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The facts and fictions of the Gondwana concept

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Wegener did not envisage that Gondwanaland was an independent continent. This concept was introduced earlier but concretised by Du Toit. His Permian ice-cap covered almost the entire supercontinent. Ahmad, however, pointed out that the ice-cap at no stage was exceptionally large. Du Toit was not aware of the glacial deposits in Arabia or Tibet, and his ice-cap would have to be enlarged considerably if it was to form deposits in these areas, particularly the latter, as well. All evidence goes to suggest that Tibet was not separated from India in the Permo-Triassic and the suture zone concept is not valid. These Tibetan glacial deposits carry Glossopteris flora and Stepanoviella and Eurydesma fauna as typical Gondwana forms. The deposits reach up to Kun Lun mountains.

The Himalayan region was separated from the peninsular basin and was part of the southern margin of an epicontinental Tethys. The ice-cap did not reach this area. However, Himalayan diamictites, as also those of Tibet should be older than the peninsular and a Carboniferous age assigned to them by Chinese geologists may be valid.

The Gondwana concept envisaged glacial deposits overlain by freshwater sediments. This seemed to apply to peninsular India, Western Australia, South Africa, etc. But of late marine incursions have been reported from India and South Africa leaving, perhaps, only Antarctica where it could truly be applied today. The ice-cap covered peninsular India and peneplained it, so that after it receded the area was significantly downwarped and this resulted in marine incursions. Umaria's access to sea was obviously to the south-east underneath the ice-cap and hence it could not carry fauna older than that of Manendragarh. Rajhara, too, was perhaps an extension of this sea, although it could have been independent.

Key-words—Gondwanaland, Continental Drift, Plate tectonics, Palaeogeography (India).

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साराँश

गोंडवाना अवधारणा के तथ्य एवं परिकल्पनायें

ऍफ़० अहमद

वेगनर की यह परिकल्पना नहीं थी कि गोंडवानाभूमि एक स्वतंत्र महाद्वीप था। यह अवधारणा पहले प्रस्तावित की गई थी परन्तु दु टॉयट ने इसे ठोस रूप प्रदान किया। उनके अनुसार परमी हिम-आवरण ने प्रायः सम्पूर्ण महाद्वीप को ढक रखा था। अहमद ने भी हालाँकि इंगित किया है कि यह हिम-आवरण काफी विशाल था। दु टॉयट अरब अथवा तिब्बत की हिमानी निक्षेपों से अवगत नहीं था अतः उनके द्वारा प्रस्तावित हिम-आवरण का और भी बड़ा स्वरूप होगा यदि इन क्षेत्रों में इससे निक्षेपों का निर्माण हुआ हो, मुख्यतया बाद वाले क्षेत्र में। सभी प्रमाणों से व्यक्त होता है कि परमी-त्रिसंघी कल्प में तिब्बत भारत से अलग नहीं था तथा सूचर क्षेत्र अवधारणा भी अमान्य है। इन तिब्बती हिमानी निक्षेपों में ग्लॉसॉप्टेरिस वनस्पतिजात तथा स्टीपेनोवियॅल्ला एवं यूरीडेस्मा जीवजात सामान्यतः पाये जाने वाले प्ररूप हैं। ये निक्षेप कुन लुन पर्वत श्रृंखला तक विस्तृत हैं।

हिमालयी क्षेत्र प्रायद्वीपीय द्रोणी से अलग था तथा अधिमहाद्वीपीय टॅथीज़ के दक्षिणी किनारे का एक भाग था। उक्त हिम-आवरण इस क्षेत्र तक नहीं पहुंच सका था। हालाँकि, तिब्बत की भाँति हिमालयी डायामिक्टाइट प्रायद्वीपीय की अपेक्षाकृत पुरातनतर होने चाहियें तथा इनकी चीनी भूविज्ञानीयों द्वारा प्रस्तावित आयु भी सत्य हो सकती है।

गोंडवाना अवधारणा के फलस्वरूप ही हिमानी निक्षेपों की परिकल्पना की गई जिनके ऊपर स्वच्छ-जलीय अवसाद विद्यमान हैं। यह अवधारणा प्रायद्वीपीय भारत, पश्चिमी ऑस्ट्रेलिया, दक्षिण अफ्रीका आदि के लिए लागू होती है। केवल अंटार्कटिका जहां कि यह आज भी इसे यथार्थ रूप में प्रयुक्त किया जा सकता है, को छोड़कर भारत एवं दक्षिण अफ्रीका से अंतिम समुद्री अतिक्रमण अभिलिखित किये गये हैं। सम्पूर्ण प्रायद्वीपीय भारत हिम-आवरण से आवरित था तथा इस आवरण के हटने के पश्चात् यहां समुद्री अतिक्रमण हुआ। उमरिया दक्षिण-पूर्व की ओर हिम-आवरण के नीचे समुद्र से स्पष्ट रूप से जुड़ा हुआ था अतएव इससे उपलब्ध जीवजात मनेन्द्रगढ़ से पुराना नहीं है। रझारा भी सम्भवतया इसी समुद्र की एक शाखा है, हालाँकि यह पृथक हो सकता है।

Concepts, limits and extension of the Indian Gondwana
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TO Wegener (1926) Gondwanaland was, at best, a notional continent, for he does not seem to have recognized it as an independent landmass. Perhaps he used it only because Suess (1885) had accepted the concept introduced earlier in India. Indeed, it was left to Du Toit (1937) to give a concrete shape to this supercontinent, separated from the northern continents by an oceanic Tethys. But the Gondwana 'concept', envisaged side by side, had some unique features—a glacial horizon, at the base, often with a profound unconformity underneath, its flora amazingly uniform over at least five of the present continents, its fauna, too, supposedly endemic, and yet their correlation intriguing even from basin to basin.

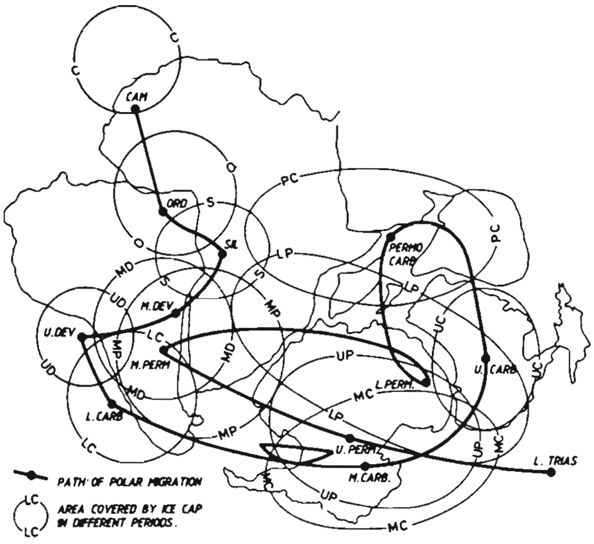
On the other hand this unusual intra-Gondwanaland similarity had led to the concept of continental drift. Vehemently denied by the agressive American school for decades, and then converted almost overnight by the evidence provided by palaeomagnetism and mid-ocean ridges, it soon got wedded instead to plate tectonics. In its defence, the American school is equally agressive once again. Of late, however, Earth expansion is making inroads in the field, for plate tectonics is faced with a number of internal contradictions. Suturing and subduction are two veritable pillars of plate tectonics, and the type area of these, the Indus-Tsangpo Suture, lies within our sphere of interest in the present study. In fact, a storm appears to be gathering around the interpretations of this feature, for it now appears certain that it existed *before* the so-called collision and subduction in the region, and northern Tibet was always a part of the Indian subcontinent, even more so than today for the Himalaya did not intervene at the time.

GONDWANA GLACIATION

Blanford, Blanford and Theobald (1856) reported the discovery of a boulder conglomerate from the Talcher Coalfield in Orissa, that they thought could be of glacial origin. Europe had just then discovered the Pleistocene glaciation in both the hemispheres, and accepted that the Earth had faced a cold spell. But this case of glaciation in the tropics could not be reconciled with the fact that a warm climate was known simultaneously from Europe and America. Western geologists, therefore, did not accept it till the discovery of the striated pavement on the bank of the Penganga by Fedden (1875). It remained intriguing for the ice here had apparently moved *towards* the pole, a feature but locally known from the Pleistocene glaciation anywhere. Although an immense amount of field-work has gone into these glacial deposits in all parts of Gondwanaland in the last over a hundred years, it is a measure of the extreme scepticism of the scientific community that in the sixties of this century the Royal Society was persuaded to depute an experienced geologist to India to confirm that the deposits so considered were really of glacial origin. He came, he saw and he was won over.

Earlier it was thought that the entire area over which glacial deposits exist in the so-called Gondwanaland was at once covered by an ice-cap (Du Toit, 1937) (Text-fig. 1). Such an ice-cap would have been about four times the present Antarctica ice-cap, and could not have existed without a profound lowering of temperature over the globe. And yet there certainly was no ice age at the time. Ahmad (1960), accordingly, suggested that not only the Gondwanaland was then at the South Pole, but it was drifting all the time, and that the ice cap at any single stage was considerably smaller than that envisaged by Du Toit. This migrating pole subjected different areas to glaciation at different times (Text-fig. 2). Ahmad (1960) has used minor differences in floral occurrences in deducing the differences in the ages of ice-caps, yet accepting these data only when these conformed to the palaeogeography of the time. Thus, Glossopteris flora in Kashmir is contained in a succession in the Agglomeratic Slates that carries the Rhacopteris flora at a lower horizon (Sharma *et al.*, 1979). More important, *Gangamopteris* in the Vihi Bed appears without any *Glossopteris*, the latter coming in later, gradually to dominate the flora. Elsewhere, the Agglomeratic Slates carry the Carboniferous *Fenestella* and above it the Permian *Eurydesma-Deltopecten* assemblage. Nakazawa and Kapoor (1979) and Acharyya *et al.* (1979) regard the Vihi Bed as considerably younger than the *Eurydesma-Deltopecten* Bed but it is more likely that these and the Agglomeratic Slate horizons were more or less contemporaneous and simple manifestations of fresh-water and marine environments in the two areas. It may be emphasized, therefore, that although the Agglomeratic Slates are not truly glacial, it is obvious that glaciation had appeared in the Carboniferous, conforming to the age assigned to the fluvioglacial deposits in northern Tibet (Wang Naiwen, Pers. comm., 1984).

In peninsular India, a *Gangamopteris-Noeggerathiopsis* assemblage is characteristic of the Damuda beds, the Talchir and Karharbari horizons carrying *Noeggerathiopsis-Paranocladus* and *Gondwanidium-Buriadia* (Sastry *et al.*, 1979) respectively, i.e., *Gangamopteris* in peninsular India appeared a while *after* the glaciation. It may, thus appear that a truly frigid climate, did not suit it, for in Kashmir, too, it might have been flourishing well



Text-figure 1—Ahmad's map of polar migration.

beyond the margin of the ice-cap. In the Salt Range, too, *Gangamopteris* occurs above the boulder bed, in fact with a thin barren bed intervening.

In the Congo Basin, Africa, *Gangamopteris*, without any *Glossopteris* at all, has been found in great abundance (Veatch, 1935). Thus, the area compared with Kashmir in this regard, both having presumably been along the margin of the Permo-Carboniferous ice-cap. On the contrary, in South Africa *Gangamopteris cyclopteroides* has been reported only from two localities and in both it occurred along with the material filling the joints in the underlying gneisses, that on the surface carry striated pavements. Obviously, *Gangamopteris* had existed well before the glaciation had set-in, was wiped out by the ice-cap cover and failed to reappear after the ice-cap had receded. The age of *Gangamopteris* was, obviously, over and hence none occurs in the overlying Gondwana beds, i.e., the ice-cap had covered the area very near the end of the Permian.

In South America, *Glossopteris* is the predominant genus in the glacial beds, and *Gangamopteris* is present only in one species, the long lived *G. cyclopteroides*. Thus, it would appear that glaciation in South America was younger than that in the Congo Basin, but older than that of South Africa, where even the two sub-species of *G. cyclopteroides* had disappeared by the time glaciation ended, i.e., the event in South America was in the Middle-Upper Permian.

The situation in eastern Australia was entirely different. There had been a strong Carboniferous glaciation, and after only a brief interval, the Permian started with glaciation that lasted till the top of the Permian, with but minor fluctuations. The Permian System comprises a marine formation at the bottom, followed by the Greta Coal Measures. A marine formation follows, with the Newcastle Coal Measures coming at the top. Yet glaciation was present all the time, closing in and receding marginally. The situation in Western Australia, on the other hand, is very similar to that in peninsular India, as, indeed, it should have been, for the two areas were in juxtaposition, and hence there existed an environmental continuation of one into the other. All these features cannot be explained by a large, single ice-cap, and there seems to be no escape from Ahmad's rapidly migrating pole.

The age of the glacial deposits of Herat (Afghanistan) and the three localities in southern Arabia (Helal, 1965; McClure, 1980) cannot be evaluated on these bases, and by analogy, they may be placed in the Permo-Carboniferous, the area having been comarginal to the ice-cap in Kashmir area (Text-fig. 3). Dickins and Shah (1979, p. 400) discuss the fauna from the Haushi Formation of Arabia and equate it with that of the Carnarvon and Canning basins of Western Australia, as also the Bhadaura and Agglomeratic Slates horizons of India. This would be in accord with the age deduced above. The glacial deposits in northern Tibet are generally marine in character, yet typical Gondwana flora is reported locally. Chinese geologists consider the fauna too, as of Gondwana affinities, and yet place the succession in the Carboniferous. The ice, it is believed, moved from south to north and thus all available evidence goes to show that Tibet, in the Carboniferous, was a part of India, and was not separated from the latter by a Tethyan Gulf of oceanic character.

Additional evidence in this regard is provided by the following lines:

1. The presence of a number of Triassic vertebrate forms, e.g., *Lystrosaurus* of typical Gondwana affinities in Sinkiang and Shansi bespeaks unequivocally of the absence of any oceanic basin intervening in the Tibetan area. Significantly, too, no deep sea sedimentary deposits have been discovered in the area to-date.

2. The suturing is believed to have been Eocene-Oligocene, whereas the ophiolites in the Indus Suture Zone belong to two different ages: uppermost Jurassic-lowest Cretaceous and Lower Cretaceous, i.e., the ophiolite emplacements took place some 50 Ma *before* the supposed suturing. This is impossible to explain on the basis of the current hypothesis.

3. In the plate tectonics speculation India should have been in the southern hemisphere when

the ophiolites were emplaced, and yet the Indian plate margin involved has suffered extensive thermal metamorphism.

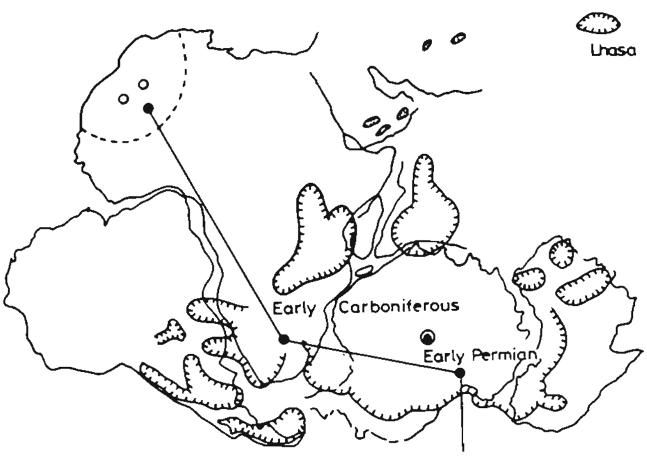
4. The ophiolites carry minerals which indicate their deep seated origin, and not obducted ocean floor. More specifically, it has been shown that the second emplacement must have originated at a temperature of 1105°-1240°C, and a pressure of 27-46 kb, conforming to a depth of 80-140 km (Liang Rixuan & Bai Wanji, 1984). Diamonds and poissanite have been reported from this emplacement and bespeak of origin at high temperature and pressure.

5. Crystal settling in the second emplacement is extensive and has resulted, at almost every exposure, in acidic rocks near the top and ultrabasic at the bottom. This indicates highly molten rock, something impossible to obtain in obducted oceanic rocks.

These lines of evidence leave one in no doubt that India was not separated from Tibet and no wonder, therefore, that the glacial deposits carry Glossopteris flora (Wang Naiwen, 1984, p. 27) and Stepanoviella and Eurydesma fauna (Han Tangling & Wang Naiwen, 1983; Yang Shipu & Fan Yingman, 1981, and others). These lines of evidence are in addition to the faunal and floral similarities from the Cambrian to the Jurassic that Ahmad (1978) pointed out in his Birbal Sahni Memorial Lecture, followed by a palaeogeographic study of the Tethyan region (Ahmad, 1981) and a review (Ahmad, 1982). If these floral and faunal similarities were restudied, there would be scores more of common forms that have come to light since.

What other evidence does any one need to be convinced that India and Tibet have stayed together from at least the Carboniferous to the Triassic and may be from Precambrian to date. All this is concrete evidence that can be checked and rechecked, ranged as it is against plate tectonic speculation of collision, subduction and progressive underthrusting (e.g., Klootwijk, 1987).

Palaeomagnetic evidence has been used extensively to determine the south polar migration (McElhinny, 1973; Vilas & Valencio, 1979; Daly & Pozzi, 1976) and the curves are fairly similar. Text-figure 3 is typical of these and it would be seen that the envisaged polar migration, as pointed out above, could not account for the glacial deposits in Tibet, Afghanistan or Arabia. Obviously the pole migrated rapidly during the period but palaeomagnetism has not been able to record this event. Also, the ice-cap indicated by Du Toit (Text-fig. 1) is too large and since his study Tibet and Arabia have been added to the areas affected without a profound lowering of global temperature. However, Ahmad (1960), has shown (Text-fig. 2) that no earlier ice-cap was as

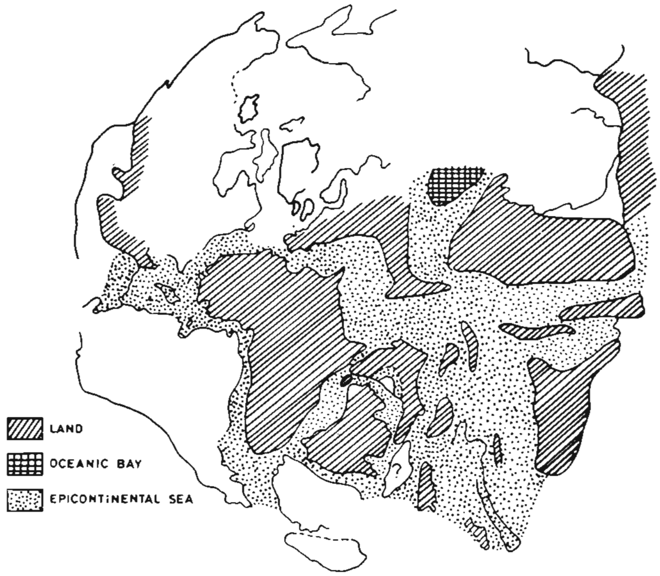


Text-figure 2—Polar migration path after McElhinny (1973). After Crowell (1977) with glacio-marine areas in Arabia, Iran, Afghanistan and Tibet added. Early Permian South Pole after Vilas and Valancio (1977).

large as that envisaged by Du Toit for the Permian and the tropical climate reported from Europe and North America rules out any significant dip in temperature. It is, therefore, obvious that the vast expanse of Gondwana glaciation was the result of a very rapid polar migration in the Carboniferous through Permian. Indeed, there seems to be no escape from it.

PENINSULAR INDIA

The basis of the Gondwana 'concept', if it could be called a concept, was on two pillars, glacial deposits at the base, followed by freshwater deposits, marked by thick coal seams. Indeed, it was thought that glaciation would always peneplane an area and result in coal deposits by reducing the inflow of sediments in the marshes. This, too, was based on observations in peninsular India, where it then appeared to be strictly valid. The entire peninsula having been isostatically downwarped by the weight of the ice cap, with vast areas continuing to be downwarped even after the cap had receded and others rebounding back gradually, sedimentation occurred in isolated downwarping basins. Epeirogenic conditions, thus, varying in mode and magnitude, an ice eroded topography, significantly peneplaned, occasionally devoid of any soil cover, and hence of plant cover, or only partly covered by newly emerging, still struggling, often ill-at-ease, floral forms, a drainage system struggling to get established, and interrupted repeatedly by virtually hundreds of thousands of lakes of all imaginable sizes, fast developing into marshes, conjointly left individualistic imprints in these basins. This line-up was formidable and led, inspite



Text-figure 3—Palaeogeography of the Tethys region (after Ahmad, 1981). The epicontinental sea extended to the Arctic region.

of obvious kinship, to significant differences in the character and thickness of sediments, the entire gamut of environmental factors and hence of contained floral remains, resulting in serious problems in correlations. On the other hand, peneplanation resulted in lack of sediments the streams carried, and with the little they possessed caught in the lakes in the higher reaches, the peat deposited was fairly free of mineral matter and hence of ash in the coal formed in these basins.

This rather confidently advocated 'concept' was upset when K. P. Sinor (1923) discovered a marine horizon within the glacial deposits at Umaria, in central India. This led to a spate of speculations about the direction from which this incursion reached central India. Ahmad (1971) suggested that this inland sea extended south-eastward to connect with the Carnarvon Basin of Western Australia, which was then adjacent. The direction of this marine incursion is still being debated, seeking in the drainage channels that came into being subsequently, whereas these fossils occur in the tillite itself, i.e., they were deposited while the ice-cap existed as the sole source of drainage. Most of this drainage must have been flowing into the Tethys to the north, many emanating from glaciers continuing the ice cover. The recognized drainage certainly came into being subsequently. It may, moreover, be emphasized that peninsular India was then downwarped by the weight of the ice and this must have facilitated the sea incursion. Many of the freshly emerging drainage channels must have been discharging into this ephemeral sea; the drainage system indicated in the Gondwana sediments came in at a later stage and later reversed to form the present drainage.

This south-eastward basin took into account the Manendragarh Basin. Later, however, the Rajhara Bed (Daltonganj Coalfield) was discovered and it appears that a large area in central India was covered by a transgressive sea in the Talchir times. Rajhara's connection to the north is not likely, though not impossible, for the Ganga Valley was not ice covered and hence not downwarped.

The suggestion that these basins are of materially different ages, is most unlikely and such interpretations of faunal remains could lead only to complications. Thus, it has been suggested that the Umaria fauna, carrying linoproductids was older than that of Manendragarh and Rajhara, with eurydesmids (Shah & Sastry, 1975; Dickins & Shah, 1979). Sastry *et al.* (1975) opine categorically that eurydesmids must have lingered on in Umaria, yet it is equally possible that linoproductids had, in fact, appeared earlier in Manendragarh. A considerable difference in the age of Manendragarh and Umaria is inconceivable. And Rajhara, as older than Umaria, makes things more difficult unless it was connected to the Tethys, independently of Umaria, which as suggested above, was not ruled out.

EXTRA-PENINSULA

The Himalayan region was separated from the peninsular basins by an emergent Ganga Basin area whereas the Indus Basin area was submerged as a gulf of the Tethys. A major difference in the two basins is that the Himalayan area was part of the southern coastal region of the Tethys, that continued as an epi-continental sea far to the north. Thus, marine conditions dominated in the region, although it was only littoral and paralic in character. It is also not likely that the ice-cap actually extended to the Himalayan region except, locally and rarely, as long glacial tongues. Similarly, marine glacials, apparently from icebergs belonging to this horizon, reached into northern Tibet right up to the Kun Lun Range, and, as mentioned earlier, are locally associated with Glossopteris flora (Wang Changsheng, 1984; Wang Naiwen, 1984).

Theoretically, the Himalayan diamictites should, as pointed out above, be older than the peninsular India tillites irrespective of whether the pole moved away rapidly, as envisaged by Ahmad (1960) or slowly, as indicated by palaeomagnetic data (e.g., Daly & Pozzi, 1976) for the former area lay along the margin or a little beyond the ice cap in Late Carboniferous. This age is suggested by the occurrence of the Rhacopteris flora below the

Gondwana flora in the Agglomeratic Slates (Sharma, 1976) and the presence of *Fenestella* below the *Eurydesma-Deltopecten* zone in the diamictite horizon, i.e., glaciation had started earlier, truly in the Carboniferous. This is confirmed by the Chinese geologists who, on the basis of the fauna, place the fluvioglacial deposits of the Lhasa Block in northern Tibet in the Carboniferous. The age of the glacial deposits in the peninsular region, it is agreed, is Permian, and Thomas and Dickins (1954) correlate Umaria with the Callytharra Formation in the Carnarvon Basin of Western Australia, and place it in the Sakmarian. For icebergs to deposit 1200 m of diamictites in Tibet the ice-cap must have been in the area for a fairly long time.

Also of significance is the occurrence in the Vihi Bed of vertebrates, *Archegosaurus, Actinodon, Lysipterygium* and others of Lower Permian affinities of Europe. The Vihi Bed carries only *Gangamopteris.* An Artinskian age (Kapoor & Shah, 1979) for it would be unlikely and it cannot but be basal Permian.

The Subansiri fauna is considered to be Uralian by Singh (1975), but Waterhouse *et al.* (1975) lay stress on the presence of *Uraloceras,* and place it in the Sakmarian. *Stepanoviella,* too, is considered to be Sakmarian by Waterhouse (1970) but is known also from the Tibetan glacials, placed in the Upper Carboniferous. Higher up in the same succession in the Subansiri area freshwater beds contain *Glossopteris,* but no *Gangamopteris* is present. The same situation obtains in the Darjeeling area as well, and it may be safe to place the horizon in the Permo-Triassic. Thus, it is possible that a complete Permian succession is present in the area.

The position in the type area of the Blaini and Krol is rather confused, for unlike other areas, no megafossils have been reported from these, whereas the micro-faunal/floral evidence is rather contradictory. However, a rich fauna of bryozoa, bivalves and brachiopods has been reported from the Garhwal Nappe (Bijni & Amri tectonic units) and the age of these boulder slates is placed between Middle Carboniferous and Early Permian, the fauna being comparable with that of the Subansiri area and the Agglomeratic Slates of Kashmir (Acharyya *et al.*, 1979, p. 424; Acharyya & Shah, 1975). But the original source of these allochthonous units is not known, and hence little reliance could be placed on the evidence yielded, even though it seems to fit-in with the views, advanced here, that glaciation had appeared in the Carboniferous.

Other areas of the so-called Tethyan Zone are the Chamba Synclinorium, Malung (Ladakh), Spiti, Nepal and parts of Higher Himalaya. A glacial horizon at the base of the succession is present in several of these areas, and Acharyya *et al.* (1979, p. 427) place these in Late Palaeozoic. To sum up, the position, as it seems to have obtained, is that the Tethys was an epicontinental sea whose southern shore-line existed within the Himalayan belt, and extended in places to Lesser Himalaya, perhaps, at times farther south temporarily. The drainage from Ganga Valley flowed into it, on the one hand and into the westward flowing Damodar on the other, these streams could not have formed any mighty rivers for the width of the intervening land, except in the west, was small and the area peneplaned. Topographic highs in this sea provided land bridges during periods of regression, allowing land plants and vertebrates to migrate from one part to another of Pangaea (Ahmad, 1978). Crawford (1975) was certainly correct when he thought that Tibet and India belonged to the same block, the northern submergent, the southern emergent. In fact, there was yet another emergent area to the north, the Siberian block. Acharyya *et al.* (1975, p. 421), however, suggest that the evidence is "against wide and extensive Tethys between Gondwanaland and Cathaysia/Laurasia", yet they do not specify whether their Tethys was an ocean or a sea nor what they would have considered a " wide and extensive" Tethys. In fact, all evidence goes to suggest that this sea extended from the Himalayan area to the south of the Siberian platform. On the contrary, Kapoor's (1979, p. 443) comment as to how Cathaysian elements "intruded in the Kashmir Gondwana" obviously lacks perspective.

DISCUSSION

The above brief review brings out clearly that in the Permo-Carboniferous times there were two major basins in the Indian subcontinent the Himalayan and the Peninsular. The Himalayan region comprised a littoral, paralic zone of an epicontinental Tethys Sea and there seems to be no doubt that it extended from eastern Pangaea to Western Pangaea, the entire width of the supercontinent, with a peripheral gulf covering most of the Pakistani area with the Bhadaura area on its eastern margin.

The other major basin in peninsular India was formed of a number of interconnected chains of large and small basins of marshy character, separated by gneissic basement, discharging into an epicontinental sea extending initially from Daltonganj to Umaria and beyond to the south-east and later on to the present west coast, somewhere to the south of the Narmada. The Narmada itself played no part in it, for the rift, apparently did not exist, being Tertiary in age.

It has been pointed out earlier that the Permo-Carboniferous glacials extended to northern Tibet.

This would lead to some interesting conclusions: (1) the marine area in the Himalayan region could hardly have escaped this glaciation. Some doubts have, of late, been expressed on this count following the discovery of some Cambro-Ordovician conodonts from a bed till lately correlated with the Talchir beds of peninsular India (Azmi *et al.*, 1981). It would thus appear that in the Himalayan region diamictites are of two different ages, some, perhaps, being Late Precambrian, and thus belonging to the most severe glacial age the Earth has known, the Varangian Glaciation. In the Cambrian the South Pole was actually to the north-west of Africa, and the North Pole somewhere near the present position of Australia actually to the west of the then Tasmania. In the Late Precambrian the pole would, perhaps, have been farther away. Neither of the poles could leave behind glacial deposits in the Himalayan region. Hence there must have been a considerable dip in the temperature resulting in a severe ice age. On the other hand some of these Himalayan glacials, must belong to the Gondwana horizon and they need to be so identified specifically; (2) that, as pointed out above, Tibet was a northward continuation of the so-called Gondwanaland, and the so-called Indus-Tsangpo feature is not a suture, as often suggested, basically on palaeomagnetic evidence. The consensus amongst the Chinese geologists is very strongly in favour of this view, and Zheng Haixiang (1981) was only expressing this when he stated that it is "not entitled to be a suture zone"; and finally (3) it seems that the area from the region of the Lesser Himalaya to Tibet and beyond downwarped more or less quietly except perhaps occasionally becoming geosynclinal in narrow belts, from the Cambrian and may be earlier, and accumulated in parts some 60 to 70 km of sediments. This has misled many a geophysicist to speculate that this was an area of double thickness, with the Indian continental crust having thrust underneath the Tibetan block. This is, otherwise too, inacceptable on several counts. Indeed, it does not seem to be realized that an 8-20 km thick ophiolite wall stands in between the two blocks. It must have come into being, in plate tectonic speculations, at the time of the collision and suturing. To be able to underthrust the Tibetan block the Indian block would have to leap-frog over it and immediately to the north sink underneath the Tibetan plate. The impossibility of this needs no stressing.

One may, then, want to know the character of the Indus-Tsangpo feature. All available evidence goes to suggest that a rift opened in the area in the Triassic and attracted a lot of sediments. The rift continued to deepen and beginning in the Upper Jurassic magmatic emplacement took place, followed by a second phase in Lower Cretaceous. The sediments in the rift were thrown up and formed a melange. Thus, Gopel, Allegre and Xu (1984) agree that it was a propagating ridge, under slow spreading condition. Wang Xibin, Cao Yougong and Zheng Haixiang (1980) conclude that it was a tensional fissure, whereas Chang Chengfa (1980) opines that Late Permian-Triassic rifting which resulted in the Panjal Traps produced the Indus-Tsangpo rift.

On the other hand, accepting continental drift, all the continental areas for the Permian time, are assembled either in a single supercontinent, Pangaea, or into two continents, Gondwanaland and Laurasia, may be into four, with Angaraland and Cathaysia, in addition. A wide triangular bay, interpreted as the oceanic Tethys, appears in most Pangaea reconstructions along its east, tapering down to around the Black Sea. Ahmad (1981, 1982) studied the palaeogeography of the region and concluded that there was no oceanic gulf or bay in the area, and instead the area was covered by an epicontinental sea. Lin Baoyu and Qiu Hongrong (1984, p. 5) reiterate that "based on characteristics of the Palaeozoic biota and sediments, at the time, both flanks of the Yarlung-Zangbo Rivers belong (-ed) to the same ancient plate". Similarly, Owen (1976, p. 250) from his studies of the sea-floor spreading data, concluded that "the evidence for a former Tethyan ocean between Gondwanaland and Laurasia is non existent", and that there is "no need to infer the presence of Tethyan oceanic crust north of India". Crawford (1975) had earlier opined that "India and Tibet were, at least in the Phanerozoic, one huge crustal block, with the southern part emergent, and the northern submerged by the Tethys." Stocklin (1981) agrees with this when he stresses that "the Tethys was essentially not a wide ocean but an epicontinental sea".

Floral and faunal exchanges, down to the level of freshwater invertebrates and insects, were too frequent all through the Proterozoic to admit of an ocean or a gulf, even a narrow one. Fieldwork by Chinese geologists has established, as pointed out earlier, that the fluvio-glacial deposits of the Upper Palaeozoic had their source in south. Also, the Lower Permian vertebrate fauna of Kashmir was of European affinities whereas the Lower Triassic vertebrates of Sinkiang, Shansi and Thailand were related to those of India, Africa and Antarctica. These, it would not be possible to explain unless a wide, unobstructed, continental ligation is accepted latitudinally across the entire Asiatic continent. Carey (1958, 1976) has, on the other hand, pointed out that it is impossible to assemble the continents on the present diameter globe without a wide gaping gore on the eastern margin, and that this gulf disappears if the continents are assembled on a globe of a smaller diameter. Since the palaeontological evidence for continuation in landmass from India to China, right across Tibet is irrefutable, one has to accept that the Earth has, indeed, expanded.

As originally put forward, the Gondwana concept envisaged glacial deposits overlain by freshwater sediments. This was equally important in the peninsular region, as also in eastern Australia and South America. However, marine incursions have since been recorded from vast areas in peninsular India and South Africa leaving very few areas, except, perhaps, Antarctica, that stand up to the original concept. In addition, it is certain that even the so-called Gondwana glaciation was not of the same age everywhere, and, instead, ranged from Upper Carboniferous to Upper Permian. This means a range of more than a geological age—about 50 Ma—a long time by any reckoning. More important is the fact that continental deposits overlying glacial beds—true to Gondwana concept—occur in Siberia (Epshteyn, 1981) and Korea. These areas never belonged to Gondwanaland, and to apply the term to these, certainly outside the classical Gondwanaland, would be a travesty.

In the above brief review of the age of the Gondwana glacial deposits in different parts of the supercontinent an attempt has been made to bring out, without making it a homily, that while evaluating minute or even minor differences in ages of two or more basins palaeontology, by itself, is not infallible and a balanced approach is essential, with the palaeogeography of the area, for any specific age, clearly understood. It is, thus, not sufficient to say that since Umaria contains linoproductids it must be older than Manendragarh with eurydesmids. Such an obviously unlikely suggestion should be provided with an explanation for it needed either an independent connection for Umaria or why an equivalent bed is not present is Manendragarh. This, palaeogeographically, seems to be impossible.

It would be of interest to go into this question in a little detail. Thus, Fox had suggested a connection to the north and Krishnan had ruled it out on the ground that it was across the Vindhyan Range that he wrongly thought existed at the time. Instead, he suggested that the bay opened along the Narmada rift. A little consideration would convince that neither of these was likely. Even though the Vindhyan Range did not exist at the time, a narrow gulf across the then emergent Ganga Basin area, would be rather far-fetched although apparently not impossible. On the other hand, Narmada River and the rift along it apparently did not exist either, being Late Tertiary or even possibly Quaternary in age. Umaria fauna is akin to that of Western Australia and the Subansiri area, and a connection with the south-east, as discussed earlier, was accordingly, more likely.

Similarly, it has been pointed out that palaeomagnetic data, too, are incapable of providing the evidence for minor subdivisions. Thus, all the studies to-date place the Permian South Pole to the south-east of South Africa in about 45°S latitude, whereas the Arabian glacial deposits (Helal, 1965; McClure, 1980) are from around 15°-20°N latitude, i.e., the ice-cap, if this pole position is accepted, must have extended for about 55° of latitude from the pole. If such an ice-cap existed today at the South Pole, it would extend to almost the Tropic of Capricorn across Australia, South Africa and South America. Without a major dip in the temperature, the possibility cannot be envisaged, and in the Permian there certainly was no such frigidity. Significantly, the Pleistocene ice-cap, at its maximum, did not extend that far. Hence an exceptionally large ice-cap could not have existed at any time during the period. The Arabian and Tibetan glacial deposits, thus, cannot be justified with this palaeomagnetically determined South Pole position, nor is the amount of polar migration suggested by this method of any help. One is, accordingly, obliged to accept the fast polar migration suggested by Ahmad (Text-fig. 2) on palaeogeographic grounds, with the Upper Permian pole coinciding with the palaeomagnetic pole assigned for the whole of Permian.

CONCLUSIONS

During the early Gondwana times two marine basins existed in the Indian subcontinent, the Himalayan, along with the Western Indian and the Peninsular. In fact, the reported discovery of Gondwana coal in parts of Sind, suggests that perhaps even parts of the western basin turned, at least locally, into a freshwater basin. However, of the Western Indian Basin little is known, for it lies concealed underneath the Indus Basin—except for the bore-hole discovery of the coal only a very small part along its eastern margin being exposed. The Himalayan Basin was evidently part of an epicontinental Tethys. Glacial sedimentation in the region started in the Carboniferous, with *Fenestella* and *Rhacopteris*, identifying the marine and continental areas respectively.

Peninsular India was largely, perhaps entirely, covered by ice, and hence, sedimentation could only begin in Sakmarian times when the ice-cap had receded towards Africa. Marine incursion existed side by side with the ice-cap, and extending from the south-east and reaching up to Umaria and, perhaps, Rajhara and elsewhere. Palaeontological evidence suggesting that Umaria is older than Manendragarh is, therefore, invalid.

Evidence is incontrovertible that Gondwana glacial sediments reached into northern Tibet. Also, the fauna known from the area from Ordovician through Permian is of Gondwana affinities, and so are the Triassic vertebrates of Shansi, Sinkiang, Korea and Thailand. The Lower Permian vertebrates of Kashmir are of European affinities. These rule out a Tethyan ocean from the region, and the suture zone concept becomes altogether inacceptable. Supporting evidence for this view is incontrovertible. Indeed, Pangaea was then the only landmass on the surface of the globe and the existing continents were parts of it. Floral and faunal migrations, to the extent these happened, would have been impossible even with a narrow ocean intervening. The above analysis has amply demonstrated that whereas for broad generalizations palaeontological and palaeomagnetic studies are valid and acceptable, both these lines of evidence are inadequate when applied to small basins or time scales. Their evidence should, therefore, be tested against palaeogeography.

As originally conceived, the Gondwana concept could hardly be applied anywhere, except very locally, and it would not be legitimate to apply it to parts of successions nor to extra-Gondwanaland areas. It has, nevertheless, served and continues to serve a purpose, for it has been responsible for numerous developments in geology.

If it is accepted that there was no oceanic gulf or bay in the eastern Asian region and if Carey's contention that this gulf can be eliminated only if the continents are assembled on a globe of smaller diameter and not on one of the present size, it seems to follow that the Earth has expanded, to about twice its size since the Permian.

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