it.

In 1952, the flora of Kuangshanchang Coal Series (ca 26°36'N; 103°30'E) from Huiche (=Huize) of north-eastern Yunnan, which is a typical Cathaysian flora of Early Permian, was reported (Hsü, 1952). It serves as a link between the flora of North China and Korea on the one side and that of Sumatra on the other. Huiche is very close to Sadiya (ca 27°18'N; 96°E) of Assam where the eastern limit of the Indian Lower Gondwana is located, but no single Gondwana element has been found in this flora. It is inconceivable that there is any relationship between the Cathaysian flora and the *Glossopteris* flora during Early Permian. To this, almost all palaeobotanists agreed (Asama, 1966, p. 177).

As to Upper Permian floras, many authors have carefully investigated on both sides. In the *Glossopteris* flora of the Indian subcontinent again no single Cathaysian element has so far been observed. Moreover, formerly a great many of the plant recorded in the Gondwanaland, which had been classified on the basis of superficial resemblances as northern genera and even species, such as, those of *Pecopteris, Sphenopteris, Alethopteris* and *Merianopteris,* are now proved on more critical study to be distinctly southern. For this reason, many plants have already been adopted new generic names, such as, *Dizeugotheca* (Archangelsky & Sota, 1960) and *Dichotomopteris* and *Neomariopteris* (Maithy, 1972, 1973).

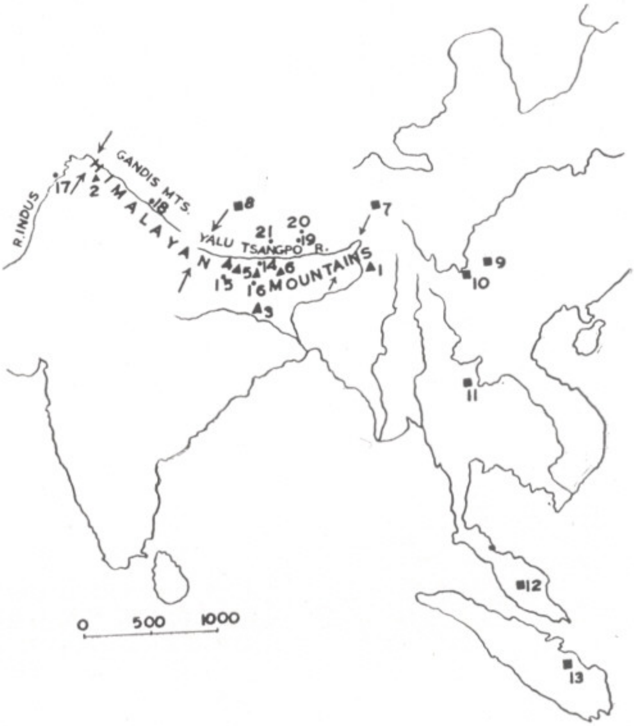
The Chinese Upper Permian plants were carefully reinvestigated by us a few years ago, though disagreeing in a few points, such as the identification of *Glossopteris guizhouensis.* This species was included in the book entitled "The Chinese Palaeozoic Plants", published in 1974.

The Upper Permian Hsianwei flora of south-western China and the Longtang flora of East China are practically the same. This flora is mainly represented by *Lepidodendron, Lobatannularia, Annularia, Pecopteris, Compsopteris Gigantopteris, Gigantonoclea, Taeniopteris, Rhipidopsis* and *Ullmannia.* The fossil woods, so far as the present author has examined, are not marked with annual rings. The tree fern *Psaronius* has frequently been recorded from the Permian of south-western China. Besides, *P. chinensis* described by Sze from the Omeishan intertrappean beds, another *Psaronius, P. hexagonus* sp. nov. have been described of the same age. This genus is now known to be widely distributed in eastern Yunnan, north-western Kueichow and south-western Szechuan, ranging from the upper part of Lower Permian to the upper part of Upper Permian, including many species which remain to be studied. The climate of Southern China was then very warm, somewhat tropical in nature.

The Hsianwei flora of Panxian (Map 1), Kueichow is mainly represented by *Gigantonoclea lagrelii* (Halle) Koidz, *G. guizhouensis* G. et Z., *G. hallei* (Asama) G. et Z., *G.*? cf. *longifolia* (Halle) G. et Z., *Pecopteris sahnii* Hsü, *P. echinata* G. et Z., *Danaeites rigida* (Y. et O.) G. et Z., *Annularia shirakii* Kaw., *A. pingloensis* (Sze) G. et Z., *A. mucronata* Schenk, *Lobatannularia multifolia* Kon'no, *Compsopteris contracta* G. et Z., *C. imparis* G. et Z., *Plagiozamites oblongifolius* Halle, *Ullmannia* cf. *bronnii* Goepp., and *Neuropteridium coreanicum* Koiwai.

The Upper Permian flora found in Northern Tibet is similar to that of Panxian, Kueichow. From Changdu (Map 1) (ca 30°31'N; 95°36'E) of north-eastern Tibet, *Pecopteris echinata, Lobatannularia multifolia, Sphenophyllum* sp. and *Lepidodendron* sp. were obtained. From Shuanghu (Map 1) (ca. 33°30'N; 86°48'E) of north-western Tibet, *Annularia pingloensis, Pecopteris shuanghuensis, Gigantonoclea guizhouensis* (Pl. 3, figs. 3-5) and *Compsopteris contracta* were collected*. The latter flora so far known to be the western most extension of the Cathaysian flora is about 640 km from Qubu and Quzong, and about 670 km from Kujian. Changdu is even much closer to Sadiya, only about 400 km apart from

*This flora is going to be investigated by the Nanking Institute of Geology and Palaeontology and the Botanical Institute, Academia Sinica.



MAP 1 — Fossil localities mentioned in this paper. ■, Cathaysia flora; ▲, Glossopteris flora; ↑, indicating the direction of crustal movement of the India plate and the Eurasia plate.

1. Sadiya
2. Gulmarg
3. Raniganj
4. Qubu
5. Quzong
6. Kujian
7. Changdu
8. Shuanghu
9. Panxian
10. Huize
11. Phetchubun
12. Pahang and Johore
13. Djambi
14. Rikaze
15. Shisha Pangma
16. Jolmo Lungma
17. Salt Range
18. Ali
19. Lhasa
20. Linzhou
21. Namulin

each other, yet there is not a single Gondwana element present in this flora.

The Phetchubun flora of Thailand) Map 1) reported by Kon'no (1963) and Asama (1966) and the Malayan flora recorded by Kon'no and Asama (1970, 1971) from the Jengka Pass, Pahang and Gunong, Blumut Area, Johore (Map 1), are closely related to the Hsianwei flora. Moreover, Ogura (1972) has described *Psaronius johorensis* and *P.* sp. from Linggiu Formation, Johore. Again, there is not a single element in common with the *Glossopteris* flora.

However, Kon'no (1965) said that " during the mid-Permian crustal movement some elements of the *Glossopteris* flora, as *Schizoneura, Rhipidopsis, Glossopteris* and possibly *Palaeovittaria* came into contact and mixed with Upper Permian Cathaysian Flora ". Lee (1974) claimed the occurrence of *Sphenophyllum speciosum* (Royle) McCl., *Glossopteris guizhouensis* G. et Z., *Schizoneura manchuriensis* Kon'no, *Phyllotheca* cf. *etheridgei* Arber and *Rhipidopsis* cf. *ginkgoides* Schmalk in the Longtang flora of Southern China and held that this flora had close connection with the Gondwana flora.

In fact, *Schizoneura manchuriensis* is quite distinct from *S. gondwanensis* Feistmantel of India. The former occurs in the Upper Permian of Liaoning, Kueichow, Kiangsu and Fukien of China and in the Lower Permian at the lower Tunguska of Siberia (Kon'no, 1965, p. 31), yet it is not found in the Indian Subcontinent. *Rhipidopsis* is known from the Permian of Angaraland, but it is not represented in the Chinese Early Permian. All species of *Rhipidopsis*, such as *R. lobata* Halle, *R. panii* Chow and *R.* cf. *ginkgoites* Schmalh., recorded in China are of Upper Permian in age. So, undoubtedly *Schizoneura* and *Rhipidopsis* must have migrated from Angaraland to Cathaysia during Late Permian. After all *Rhipidopsis ginkgoites* is a typical Angara plant. *Phyllotheca* is quite common in the Upper Permian of Angaraland. At least four species, *Phyllotheca equisetitoides* Schmalh., *P. paucifolia* Schmalh., *P. magnivaginata* Radezenka and ?*P. grandis* Rass., have been recorded in Siberia. All of them are Late Permian in age. *Phyllotheca etheridgei* Arber is a typical Gondwana plant but whether the specimen from Kueichow (The Chinese Palaeozoic Plants, 1974, p. 60, pl. 34, figs. 8-10) can be compared with this southern species is very doubtful.

It is well-known that towards the end of Carboniferous, the sea retreated from North China, so Angaraland and Cathaysia were no longer separated by sea water. Many plants, like *Callipteris, Rhipidopsis, Schizoneura, Phyllotheca* and *Zamiopteris* were able to migrate freely from Angaraland, via. Gansu (=Kansu) and northeastern China, first to North China and then to other parts of China.

The specimens, named as *Glossopteris* cf. *angustifolia* from Phetchubun are " imperfect and few, being one each for the species, besides, they are parts of the leaves and are poorly preserved, so that even the nervation is indistinct " (Asama, 1966, p. 198). In fact, these specimens are indeterminable. It is, therefore, not advisable to take them as evidence.

The specimens named as *Glossopteris guizhouensis* (The Chinese Palaeozoic Plants, 1974, pp. 137-138, pl. 110, figs. 3-4) from Panxian, Kueichow, are also imperfect and poorly preserved. These leaves are spade-like, without apex, but with entire margin. Their lower portions taper and become flattened towards their bases. Though they have a prominent midrib and reticulate secondary venation, their texture is rather thin and their lower portions abruptly narrow. This made me think that this kind of leaf perhaps have nothing to do with *Glossopteris*. In this connection, while determining the genus *Glossopteris*, it is wise to follow the advise of Edwards (1955), who advocated that " records of northern Glossopterids should now be treated with the utmost suspicion unless they are based on the very characteristic fructification ".

The specimens described by Zeiller (1903) from the Upper Triassic of Yunnan and Vietnam, named as *Glossopteris indica* (pl. 16, figs. 1-5) and *G. angustifolia* (pl. 56, fig. 2) along with some specimens named as *Noeggerathiopsis hislopi* which are usually taken as evidence for the migration of Indian Gondwana elements to the Cathaysian province. But these plants were wrongly identified. They actually are leaflets of some compound leaves of *Sagenopteris glossopteroides* and *S. stenofolia* (Hsü *et al.*, 1974). The specimens named as *Noeggerathiopsis hislopi* (pl. 40, figs. 1-9) actually are *Glossophyllum zeilleri* (Seward) Sze.

It is true that the specimens named *Sphenophyllum speciosum* (Royle) McCl. from Kueichow and Kiangsu (The Chinese Palaeozoic Plants, 1974, p. 45, pl. 25, fig. 11; pl. 26, figs. 1-3) are hardly distinguishable from the Indian plants described by Feistmantel and others, but the former are usually with more veins than the latter. Moreover, Pant and Mehra have pointed out that the Indian *S. speciosum* is distinct from all the northern species in the number and form of the leaves (in northern forms the number varies from 6-12) and to a less extent, with details of venation. In the Chinese specimens 1-2 veins enter a leaf while in the Indian specimens frequently only a single vein enters a leaf, though there are two or three (Surange, 1966). Whether the Chinese fossils are identical with the Indian ones remains to be proved. Even if they are identical, it is not surprising that many homosporous plants are cosmopolitan. Spores can be easily dispersed far away from continent to continent with the aid of wind.

UPLIFT OF THE GANDIS MOUNTAINS DURING EOCENE

A few years ago, Sahni and Kumar (1974) made a review of the Palaeogene palaeogeography of the Indian Subcontinent. They claimed that the Early Palaeogene of the Indian Subcontinent is characterized by marine oscillations which left up a transitional series of marine to fluvial sediments in North India. Towards the end of the Palaeogene, the sea gradually retreated from the northern part of the subcontinent and disappeared altogether by the Middle Miocene. At present, no Cretaceous to Palaeogene land flora has been reported from southern side of the very Himalayan region.

Chowdhury (1966) reviewed the Tertiary floras of the Indian Subcontinent. Based upon the investigation of fossil woods, Chowdhury thinks that the Deccan intertrappean flora represents a flora flourishing in a region about 30° south of equator. According to many authors, the age of the Deccan Traps probably is Palaeocene (Sahni & Kumar, 1974).

In the south-western corner of Tibet, at the foot of the southern slope of the Gandis Mountains, north to the Himalayas, there is a coal series, occurring in the locality Menchi of the district Zhada in the Ali region (Map 1). It attains a total thickness of more than 2,300 m and consists, in ascending order, of a basal conglomerate about 100 m thick, grey sandstones of 450-500 m thick, some greyish siltstones and shales about 410 m thick, intercalated with several coal seams, greyish siltstone and tuff about 200 m thick. From the shales, *Eucalyptus geinitzii* (Heer) Heer, *E. attenuata* Newb., *E. latifolia* Hollick, *E. angustifolia* Newb., *Eugenia* cf. *hilgardiana* Berry, *Phrynium subcapitatum* sp. nov. and *Cyperacites haydenii* Lesq., were obtained. This flora looks rather like that of the Rikaze Group mentioned above but younger. As two species, *Eucalyptus geinitzii* and *Cyperacites* cf. *haydenii* have been recorded in the Rikaze Group. This flora is tentatively assigned by Geng (unpublished paper) to Early Eocene. Apparently it is a tropical flora and reflects a climate warmer than that of the Rikaze Group. It is quite distinct from the Indian Deccan Intertrappean flora. Probably it represents a flora of lower altitude, not higher than 1,100 m above the sea level, flourishing in a region about 20°-30° north of the equator. Judging from its present altitude (5,140 m) the Ali region must have uplifted more than 4,000 m since the preservation. The isotopic determination of the rocks taken from the Gandis gives an age of 30-79 m.y. (Chang & Zhang, 1974). The igneous activity would have started much earlier than the Himalayas. As the isotopic determination of the rock taken from the Himalayas shows that the igneous activity started 10-30 m.y. ago, probably at Miocene. This indicates that the Gandis unheaved since Eocene, much earlier than the Himalayas.

UPLIFT OF CENTRAL TIBET DURING MIOCENE

Some plant fossils were found in a series of greyish sandstones in Mongxiang, named the Wulong Formation, of the district Namulin (ca 29°39′N: 89°E), about 200 km west of Lhasa. These sandstones are lacustrine in origin, about 5,750 m thick. The basal conglomerate is of purplish colour more than 1,500 m thick. Above it are grey to greyish sandstones and conglomerates of 4,000 m thick, in which the plant fossils are preserved. Above the fossil-bearing sandstones lie volcanic rocks of more than 250 m thick.

At the locality Wulong, of this district, a part of plant fossils has been reported (Li & Guo, 1976) from the Wulong Formation. Fossils found from the lower part of this formation are *Populus latior* Br., *Betula parantilis* L. et G., *Carpinus grandis* Ung., *C. wulongensis* L. et G., *Ulmus hedini* Chaney, *Ribes* and *Crataegus* sp. Those from the upper part are *Quercus wulongensis* L. et G., *Q. prespathulata* L. et G., *Q. namulinensis* L. et G., *Thermopsis prebarbata* L. et G., *Rhododendron sangugawaense* H. et U., *R. namulinense* L. et G., *Salix* sp., *Phragmites* sp. and *Cyperacites* sp. The age of this flora has been assigned by Li and Guo (1976) to be Middle to Late Miocene, but according to present evidence it is possibly Early Miocene. It indicates that during Early Miocene the flora was mainly composed of deciduous broad-leaved trees, thriving under a warm and wet climate. It reflects the land upheaval of the Central Tibet was rather gradual during Early Miocene, probably not over 1,500 m above the sea, but at present this region is 3,700-4,400 m in altitude.

UPLIFT OF HIMALAYA MOUNTAINS DURING LATE PLIOCENE

Probably a significant progress in the study of the Himalayan uplift problem is the discovery in 1964 of a plant fossil-bearing bed of Late Pliocene age at the foot of the northern slope of Mt. Shisha Pangma in Central Himalayas. Plant fossils occur in a series of greyish sandstones, named Yepokangra Group, having an exposed thickness of about 1,000 m. In its lower part, some leaves of evergreen oaks, *Quercus semicarpifolia* Sm. (Pl. 3, fig. 7), *Q. pannosa* Hand.-Mzt. and *Q.* cf. *senecens* Hand.-Mzt. (Pl. 3, fig. 6), a leaf of Cyperaceae (?), a large amount of pollen of *Quercus* and *Cedrus* (mostly of *C. deodara* Loud.) as well as some pollen of *Abies, Picea, Pinus, Tsuga, Betula,* Ericaceae, Labiatae and Cyperaceae and spores of *Pteris, Polypodium* and *Selaginella* were found. The sporopollen assemblages of the upper and the lower parts of this group are quite similar. Owing to the increment of the amount of *Abies* pollen and the appearance of the pollen of *Picea, Pinus,* shruby and herbaceous plants, as well as spores of *Selaginella,* the flora of the later stage is more complex in composition than that of the earlier, indicating that the later flora is closer to that developing in temperate climate, rather warm and wet. The fossil locality is 5,700-5,900 m above sea level where at present plants can no longer grow even in mid-summer at such an altitude. As *Quercus semicarpifolia* is a kind of evergreen woody plant, it still grows on the southern slope of the Himalayas and is widely distributed in south-western China on the hills of 2,200-3,600 m. Evidently, Mt. Shisha Pangma has uplifted over 3,000 m since Late Pliocene (Hsü, 1973).

On the north-eastern side of Mt. Shisha Pangma, there is in Nieniexiongla, (about 50 km to the Mount), a series of lake and river deposits, mainly composed (see Map 2) of clays and sandy soil, named the Dadi Group. Amounting to a thickness of about 230 m it is of the same age as the Yepokangra Group. Judging from sporo-pollen assemblage (Li *et al.*, unpublished paper), the plant successior in this area may be divided into three stages: The *Cedrus-Quercus* forest stage, the forest-grassland stage and the alpine meadow stage.

The *Cedrus-Quercus* forest stage may be again subdivided into three substages: the *Cedrus* forest substage, the *Quercus-Cedrus* forest substage and the *Quercus* forest substage. The first substage predominates in *Cedrus* forest, along with *Quercus, Pinus, Picea, Abies, Podocarpus, Keteleeria, Carya, Tsuga* and some trees of *Betula, Alnus, Salix* and *Ulmus*. Shrubs and herbaceous plants were then not well-developed. The chief undergrowth includes members of Rosaceae, with some rhododendra. Herbs are *Thelictrum, Pteris, Selaginella* and some members of Polypodiaceae, Polygonaceae, Chenopodiaceae and Labiatae. In the second substage the forest consists of *Quercus* and *Cedrus,* while *Pinus, Abies* and *Picea* are next in importance. Other trees comprise *Salix, Carya, Betula, Alnus, Carpinus, Magnolia* and some members of Cupressaceae, shrubs and herbaceous plants consists of *Rhododendron, Rhamnus, Elaeagnus, Pteris, Archangiopteris, Angiopteris* and members of Rosaceae, Oleaceae, Chenopodiaceae, Labiatae, Compositae, Umbelliferae and Polypodiaceae along with some water plants, *Nelumbo* and *Salvinia.* In the third substage, *Quercus* is the most predominant genus while the other plants include *Pinus, Salix, Cedrus, Rhododendron* and *Artemisia,* with traces of *Thalictrum,* Rosaceae, Polygonaceae, Chenopodiaceae, Boraginaceae, Leguminosae and Polypodiaceae. *Cedrus-Quercus* forest stage flourished under a rather warm and wet climate.

In the forest-grassland stage, the flora is mainly composed of *Pinus, Quercus, Artemisia* and some members of Cyperaceae, Gramineae and Chenopodiaceae, reflecting a cooler and rather dry climate. It is worthwhile to mention here that *Hipparion* remains were recorded in this stage.

In the alpine-meadow stage, the only fossils found are *Artemisia* and *Selaginella* which indicate that the climate was even cooler and drier than before.

Judging from sporo-pollen assemblage, Nieniexiongla should lie at an altitude over 2,500 m. At present, that place is 4,830-5,040 m high. It indicates that since Late Pliocene an uplift of about 2,300 m has taken place there.

Remains of *Hipparion* have also been recorded from the Woma Basin (Map 2) of the Jielong District, about 50 km west of Mt. Shisha Pangma and from the district Zhada of Ali region. It recalls us that that *Hipparion* remains are also preserved in the Siwaliks of Punjab. This means that *Hipparion* could freely pass across the Himalayas and wondered from Punjab to Tibet. By that time, the Himalayas

MAP 2 — Fossil localities in southern Tibet.

was not so high as present. There was no barrier to prevent the seasonal winds of the Indian ocean passing over the Himalayas. The climate of Tibet would be warm and wet to allow the evergreen forests flourishing on the hills of Tibet.

The flora shown by sporo-pollen assemblages obtained from Late Pliocene rocks overlying the Hipparion beds consists predominantly of *Picea*. In the district Punan, the Late Pliocene flora found in a lignite deposit is also represented by a predominance of *Picea* forest along with trees of *Cedrus, Quercus, Alnus* and some herbs of Liliaceae, Chenopodiaceae and Cyperaceae and the ferns (*Lepisorus* and others), all indicating that the climate was rather cool just as reflected by the Late Pliocene forest of Nieniexiongla. The Ali region was then around 2,500-3,000 m above the sea level, but at present it is generally around 5,140 m. It means that since Late Pliocene the Ali region must have also uplifted about 2,500-3,100 m.

HIMALAYAN UPLIFT DURING THE QUATERNARY

The question as to what extent the Himalayas had been uplifted during the Quaternary period had been discussed long, long ago by some geologists. In 1859, Godwin Austen suggested that the Kashmir Himalayas had been thrown up over 8,000 or 10,000 ft within a comparatively modern period, but he gave no fossil evidence.

Puri published in 1946 a paper on the Lower Karewa flora of the Early Pleistocene in Kashmir. The flora is composed of oaks, laurels, figs, box, alder, *Mallotus, Pittosporum, Myrsine, Rhamnus,* a few water plants, e.g. *Trapa,* and some conifers (*Pinus, Cedrus,* etc.). The fossils were found in Liddarmarg about 4,000 m high on the northern slope of the Pir Panjal Range, a side branch of the western Himalayas, where the majority of the fossil species constitute a vegetation adapted to an altitude of 2,700-3,000 m. As *Trapa* is a group of plants which on physiological and ecological grounds can not grow in the Kashmir Himalayas at altitudes higher than 2,300 m. So Puri suggested that the Pir Panjal Range has since been uplifted by at least 2,700 m in the Quaternary period.

Twentysix years ago, when the author was with Birbal Sahni Institute of Palaeobotany, he made some palynological investigations with Dube on the lignite of

TABLE 1 — UPLIFT OF CENTRAL HIMALAYAS SINCE LATE PLIOCENE

AGE	LOCALITY	TYPE OF VEGETATION	ALTITUDE ESTIMATED (in m)	PRESENT ALTITUDE (in m)	NET ELEVATION (in m)
Post Glacial	Yali	Alpine shrubs	3,400-3,700	4,300	600-900
Middle Pleistocene	Jiabula	*Picea* forest	3,100-3,500	5,100-5,200	1,600-2,000
	Peikucuo	*Pinus*-broad-leaved mixed forest	2,500-3,100	4,660	1,560-2,160
Early Pleistocene	Puli	*Pinus*-broad-leaved mixed forest	2,500-3,400	4,400	1,000-1,900
Late Pliocene	Yepokonyara	*Cedrus-Quercus* forest	2,500-3,100	5,900	2,800-3,400

Laredura and the clays* of Hajabal and Botapathri of the Lower Karewa Formation on the northern slope of the Pir Panjal and compared them with the recent deposits of the Manusbal Lake near Srinagar and that of the Kolali Glacier of Kashmir. The sample of glacial deposit was taken from a spot about 3,733 m high. The Manusbal Lake, Laredura, Hajabal and Botapathri are about 1,880 m, 2,233 m, 2,200 m and 3,083 m high respectively.

The pollen assemblage of the lignite consists mainly of *Pinus, Abies, Betula, Cedrus, Juglans* and *Quercus,* while the Manusbal Lake deposit contains a large amount of *Pinus* pollen and *Fraxinus.* This indicates that some differences should have existed in the vegetation, but the Kashmir Valley had not very much elevated since then. But the clays contain a great deal of pollen of *Abies* and *Picea,* up to 36% of the total number, but none of *Alnus, Corylus* and *Fraxinus.*

However, predominance of *Abies* and *Picea* pollen in the clays and the glacial deposit had been observed. As *Abies* and *Picea* pollen are alpine trees flourishing at present at an altitude of 3,000-5,000 m of the Pir Panjal, Botapathri would have since been uplifted by about 800-1,000 m.

On the main Himalayas, very recent work has been done in Mt. Jolmo Lungma (=Mt. Everest) region (Hsü *et al.,* 1976; Chow *et al.,* 1976).

The Early Pleistocene vegetation is represented by the Puli flora found in Puli (see Map 2), about 220 km east of the Mt. Jolmo Lungma, at an altitude of 4,400 m.

*The clay samples were given by the Geological Survey of India, Calcutta.

It is of an alpine coniferous-broad-leaved mixed forest, which is mainly composed of *Pinus, Abies, Betula, Carpinus, Quercus* and *Alnus* with few *Picea, Tsuga* and *Ulmus.* The undergrowth shrubs and herbs are *Humulus, Artemisia* and some members of Gramineae, Cyperaceae, Compositae, Umbelliferae, Chenopodiaceae, Polypodiaceae and others. This type of forest grows at present in Yadong (=Yutung) on the southern slope of Central Himalayas at an altitude of 3,500-3,400 m which indicates that this region of Himalayas has since been uplifted 900-1,000 m.

The Middle Pleistocene deposits occur in two localities: Peikucuo (see Map 2), about 60 km, north of the Mt. Shisha Pangma), and Jiabula (see Map 2, about 44 km north-west of the Mt. Jolmo Lungma) of 4,660 m, and 5,100-5,200 m respectively.

At Peikucuo, the Middle Pleistocene forest is mainly composed of *Pinus,* mixed with *Betula, Quercus, Alnus* and *Carpinus.* The undergrowth comprises mainly of some members of Liliaceae, Chenopodiaceae, Gramineae and Compositae. Similar forest is flourishing on the southern slope of Central Himalayas at an altitude of 2,500-3,100 m.

At Jiabula, the Middle Pleistocene flora consists mainly of *Picea,* with some *Quercus, Pinus, Tsuga, Abies, Cedrus, Betula, Carpinus, Alnus, Juglans* and *Salix.* The undergrowth is composed of *Ephedra, Artemisia, Thalictrum* and some members of Cruciferae, Caryophyllaceae, Chenopodiaceae, Gramineae, Cyperaceae, Labiatae, Compositae and Polypodiaceae. Branches and cones of *Sabina recurva* (Buch.-Hamit) Antonia and *Picea spinulosa* (Griff.) Henry have been obtained. At present *Sabina recurva* is widely distributed in Central

Himalayas and the Yalu-Tsangpo valley at an altitude of 3,100-4,500 m. *Picea spinulosa* is an alpine forest plant thriving at 2,500 m in Jielong, but rarely growing over 3,400 m. The forest flora, therefore, would have grown at an altitude of 3,100-3,500 m.

All these indicate that in these regions, the Himalayas has since been uplifted by 1,560-2,160 m, 1,850-2,650 m and 1,600-2,000 m respectively.

The Post Glacial vegetation is represented by the Yali flora preserved along with palaeolithic implements in Yali (see Map 2). This flora includes *Lonicera* cf. *hispida* Pall. ex. Roeu. et Schult., *L.* cf. *tomentella* H.K. et Thomas, *Viburnum* cf. *crubescens* L., *Rosa* sp., *Rhamnus* sp. and *Salix* sp. This kind of vegetation at present grows at an altitude of 3,400-3,700 m, whereas Yali is now 4,300 m high. It means that Yali has since uplifted by 600-900 m. At that time, the ancient man must have enjoyed a mild climate essentially similar to that of the district Quxiang of Tibet at present.

CONCLUSIONS

1. The recent discovery of the *Glossopteris* flora from the Qubu Formation of Southern Tibet and the *Gigantopteris* flora from Shuanghu of Northern Tibet shows no relationship with each other. This strongly supports the view of Continental drift that the India block drifted in Cretaceous from the south-eastern corner of Africa and later on in Eocene joined up with Asia to become its subcontinent.

2. The Cretaceous to Early Eocene plant fossils obtained from Lhasa, Rikaze and Ali of Tibet are of northern affinity which indicates that the initial contact of the India block with the Eurasia probably took place sometime after Early Eocene.

3. The suture between the India plate and the Eurasia plate may lie in the belt of basic to ultrabasic rocks, along the Yalu Tsangpo valleys.

4. The uplift of the Gandis Mountains probably occurred since Eocene, earlier than that of the Himalayas.

5. The Himalayan uplift is a consequence of the collision of the drifting India plate against the Eurasia plate.

6. The Himalayan uplift probably began in Miocene and proceeded more actively in the Quaternary.

7. The uplift of the Tibetan Plateau is closely connected with the Himalayan Uplift and is also caused by the collision of the drifting India plate against the Eurasia plate.

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EXPLANATION OF PLATES

Plate 1

1-4. *Glossopteris communis* Feist. × 1. figs. 1-3, from Qubu Formation, Qubu, southern Tibet, China; fig. 4, from the same formation, Kujian, Southern Tibet, China. Upper Permian.

5-6. *Glossopteris angustifolia* Brongn., fig. 5. × 1; fig. 6. × 3. From Qubu Formation, Kujian, Southern Tibet, China. Upper Permian.

Plate 2

1. *Glossopteris indica* Schimper. × 1. From Qubu Formation, Qubu, Southern Tibet, China. Upper Permian.

2. *Raniganjia qubuensis* Hsü. × 1. From Qubu Formation, Qubu, Southern Tibet, China. Upper Permian.

3-4, 5-6. *Dizeugotheca qubuensis* Hsü, figs. 3, 5. × 1; figs. 4, 6. × 3. From Qubu Formation, Qubu, Southern Tibet, China. Upper Permian.

Plate 3

1-2. *Dichotomopteris qubuensis* Hsü, fig. 1. × 1; fig. 2. × 3. From Qubu Formation, Qubu, Southern Tibet, China. Upper Permian

3-5. *Gigantonoclea guizhouensis* G. et Z., fig. 3. × 1/6; figs. 4-5. × 1. From Hsianwei Group, Shuanghu, Northern Tibet, China. Upper Permian.

6. *Quercus* cf. *senescens* Hand.-Mzt. × 1. From Yepokangra Group, Mt. Shisha Pangma, Central Himalayas, Southern Tibet, China. Late Pliocene.

7. *Quercus semicarpifolia* Sm., × 1. From Yepokangra Group, Mt. Shisha Pangma, Central Himalayas, Southern Tibet, China. Late Pliocene.

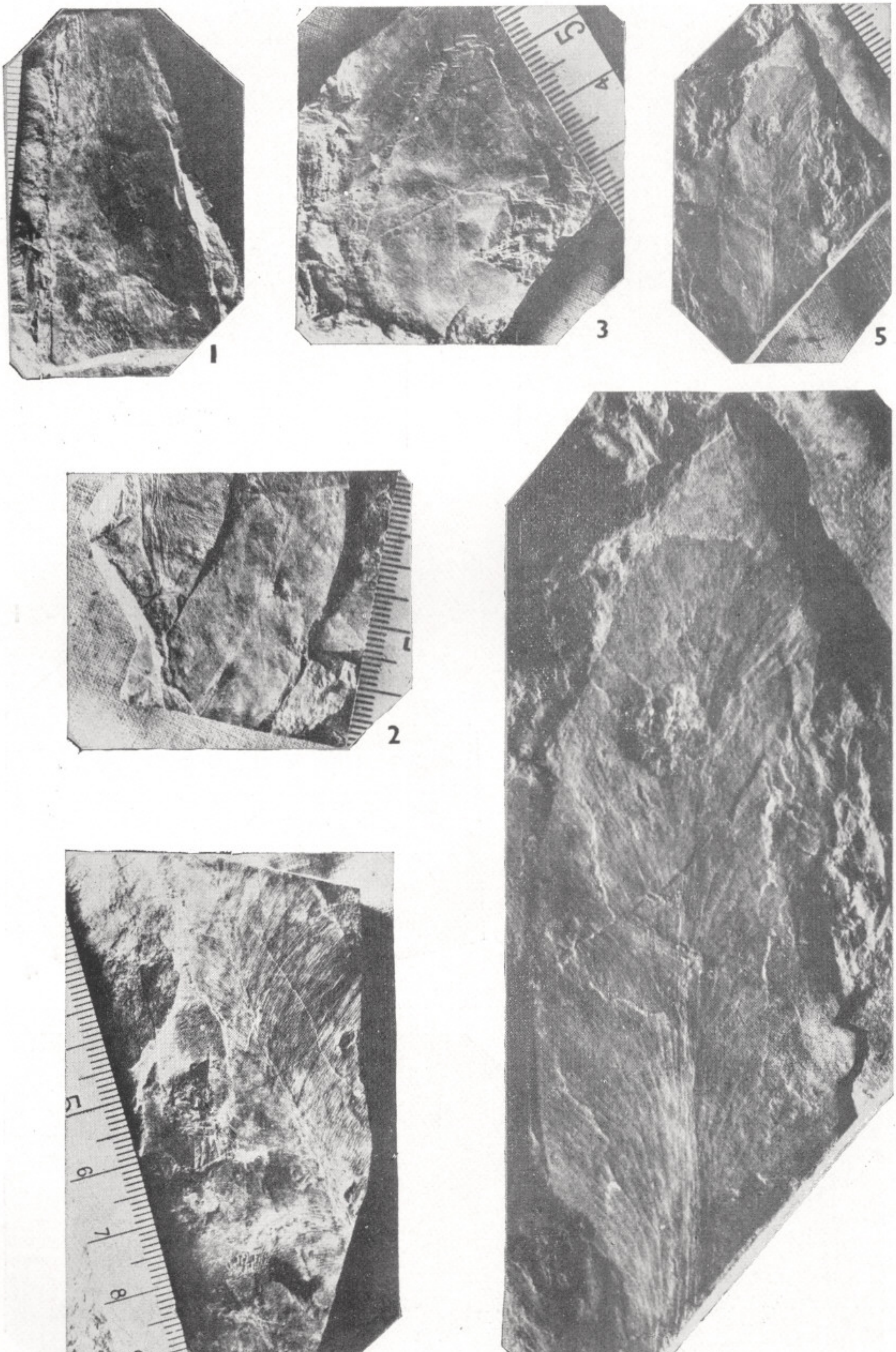

PLATE 1

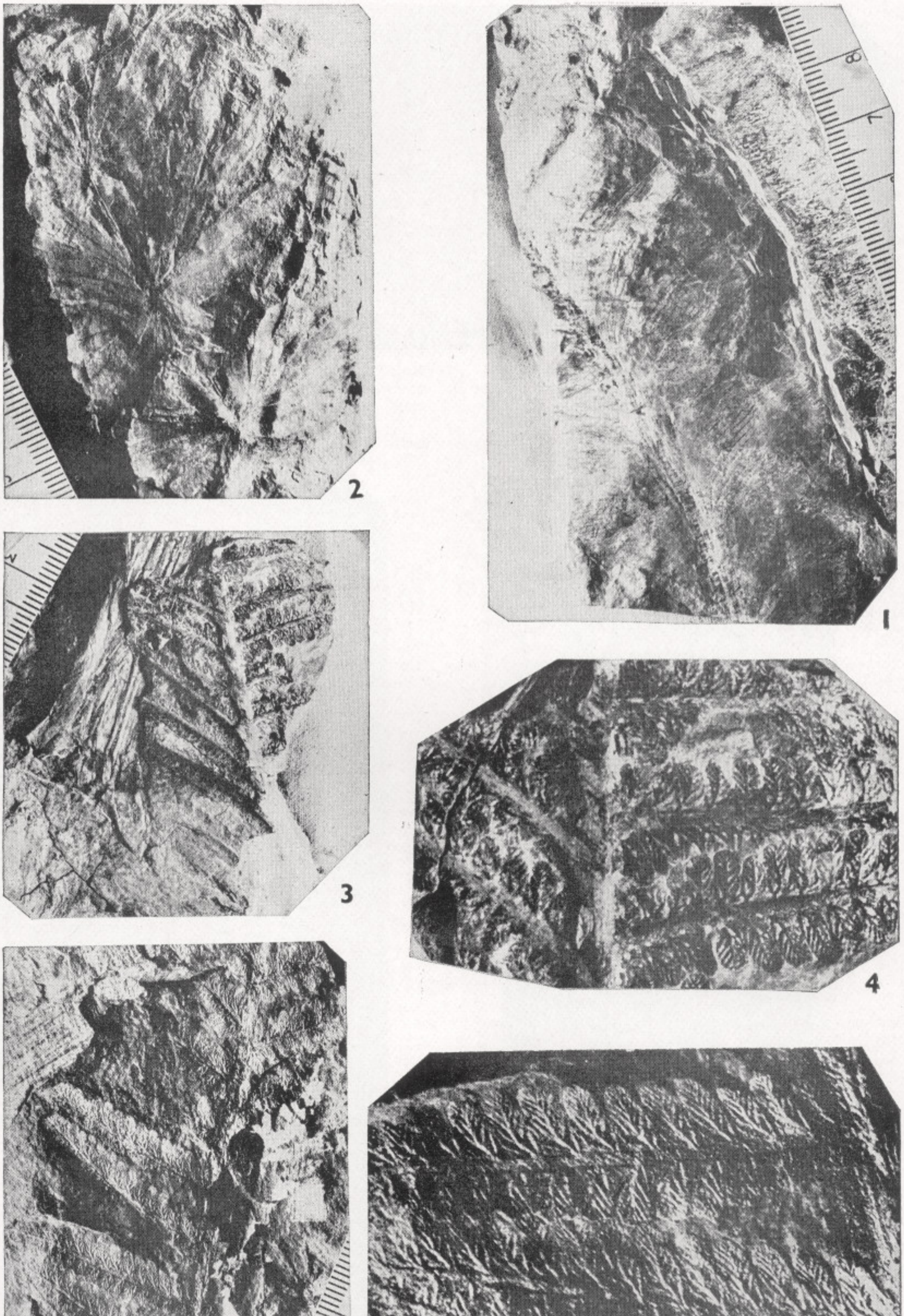

PLATE 2

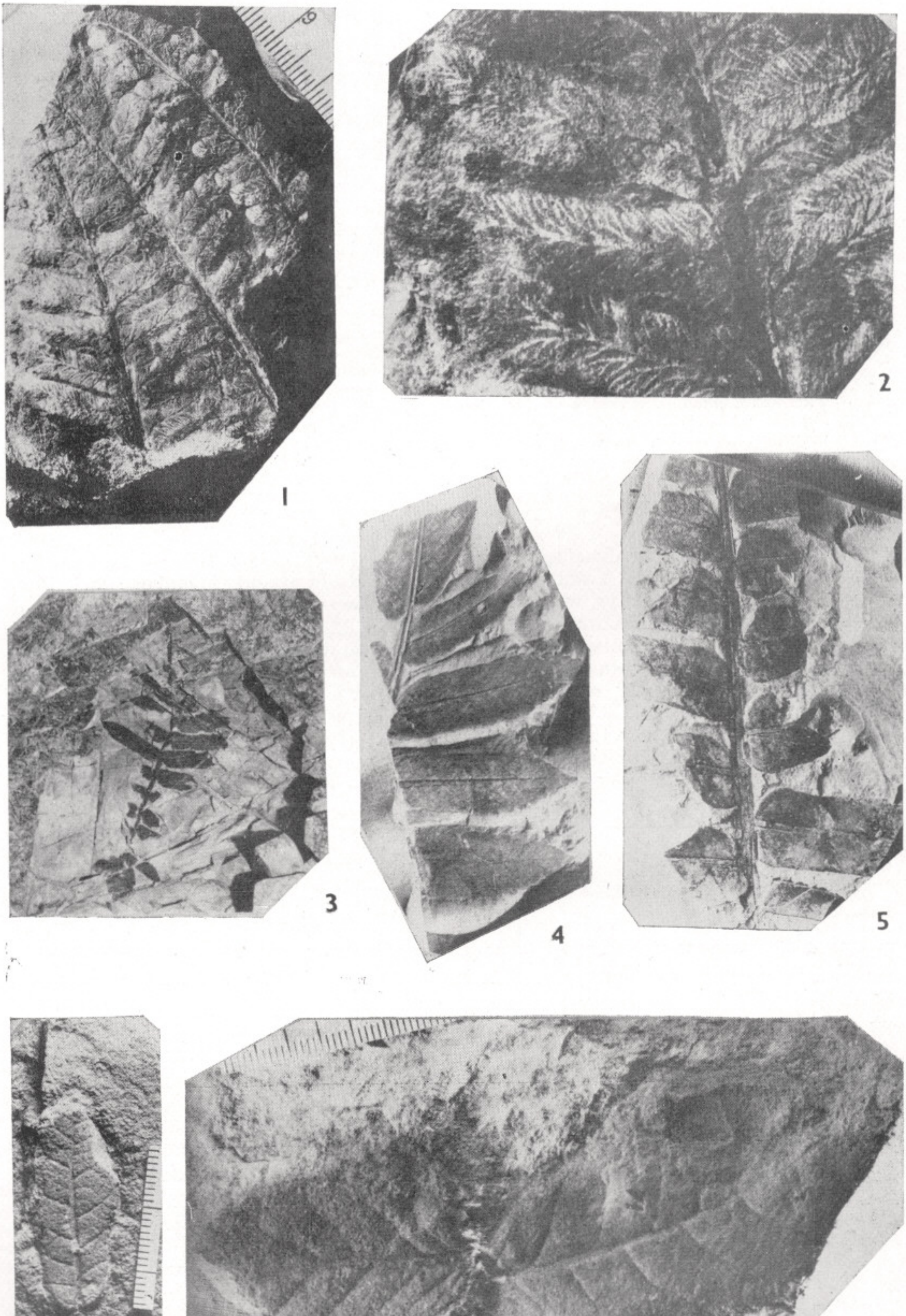

PLATE 3