THE OCCURRENCE OF *GLOSSOPTERIS* FRONDS IN THE NORTH-EAST FRONTIER TRACTS, WITH A BRIEF REVIEW OF THE GONDWANAS OF NORTH-EASTERN INDIA *

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INTRODUCTION

During the field season of 1952-53, two specimens of *Glossopteris* were collected by one of us (T. Banerjee) from certain slaty beds in a road section below Flat Two, in the Sela Sub-Agency, N.-E. Frontier, Assam. The presence of these fronds firmly establishes the Lower Gondwana age of these sediments, and this record now forms the easternmost extent of this genus in the Indian sub-continent. A careful search of these slates (believed to the Damudas), further to the north-east, is likely to yield fruitful results.

GEOLOGY

In the submontane tracts of the Assam Himalaya lying immediately to the east of the Bhutan border, a strip of Damuda beds (Permian in age), nearly four miles in width, overlies the Upper Tertiary Tipam rocks in an extensively inverted sequence with the Damudas apparently overlain by the older Dalings to the north. The beds strike parallel to the grain of the hill ranges and, as shown below, extend laterally as a more or less continuous formation along the foot of the Himalaya for considerable distances to the east and to the west, where similar rocks were previously observed by Mallet (1874), La Touche (1885), Pilgrim (1906) and others.

The area from where the fossils were obtained has been examined in recent years. The rocks comprise hard, gray, coarse, and pebbly to medium grained, well cemented, jointed and fractured quartzitic sandstones, inter-stratified with black carbonaceous slaty shales and thin coal seams. The beds have suffered much disturbance and have been somewhat metamorphosed. The sandstone is intimately

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veined with quartz; the coal has been rendered flaky and powdery and the beds sometimes show local acutely overturned folds.

Description of Fossils

Only two specimens were obtained from the slaty shales in the Sela area, of which one is fairly well preserved. The better preserved, but incomplete frond (Figs. 1, 1A), measures about 8·5 cm. in length, and it is at least 3 cm. broad with a clearly marked, comparatively thin, persistent midrib from which bifurcating and freely anastomosing secondary veins arise at acute angles arching slightly outwards a short distance from the midrib. The tip of the leaf is not clearly seen, but it would appear that it was somewhat blunt. The base is not preserved. The secondary veins are numerous, crowded, and more or less parallel with narrow, elongate meshes which are longer near the midrib, but contracting towards the margin.

In our opinion this specimen which is undoubtedly a *Glossopteris*, may be accommodated with some hesitation in the species *Glossopteris indica*. Owing to its fragmentary nature, we are at present inclined to refer it as *Glossopteris* cf. *G. indica*.

The second specimen figured here (Fig. 2) is a rather poorly preserved, comparatively narrow frond about 2·5 cm. broad and more than 10 cm. long. A distinct midrib is present; the anastomosing secondary veins are hardly visible; but there are sufficient indications to justify its inclusion in *Glossopteris*, although specific determination is difficult. It may probably belong to the same species as the one described above.

Beyond indicating that the sediments are undoubtedly Lower Gondwanas, the specimens are not helpful for closer age determination. But the narrow strip of the Gondwanas of the north-east Himalayan foot-hills, stretching more or less continuously from Abor Hills in the east to Nepal, and further to the west, are generally believed to be the Damudas.

Gondwana Sediments in other parts of North-Eastern India

Opportunity is taken to review briefly our knowledge of the known fresh-water Gondwana sediments and the marine intercalations in Assam and the adjoining territories in north-eastern India the distribution of which is of importance in Gondwana palaeogeography.

Darjeeling Area.—At Pankabari, on the Darjeeling Gondwanas, Hooker (1854) and Mallet (1874) reported the occurrence of *Glossopteris* sp., *Vertebraria indica*, *Phyllotheca* sp. and *Sphenophyllum speciosum*. The Lower Gondwanas in this area are composed mostly of highly disturbed and crushed, grayish, massive-bedded, felspathic, and occasionally calcareous sandstones and sandy micaceous shales which are sometimes carbonaceous with occasional coal seams (Mallet, 1877; Bose, 1890; Ray, 1947). A glacial boulder bed has been reported by Fox (1934, p. 9) and Auden (1935) above Tindharia station occupying a position at the base of the Gondwanas. This discovery, according to Fox (1934, p. 9), has rendered uncertain the correlation of the Darjeeling and the Eastern Himalayan Gondwanas with the Raniganj and he suggests the possibility of the Himalayan Gondwanas belonging to the Barakars. As shown elsewhere in this paper, the question of their age cannot be considered as settled and needs careful re-examination.

Sediments believed to be the Damudas have been recognized in a narrow, more or less continuous belt further to the east of Darjeeling up to the region of the Abor Hills; but till now undoubted plant fossils have not been found in these sediments. The present discovery is therefore of some significance.

Sikkim.—Quite recently G. N. Dutt and S. N. Sen of the Geological Survey of India, located plant-bearing Gondwana beds in the Rangit valley in Western Sikkim,

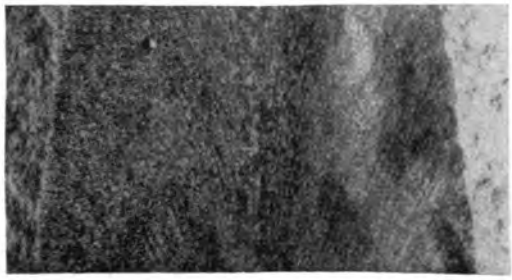

FIG. 1. *Glossopteris* cf. *G. indica*. ×Nat. size.
FIG. 1A. *Glossopteris* cf. *G. indica*. Same specimen as above, enlarged to show venation. ×2.
FIG. 2. *Glossopteris* sp. A poorly preserved specimen, probably belonging to the same species as the one figured above. ×Nat. size.

The specimens are preserved in the Museum of the Geological Survey of India.

situated some distance to the north of the fossil locality Pankabari in the Darjeeling area. The poorly preserved plant remains were collected by Dutt from a locality about two miles west of Asangthang from slightly altered sandstones a few hundred feet above certain 'pebble beds' (believed to be the equivalents of the Talchir boulder bed) which, apparently, occupy a basal position in the series and are well developed near Khandosangphu and Khemgaon. The plants include *Schizoneura, Vertebraria indica* and a doubtful *Glossopteris* (? *Gangamopteris*). Sen's specimens come from a locality about two miles north-east of the junction of the Rangit and the Roathak Khola, north of Naya Bazar, and include an imperfect specimen of *Glossopteris,* probably *G. indica.* These recent fossil finds in Western Sikkim conclusively prove that this series of sediments (at one time thought to be a part of the Dalings), occurring isolated from the Gondwana exposures of the southern foot-hills of the Darjeeling Himalaya, is also undoubtedly Lower Gondwana.

The Gondwanas are particularly well exposed in the form of a 'window' in the Rangit valley, 12 miles north of Darjeeling (Ghosh, 1952, 1953) and contain a few thin seams of semi-anthracitic coal (see also La Touche, 1910; Mallet, 1874). The sediments which have been traced for about 14 miles along the bridle path from Naya Bazar nearly to the base of the descent from Rinchinpong, consist mainly of grey, gritty and felspathic sandstones and carbonaceous slates 'and have at their base tillite and varved slates.....' (Ghosh, 1952). The tillite recalls the glacial boulder bed of the Himalayan foot-hills reported by Fox (1934, p. 9) and Auden (1935) at Tindharia, in the Darjeeling foot-hills, and the pebble beds noticed at the base of the Gondwanas in the Lish valley south of Kalimpong, the Balipara frontier area, the Abor Hills and in the Kosi valley in Nepal. The Lachi pebble bed of North Sikkim mentioned below may also represent a contemporaneous stratigraphical horizon of glacial origin.

North of Namchi near Khemgaon in W. Sikkim, A. M. N. Ghosh (1952, 1953) and T. Banerjee found *Spirifer* (? *Neospirifer* cf. *moosakhailensis*) and fragments of other 'Permo-Carboniferous' marine brachiopods and bivalves in a loose block. G. N. Dutt informs us that he re-visited the area and located the source bed of the fossiliferous rocks, and in exposures of these marine beds between the Tista and the Rangit rivers, he collected many more fossils including, species of *Spirifer* (? *Neospirifer*), *Productus, Fenestella* (? *Fenestrellina*), etc.

Wager (1939) collected Carboniferous and Permian marine shells from the Lachi ridge in N. Sikkim. Based on the study of these fossils Muir-Wood and Oakley (1941) have recognised two fossiliferous horizons, namely, a Middle or Upper Carboniferous consisting of limestones and shales and an Upper Permian * mostly of sandstones. The former contain *Productus* sp., *Athyris* sp., *Spirigerella* sp., *Straparollus* sp., and *Ellipsellipsopa* sp. In the Upper Permian horizon of fossiliferous sandstones were recognised *Waagenoconcha purdoni* (Dav.), *Camarotaechia* sp., *Uncinunellina jabiensis* (Waag.), *Syringothyris lydekkeri* (Dien.), *Batostomella* sp., *Fenestrellina* aff. *fossula* (Lons.), *Nuculana* sp., *Parallelodon* aff. *tenuistriatum* (Meek and Worthen), *Pleurophorus* sp., *Aviculopecten hyemalis* (Salt.), *A.* aff. *leniusculus* (Dana) and *Pleurotomaria* aff. *orientalis* (Roem.). Between these two fossiliferous horizons occur certain 'pebble beds' about 600 ft. in thickness. The 'pebble bed' is a grit composed of ungraded angular quartz grains and felspar set in a very fine paste of quartz and mica with sparsely scattered pebbles consisting of dark quartzites and pinkish limestone. The beds are suspected to be the equivalents of the uppermost Carboniferous Talchir boulder bed of the Peninsula and the Blaini boulder bed of the Simla region (Muir-Wood and Oakley, 1941; Auden, 1935).

There is also a slightly higher horizon in the sandstones overlying the 'pebble beds', containing Orthotetid, *Chonetes wageri* Muir-Wood, *Dictyoclostus* cf. *gratiosus* (Waag.), *D.* cf. *subcostatus* (Waag.), *Linoproductus* cf. *cora* (d'Orb.), *Marginifera*

* The possibility of this horizon being Lower Permian should also be borne in mind.

himalayensis Dien., *Pustula* sp., *Neospirifer moosakhailensis* (Dav.), *Spiriferella rajah* (Salter), *Goniocladia* sp. and *Rhombopora* cf. *circumcincta* Reed.

According to Muir-Wood and Oakley (1941, p. 66) the two upper Lachi fossil beds overlying the glacial 'pebble beds' are of 'Upper Permian, Kazanian age (= Productus shales and Zewan beds)'. The underlying lower fossiliferous bed, in their view, would be Middle or Upper Carboniferous and may belong to the Mount Everest Limestone. The Lower Permian is probably missing in this sequence.

Subansiri Gorge.—The above occurrences of marine fossils at the base of the Gondwana in Sikkim recalls Maclaren's (1904) find of boulders of fossiliferous Permo-Carboniferous limestone at the mouth of the Subansiri gorge about 350 miles to the west of the above locality. About 20 boulders and pebbles of fossiliferous limestone, some arenaceous and the others argillaceous, were picked up by him, and these revealed the following genera and species (Diener, 1905):—from the arenaceous limestone boulders: *Productus* cf. *pustulosus* Phill., *Spirifer* sp., *Spiriferina* sp., *Reticularia* cf. *inaequilateralis* Gemm., *Dielasma* aff. *uralica* Krot., *D.* aff. *biflex* Waag., *Dielasma* sp.; from the hard, bluish argillaceous limestone boulders: *Chonetes* cf. *carbonifera* Keys., *Mylina* sp., *Monopteria subansirica* Dien., *Laxonema* sp., *Pleurotomaria* aff., *punjabica* Waag., *Bellerophon* sp., *Fenestella* sp. and impressions of Crinoidea. According to Diener these fossils recall the Kuling shales of Lilang and Spiti which are generally rich in *Chonetes carbonifera.* Maclaren correlated this horizon with the Lower Productus limestone of the Salt Range and suggested a close connection with similar beds in Spiti and China, and 'possibly of Tenasserim and Southern Shan States'. Muir-Wood and Oakley (1941), however, correlate the fauna with that of the Upper Productus limestone. The correct horizon needs future verification.

Although the specimens were not obtained from beds *in situ,* there is not much doubt, 'from the lithological characters of the boulders, that they could not have travelled for any great distances' (Holland, 1905). Maclaren (1904) himself suggested that the locus may possibly be looked for at the base of the Damuda series 'at no very great distance from the Assam plain'. Alternatively, he suggested that the original beds might occur at the edge of the Tibetan plateau. But from the nature of the boulders which we have examined, it appears to us that the first suggestion is more plausible. In recent years B. Laskar of the Geological Survey of India again found two or three boulders from the Subansiri, composed of hard, bluish, argillaceous limestone in which the only fossil identifiable was a poorly preserved *Chonetes* cf. *carbonifera* Keys. It is, therefore, of prime importance to search for the original beds from which these boulders have been derived, most probably at no great distance from the belt of Tertiary sediments.*

Abor Hills.—Rolled limestone boulders which are slightly arenaceous containing badly preserved crinoid ossicles have also been reported in the upper course of the Sireng river in the Abor Hills (Coggin Brown, 1912). 'These rocks undoubtedly belong to the base of the Gondwana series, and must occur somewhere in the steep jungle-covered ravine slopes of the upper Sireng' (Coggin Brown, 1912). According to Muir-Wood and Oakley (1941, p. 60) the Subansiri fauna and the Abor Hills marine limestone boulders with the poorly preserved fossils providing very meagre data for correlation, may be of the same age as the upper Lachi fossil horizons overlying the glacial 'pebble beds'. The fossiliferous beds of the Rangit-Tista area in south-western Sikkim may also be of the same age (Upper Permian).

With regard to the fresh-water sediments in the Abor Hills, near Rammidumbang contorted black carbonaceous shales (coaly in places), believed to belong to the Lower

* Early in 1953, Laskar again visited the area and he informs us that he located the bed composed of the hard, bluish, fossiliferous limestone in the Ranganadi basin, about 20 miles south-west of the Subansiri (Maclaren's locality) and only a few hundred feet from the Tertiary belt lying to the south.

Gondwana, have been recognised. Hard, white sandstones, contorted grey slates and reddish brown shales are well exposed in the Sirpu stream. There are also quartzites, carbonaceous shales interbedded with quartzites, and a 4'-5' thick coal seam. Gondwanas are also exposed in the upper Sireng valley to the south-west of Kalak where sandstones and shales are prominent.

Bhutan.—In Bhutan (Pilgrim, 1906; 1906*a*) the Gondwanas are well exposed in the Kala Pani where soft sandstones interbedded with crushed coal seams occur. The upper bands of sandstone are quartzitic with thin intercalations of carbonaceous shales. Similar sediments also occur in the Bor Naddi, 12 miles to the west and in the Nunai Naddi, four miles to the east.

Aka Hills.—La Touche (1885) recognised Lower Gondwana sediments in the Aka Hills in the Lower Himalaya to the north of Tezpur in Assam. The geological features are similar to those of the Gondwanas in Sikkim to the west and the Daphla to the east.

In the upper waters of the Bhareli river, Damuda rocks are found as narrow contorted bands of hard quartzitic sandstones interstratified with carbonaceous shales and seams of coal, dipping at high angles to the south.

Dikrang Valley.—Further east on the Dikrang river, south-west of the Subansiri and the Ranganadi, are found clay shales, often carbonaceous and interstratified with thin bands of sandstone. The carbonaceous shales occasionally pass into a crushed splintery coal.*

Garo Hills and ?Tripura.—The only other undoubted occurrence of Lower Gondwana sediments in the north-eastern parts of India, is in the western extremity of the Garo Hills at Singrimari where Fox (1934, p. 29) discovered a small patch of carbonaceous shales containing specimens of *Vertebraria indica.*

In 1952, S. N. Sen of the Geological Survey of India handed over two specimens of plant impressions on carbonaceous shales from Tripura State which proved to be *Vertebraria indica.* But the true provenance of these undoubted *Vertebraria* requires confirmation before anything further could be stated on the significance of the occurrence of Gondwana sediments so far east in a major basin of Tertiary sediments.

Conclusions

The distribution of the fresh-water Gondwana sediments with the marine Permo-Carboniferous deposits at the base in the eastern Himalayan region, although still not fully known, gives us some idea of the trend of the northern coast line of Gondwanaland. Holland (1905, p. 135) expressed the opinion that 'the Crystalline axis of the Himalayas has been a long persistent land-mark in the physical history of Central Asia, marking approximately the northern boundary line of the great Gondwana continent, and forming the southern shore of the . . . Tethys'. While it may be partly true, it should be remembered that the 'Crystalline axis' or the 'Central gneiss' of the Himalaya, is apparently a mixture of rocks of different ages, mainly granitic in composition, some of them pre-Tertiary and some Tertiary in age.

In the Lachi area in North Sikkim, as shown above, there was a marine phase in the Middle or Upper Carboniferous times. This sea did not apparently reach the Darjeeling-Subansiri-Abor Hills region in the Himalayan foot-hills. But it should be remembered that we have as yet no satisfactory data available indicating the definite age of the Dalings or the Baxas. Parts of the Carboniferous might be represented by the former. But it is not unreasonable to hope for future dis-

* The marine fossiliferous band recently located by B. Laskar in the Ranganadi (verbal communication), may most probably extend south-eastwards in the vicinity of the Dikrang valley and should also be searched further south-westwards at the base of the Gondwanas. It is most likely that this marine band may be traced from Abor Hills (where fossiliferous limestone boulders have been found in the upper Sireng valley), to the Dikrang and perhaps even further westwards along the foot-hills within a short distance of the Tertiary sediments.

coveries of organic remains which may throw considerable light on the age and the palaeogeography of these regions.

The later retreat of the Middle or Upper Carboniferous sea northwards was followed by the spread of ice-sheets during the uppermost Carboniferous. The extension of the Gondwana ice-sheet from the south as far north as, and probably beyond, Lachi is suggested by the glacial bed ('pebble bed') in northern Sikkim. The tillites with varved slates in Western Sikkim (Ghosh, 1952) clearly suggest glacial conditions on land, for varved clays are seldom, if at all, formed by the action of ice drifting into shallow seas from glaciated continental margin. It would therefore appear that Gondwanaland extended over most of Nepal, Sikkim, Bhutan and to the north of the Dafla and Abor Hills. If we accept the views of Muir-Wood and Oakley, the Lower Permian in the north-eastern parts of India is apparently not represented due to non-deposition, unless, of course, parts of the Baxas are proved to occupy that position. During the Upper Permian, shallow marine conditions again prevailed in most parts of Sikkim extending westward to Kumaon, Garhwal and Kashmir, and eastward up to the Subansiri river and Abor Hills regions lying to the south of the 'Crystalline complex'.

It is possible, as Fox (1934, p. ii) has stated, that the Gondwana sediments were deposited widely over north-western Assam and north-eastern Bengal as part of the Damudas of the Bengal and Bihar coalfields, and the present discontinuity is due to 'dislocations by faulting and mountain uplift and to enormous erosions of exposed surfaces since the close of the Palaeozoic era'. 'Furthermore, there are now cogent reasons for believing that a line of faulting trends up the Brahmaputra side of the alluvium from the delta above Barisal NNW into Cooch Behar towards the western border of Bhutan. The upthrow side of the fault is the Garo Hills of Assam (where a small patch of Lower Gondwana sediments is seen in the western extremity), so that the movements tend to drop the coal measures, if any (between the Garo Hills and the Bengal-Bihar coal measures) deeper under the alluvium' (Fox, 1934, p. 30). Mallet (1874, pp. 32-33) has also suggested that the coal-bearing Damudas may underlie the alluvium between the Darjeeling Himalaya and the Rajmahal Hills. In the Brahmaputra Valley, in northern Assam, the evidence of gneissic inliers and other factors suggests probable severe overthrusting in the Himalayan region and extensive erosion of the areas to the south of it before the Gangetic alluvium was laid down, so that except close to the Himalayan foot-hills in the valley where the thickness of the alluvium is likely to be great, the Gondwanas are not likely to be present.

The Gondwana sediments in Sikkim and the southern foot-hills of the Himalaya, as mentioned above, are believed by some to be Upper Permian, probably representing the upper part of the Damudas; but *Glossopteris* and certain other elements of the Gondwana flora (*Noeggerathiopsis hislopi*, *Palaeovittaria kurzi*, etc.) have been reported to occur in younger rocks (? Rhaetic) in Tongkin beyond the Shan States (Zeiller, 1903), and if this is correct their likely path of eastward migration across the marine barrier of the Tethys at some period before the end of the Triassic, probably by means of a land-bridge or an island chain, might have lain in the north-eastern parts of Assam, possibly in the vicinity of the north-eastern syntaxis and the adjoining territories to the north. Jongmans (1937, 1937*a*), Sahni (1938), Halle, Just (1952) and some others, however, believe that Zeiller's *Glossopteris* from Tonkin may not be true *Glossopteris* and that the southern flora never invaded the Cathaysia flora (see also Holland, 1943-44). Nevertheless, some minor resemblances are there which demand an explanation. Detailed field investigations in the difficult parts of the country in N.E. India may throw some light on this aspect of Gondwana palaeogeography, in addition to bringing to light a more representative fossil flora from that region which may show the presence of eastern elements as well.

In this connection the discovery by Fox (1931, p. ii) in the lower Barakars (Lower Permian) of the Jharia coalfield, of calamitean shoots which are closely

related to, if not identical with *Lobatannularia* sp. (Kawasaki, 1927; Halle, 1927; Seward, 1931, pp. 235, 236) characteristic of the Lower Permian Shansi flora of China (Upper Shihhotse series), is of considerable interest. The Shansi flora, as in the case of the Russian Kusnezk flora both of which are essentially Permian, shows a large number of plants of Mesozoic type, and *Lobatannularia*, among others in the Shansi flora, is of further significance as forming a connecting link, according to Seward (1931, p. 329), between the Palaeozoic and the Mesozoic floras.

The Indian specimens occur in the floor shales of the IX seam near Barwabera. This solitary report which has nearly been lost sight of in a large memoir by Fox (1931), requires emphasis and a detailed illustrated account of these interesting specimens is now under preparation by the senior author, who has recently re-examined the specimens. Although this form is very poorly represented at the only locality known in India and no other forms characteristic of the eastern Permian flora have been found so far, it will, nevertheless, be unwise not to bear in mind the possibility of intermigration between the Chinese Shansi flora (Gigantopteris. flora) and the Indian Gondwana flora across the marine barrier. Evidence at present available is no doubt too meagre to draw far reaching conclusions. It is all the more important, therefore, to search for possible traces of the eastern Shansi flora in the Gondwana sediments particularly of the north-eastern parts of India which probably lay in the path of migration. Hsü (1952, p. 260) considers it hardly possible that there was an early Permian land connection between Gondwanaland and Cathaysia, but the possibility of such a connection should not be easily discarded on grounds which are not entirely convincing.

A noteworthy feature of the generally metamorphosed Gondwana sediments of the Himalayan region in North-East India, is the rarity of fossil finds. While a careful search may bring to light megafossil impressions in more satisfactory numbers, it is most unlikely that microfossils like spores may be met with in altered sediments, as these microscopic remnants of actual cutinous vegetable substance (and not impressions or casts) are usually destroyed by metamorphism because they are generally smaller than the average size of the newly formed minerals and have a tendency to volatilise easily during the process of sediment alteration. Numerous samples of somewhat metamorphosed Gondwana rocks including coal have been examined in the Survey laboratories during the past few years without satisfactory results. But we could certainly expect future finds of megafossils in the Himalayan Gondwanas which were deposited in the marginal areas of the ancient continent and have not suffered a high metamorphism.

Digressing from the main topic of this paper, it is suggested that search should also be made for traces of organic matter (*a*) in the metamorphosed Dalings (Nepal, Sikkim and Darjeeling areas), consisting predominantly of slates and phyllites passing into mica-schists where they merge with the Darjeeling gneiss; (*b*) the Baxas (Bhutan area), mostly composed of slates, phyllites, quartzites, mica-schists, limestones and dolomites; (*c*) and other argillaceous schists and gneisses of the Himalayan region in the north-eastern parts of India, where they all apparently overlie the Gondwanas in inverted sequence. Although their respective ages have not been proved, it has been suggested by Wager (1939) that the Dalings, once a thick dominantly argillaceous deposit, now largely chlorite schists, may be Carboniferous or somewhat earlier in age, while the Baxas may represent metamorphosed ?(Permo-) Carboniferous sediments.

We may also recall the independent suggestion put forward by Auden, and Heron (Auden, 1935, p. 162) that 'the pelitic component of the Darjeeling gneiss may be the same as the Daling series... If the above correlations are correct this would mean that the sedimentary part of Darjeeling gneiss is the same as the Mount Everest pelitic series' (Carboniferous or somewhat earlier) (Wager, 1939, p. 186). Ray (1935, pp. 29, 41, 44; 1947) also thinks that the Darjeeling gneiss and the Daling series may represent different metamorphic facies of one continuous

sedimentary succession, and suggests the 'increasing possibility' of the Dalings and the Darjeeling gneiss being Palaeozoic. That the Gondwanas and the Dalings may perhaps be considered as constituting one continuous formation showing different grades of metamorphism is also suspected by him (Ray, 1947, p. 118). This suggestion has been questioned by Ghosh (1952, p. 197). However, it should be remembered that some of the sediments in Western Sikkim previously referred to the Daling series, have now been proved to be Gondwanas.

However shapeless one's present ideas may be on the age of the Dalings and the Baxas, the important point is to remember that organic remains have been found in the past in highly altered Palaeozoic and later sediments, and if Wager's suggestion as to the age of the above series is anywhere near the truth, a serious search for fossils in the metamorphic rocks of the Himalaya should be made which, if successful, may help to fix their age with a greater degree of certainty, and will go a long way in understanding more fully the processes of metamorphism and the nature of deformation in the region of metamorphism in orogenic belts. It may be of interest to recall that fossils such as the ammonite *Ariatites* have been known to occur in zoisite-biotite-schist (Liassic Bündner Schiefer, Switzerland), the lamellibranch *Gryphea* in marble (Bündner Schiefer), the anthozoans *Halysites* and *Favosites* in marble (Silurian, New Hampshire), the lamellibranch *Cardinia* in zoisite-garnet-mica-schist (Bündner Schiefer), the brachiopod *Spirifer* in quartz-plagioclase-garnet-biotite-gneiss (Silurian, New Hampshire), the lamellibranch *Halobia* in solid garnet rock (Triassic, Navada), etc. (Bucher, 1953).

As Bucher (1953, p. 292) explains the preservation of fossils in such highly altered sediments, '... typical metamorphic rocks, such as chlorite and mica schists, can form as a result of re-crystallization alone, with or without introduction of atoms or ions, in the presence of pressure differences that give direction to crystal growth, but need not produce differential movements. This does not mean that in many, perhaps most, cases mechanical effects did not play a rôle also, at least on the microscopic scale. But they are incidental, not essential to the production of schistosity in metamorphism. That is why fossils are not destroyed by metamorphism, provided they are much larger than the average size of the newly formed minerals.'

As regards the Dalings and the Baxas, however, the possibility should be borne in mind that parts of these were originally sediments which occupied the deeper parts of the Himalayan geosyncline, and generally benthonic fossils are found to be rare in such sediments. 'A careful analysis, ... leaves little doubt that, of all possible factors, considerable depth of water is the one that will reduce the benthonic fauna drastically, no matter what sediment accumulates on the sea floor.' In such areas a marine depression of sufficient depth was produced to prevent the occupation by a normal benthonic fauna. This aspect has also been discussed in some detail by one of us (Jacob, *in the press*) in a paper on the radiolarian cherts found associated with ultramafics in the Andaman geosynclinal belt. However, attempts should be made to look for fossils in the metamorphosed sediments in the Himalaya which, at first appearance, may be most unpromising. The extreme hardness of these rocks which prevents easy accessibility to the usually poorly preserved and comparatively rare fossils in them and the general unpreparedness to expect remains in highly metamorphosed rocks, might have contributed, in part, to the scarcity of fossil finds in them.

We are grateful to Dr. M. S. Krishnan, Director, Geological Survey of India, for his valuable suggestions.

SUMMARY

In this paper is described a few fronds of *Glossopteris* recently found in the Sela Sub-Agency in the North-East Frontier tracts of Assam. The discovery conclusively proves that the fresh-water sediments which yielded these fossils undoubtedly belong to the Lower Gondwana. These sediments run in a more or less continuous belt along the foot-hills of the Himalaya from Nepal

to the Abor Hills in the east. *Glossopteris* and certain other genera were previously known from the Darjeeling area and the present record now forms the easternmost extent of this flora in the Indian sub-continent.

Our knowledge of the known fresh-water Gondwana sediments, and the marine intercalations, in Assam and the adjoining territories in north-eastern India, of importance in Gondwana palaeogeography, is also reviewed. The recent finds of *Glossopteris*, *Schizoneura* and *Vertebraria* and an underlying marine Permian in the Rangit valley in Western Sikkim, and the location of a definite fossiliferous Permian bed in the Subansiri-Ranganadi area in the foot-hills of the Assam Himalaya are briefly mentioned. The age of the Gondwana sediments of the Himalayan region in the north-eastern parts of India and the probable palaeogeographical conditions that prevailed at the time are also discussed.

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