LATERITES AND LIGNITES OF NORTHWESTERN INDIA AND THEIR RELEVANCE TO THE DRIFT TECTONICS OF THE INDIAN PLATE

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ABSTRACT

Laterites and lignites of northwestern India range in age from Early Palaeocene to Early Oligocene and their formation in terms of volume was controlled by the anticlockwise rotation of the Indian plate during its drift to its present position. Thus the laterite/lignite of the Himalayas are meagre in comparison to those of Gujarat and Rajasthan region.

THE Palaeocene laterites and Eocene lignites of Gujarat, Rajasthan, NW Uttar Pradesh and Jammu–Kashmir states show a very conspicuous linear alignment when plotted on the map (figure 1). There are laterites and lignites in the southern and eastern regions of India but most of them are younger in age. Bauxite and bentonite deposits, generally considered as products of lateritization, are commonly found in this linear laterite belt, but not necessarily in close association with one another. Lateritic profiles in each of the above mentioned states differ considerably as a manifestation of the diversity of parent rocks, drainage patterns during lateritization and the duration of this process. Despite the diversity of parent rocks and topographical environments, the stratigraphic position of all these laterites and lignites is identical. Laterites, bauxites and bentonites range in age from Early Palaeocene to Late Palaeocene and the overlying lignite seams and the rocks in which they are interbedded have an age range from Early Eocene to Early Oligocene.

In Gujarat, laterites and associated mineral depostis are widely distributed in Kutch, Saurashtra, Kaira, Sabarkantha, Surat and Valsad districts. The Kutch laterites are exposed as a linear belt extending over 100 km in length with a maximum width of only 3 km. This may be due to their being overlapped by the younger Tertiary formations. This lateritic horizon has been named as Madh series and assigned a Palaeocene age based on the fact that it overlies the Deccan basalts and underlies the Eocene rocks[1–4]. A pioneer worker had placed it in the Lower Eocene period[5]. This lateritic horizon is occasionally overlain by Middle Eocene numulitic limestones and mostly by the Lower Eocene Kakdi stage composed of black shales with lignites, gypseous shales with red ochre, glauconitic shales with thin fossiliferous marls, grey shales with clastic laterites and brown shales with gypsum. An estimated 150 million tonnes of lignite are reported in this region[6].

In Saurashtra, laterites are seen capping Deccan basalts and underlying the Gaj formations of Oligocene-Miocene age along the western fringes of the Gulf of Cambay to the east and the coastal areas of the Arabian sea to the south. As in Kutch, the laterites occur as a 50 km long linear belt with a maximum width of about 5 km. In the Jamnagar district of northern Saurashtra, extensive laterite cappings with bauxites are also encountered. There are no younger sedimentary rocks overlying the laterites, thus indicating that this area may not have been submerged since the outpouring of the Deccan basalts. The Cambay basin rift zone, lying between Saurashtra and the Mainland Peninsula, trends roughly N–S and consists of an aulacogenic sedimentary sequence rich in petroleum. The lowest member of this sedimentary unit has been assigned a Late Palaeocene-Early Eocene age[7,8]. The laterite horizon, encountered in many oil wells and lying between this sedimentary unit and the Deccan basalts, is considered to represent an erosional unconformity[9]. Thin lignite seams are seen interbedded with Eocene and Early Oligocene strata in the Cambay basin north of the Narmada river. Economically viable deposits of Tertiary lignite have recently been discovered near Rajpardi village in Broach district. This is an extension of the Cambay basin south of the Narmada river. This Tertiary rock sequence has been tectonically classified as the Narmada block and has been assigned an Eocene age[10–12]. The Tertiary rocks exposed in Surat and Valsad districts of South Gujarat are also considered to represent the continuation of the Cambay basin sedimentary sequence. Between this Tertiary sequ-

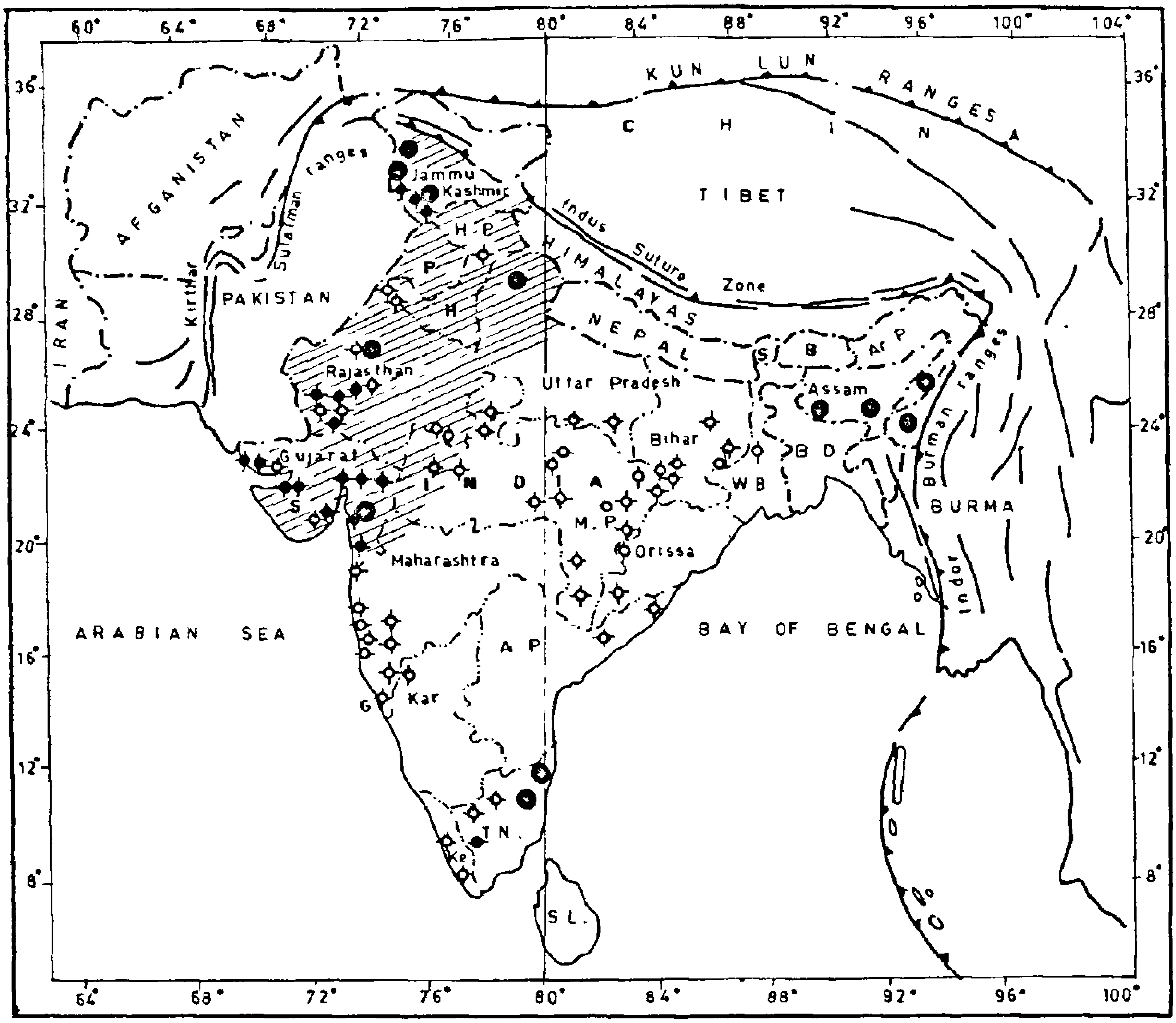

Figure 1. Distribution of Tertiary laterites, bentonites, bauxites and lignites (with gradual decrease in age from north to south). The plots within stripped lined area are Palaeocene in age and are discussed in this paper. Filled circles with four-sided dashes represent laterites and bauxites under discussion; open circles with four-sided dashes are also laterites and bauxites, the details of which are under preparation; open circles with two-sided dashes denote bentonites and Fuller's earths; and solid circles are lignites and coals. K and S in Gujarat state indicate Kutch and Saurashtra respectively; and the other alphabetical symbols correspond to the names of various Indian states.

ence and the Deccan basalt there is also a laterite horizon.

In the central and northeastern parts of Gujarat, laterites with bauxites are seen exposed around Kapadvanj and Tayabpur villages in Kaira district and around Ambalyara and Harsol villages in Sabarkantha district. Due to the absence of any sedimentary cover it is difficult to assign an exact age to these laterites and bauxites, but they can be correleted with those of the Cambay basin, Saurashtra and Kutch as they have been derived from the same parent rocks viz Deccan basalts.

The extensive exposures of Deccan basalts in Gujarat, as compared to the Traps of the adjoining states like Maharastra and Madhya Pradesh, are considered to represent the uppermost flows of the entire Deccan basalt activity in this region[13–15] Radiometric K-Ar dating of the intrusive rocks (gabbros, dolerites, lamprophyres, etc) in basalt, from Mount Girnar in western Saurashtra, yield an age range between 56 m.y. and 65 m.y. thus indicating an Early to Middle Palaeocene age[16–18]. Hence, the basaltic lava flows, the parent rocks of laterites, must be even older and most probably of Late Cretaceous age. The assignment of a Palaeocene age to the laterite horizon of Gujarat is most appropriate as it underlies Eocene strata and overlies the Late Cretaceous Trappean rocks. The interpretation suggesting that the Deccan Trap volcanic activity extended over a period of time of the order of 5 m.y.[19], vindicates our studies.

In Rajasthan, laterites with minor bauxite deposits are found capping Deccan basalts in the southeastern region. The age cannot be assigned as there is no sedimentary cover over these laterites. A lateritic horizon within which high grade deposits of bentonite, with an approximate total reserve of 19 million tonnes, is encountered in the desertic areas (Thar) of western Rajasthan. Enormous deposits are reported in the Barmer district, with minor occurrences in Jodhpur, Bikaner and Ganganagar districts. The age of these lateritic clays and bentonite has been assigned as Pre-Eocene, evidenced by the occurrence of 20 million tonnes of lignite seams embedded in Palaeocene-Eocene strata near Palana village south of Bikaner city[20]. These Palana lignite seams are overlain by the Marh sandstone and Jogira Fuller's earth interbedded with limestone containing fossils of ostrea and foraminifera. The 9 m thick numulitic limestone, struck while drilling for groundwater, at a depth of 407 m in the Karnpur area of Ganganagar district, is considered to be post-bentonite and lignite in age. The bentonite group (Akli formation) in the Barmer area is overlain by the Mandai sandstone with ill-preserved leaf impressions and this is in turn overlain by the Kapurdi Fuller's earth horizon, known as sticky clays, containing pelecypod fossils[21]. This indicates that the marine transgression in western Rajasthan was after the period of bentonitization and lignitization. The Eocene sea extended up to the western fringes of the Aravalli mountain chain[22]. This depression was partly tectonically connected with the Cambay basin rifting and mainly with the regional subsidence of the Indus-Quetta Tertiary geosyncline[23]. The source rocks of these bentonites and Fuller's earth in this region are the Malani volcanics of Precambrian age, consisting of andesitic and rhyolitic flows, volcanic tuffs and ashes[24]. The Fuller's earth horizon represents the reworking and deposition of the earlier formed bentonites of continental origin. This Fuller's horizon is obviously younger than the laterites and lignites.

In NW Uttar Pradesh, minor occurrences of laterites and lignites are exposed around Ranibagh and Bhowali villages in the Kumaun Himalayas. These laterites have been formed by the weathering of the Krol belt rocks which have been correlated with the Jammu limestone[25]. The black shales within which lignites are embedded form the base of the Subathu formation consisting of various rock types including shelly limestones with oysters and numulites. These rocks extend into Jammu-Kashmir in the west, running through Pauri-Garwal and Himachal Pradesh Himalayas. Minor outcrops of laterites or ferruginous shales and ferruginous sandstones are reported in the latter two localities, overlain by black shales with debris of plant fossils.

In Jammu-Kashmir, laterites of ferruginous shales and bauxites occur as blankets covering the Permo-Carboniferous Sirban limestone (Jammu limestone[25]). Bauxite deposits are located around Chakkar, Sangar Marg, Salal Fort Hill and Chhaparbari in the Riasi and Narshera Tehsils and near Khanda and Thakalia in Poonch. Lignite and coal deposits are found in Kalakot, Metka; Mahogala and Jangalgali areas. Over 10 million tonnes of coal have been estimated. The nature of the coal is semi-anthracitic, in contrast to the lignites of Gujarat and Rajasthan. The transformation from lignite to anthracite has been induced by tectonic activity during the Himalayan orogeny. The seams of coal are highly folded and crushed[26].

Recently, officers of the Geological Survey of India have classified the bauxite formation as a separate series altogether, overlying the Sirban limestone with a profound disconformity. It consists of basal red sandstones and ferruginous shales, followed by pisolitic bauxite and aluminous clays, carbonaceous shales with dicot and monocot plant fossils, and red non-pisolitic bauxite and grey aluminous clays at the top. This series is overlain unconformably by the Subathu group consisting of black and grey shales with coal seams overlain by grey shales with bands of numulitic limestone. The Subathu rocks are in turn overlain disconformably by the brackish to fluviatile fresh water Murree series of Lower to Middle Miocene age. The upper age limit of the bauxite series is definitely Pre-Eocene as it underlies the Eocene Subathu formations. Based on the discovery of angiosperm plant fossils, the lower age limit cannot be older than late Cretaceous; most likely Palaeocene[27]. Our regional studies reveal a Palaeocene age for this bauxite series, correlatable with those of Gujarat and Rajasthan, as the overlying Eocene strata are identical. To assign a Cretaceous age to this formation is not plausible because at this juncture the Indian plate had just started drifting apart from its original position between latitudes 40°S and 60°S in the Gondwanaland[28]. According to Koppen's climatic classification, any landmass situated above or below latitudes 40°N and 40°S respectively, must necessarily suffer from a temperate climate[29]. This is not at all conducive for the development of laterities, bauxites, bentonites and lignites/coals.

It is well known that lateritization is a process of chemical weathering of rocks, essentially in a tropical climate, where there are very hot summers and heavy rainfall during the monsoon season. Literature pertaining to the environmental aspects of lateritization has been excellently reviewed[30]. This type of tropical climate is strictly restricted to the linear equatorial zone with the exception of topographically controlled areas. In order to explain the formation of the Indian laterites and the accompanying thick tropical forests, we have to consider the drift tectonics of the Indian plate as it was moving across the equatorial zone. The linear belt of laterites and lignites under study, is now trending in a NE–SW direction. But if we consider the palaeoposition of the Indian plate during its early stages of drifting from the Gondwanaland, it is found that it was trending E–W coinciding with the alignment of the latitudinal positions (figure 2A). Thus, these Palaeocene laterites and Eocene lignites must have developed when the Indian plate was in the equatorial zone. The time span for the development of these laterites and lignites was quite short. This corresponds to the speed and the time spent by the Indian plate in the equatorial zone as determined by the studies of magnetic anomalies of the Indian ocean and the Arabian sea floors[31–34]. These thick tropical forests could not have survived under a climate with lesser rainfall which was encountered when the northern part of the Indian plate moved above latitude 10°N prior to 53 m.y. These forests

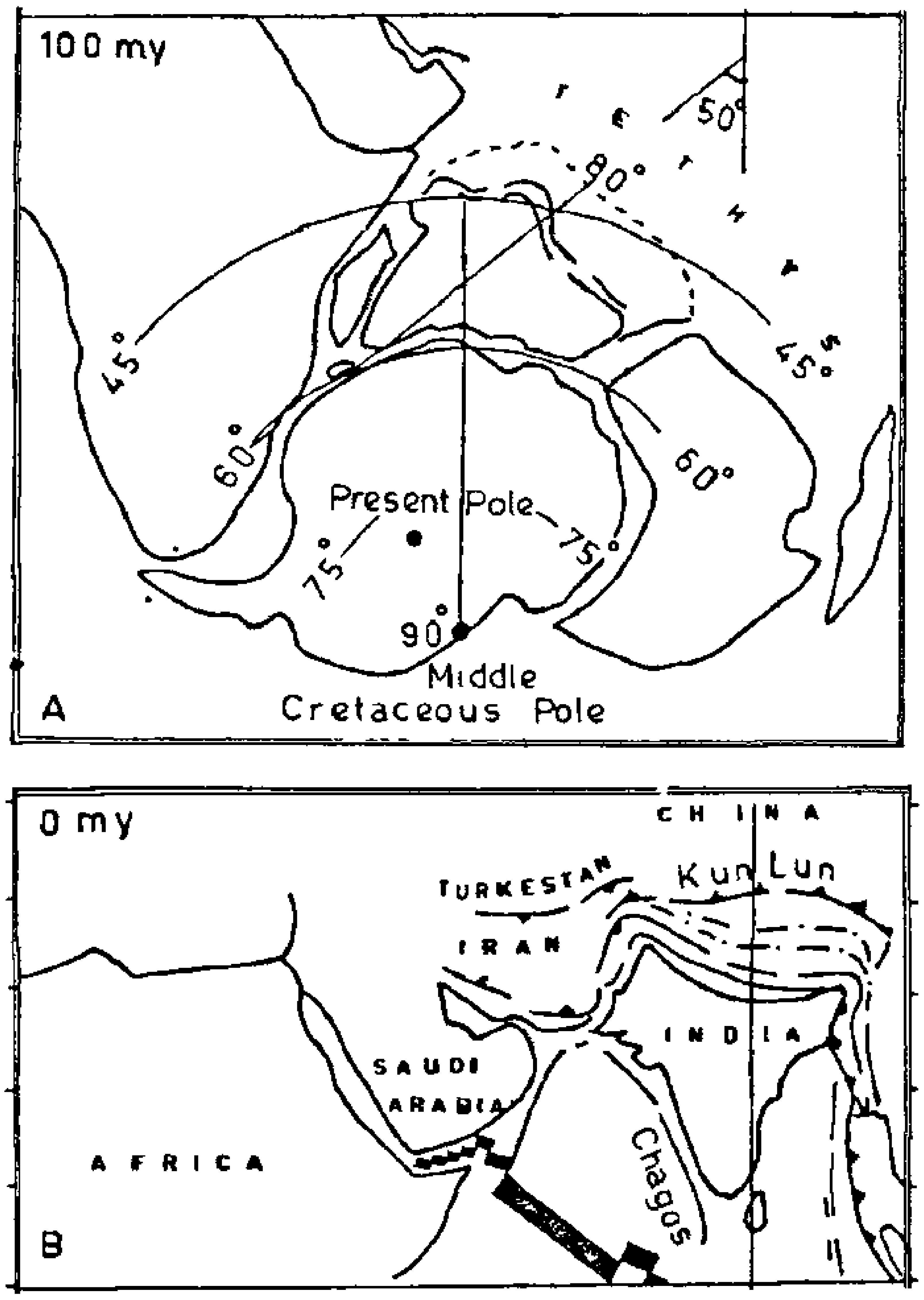

Figure 2. **A.** Palaeopositions of the Indian plate and other surrounding continents in the Gondwanaland (after the best fit of Smith and Hallam[28]). This illustrates the position of the Indian plate with the alignments of the then latitudes and longitudes. The location of the Middle Cretaceous pole is after Creer (Earth Science Reviews, 6, 369–466). The shape of India is presented in terms of Greater India's Concept, indicated by broken line. **B.** Present configuration of the Indian plate having been rotated anticlockwise for a total amount of 50° with respect to its original position in the Gondwanaland.

were ultimately destroyed and deposited as lignite seams in depressed areas during the Early Eocene in the north, but this deposition extended up to Late Eocene-Early Oligocene in the south. Hence, it is logical to suggest that the Indian plate was rotated by 40° *in an anticlockwise direction*, after this particular linear laterite belt had crossed the equatorial zone while the total rotation was 50° (figures 2A, B and 3). Thus, the Indian plate was rotated by only 10° or even less during its journey in the southern hemisphere. This geological evidence is in

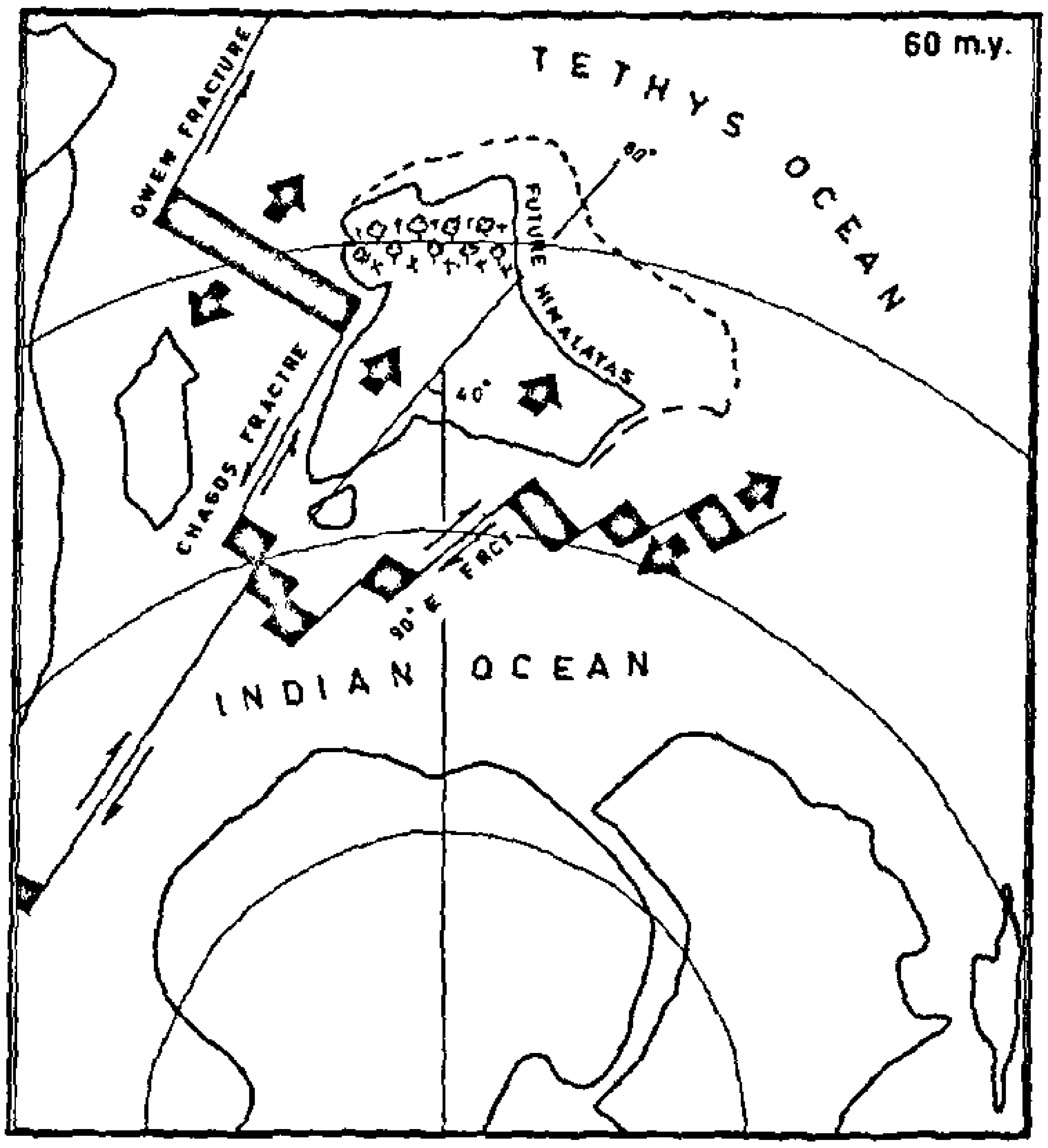

Figure 3. Palaeoposition of the Indian plate during which the northwestern laterite and lignite belt was being formed, indicated by forested area. Broken line indicates the possible extension of Greater India which we believe to have drifted away much earlier than the main Indian plate.

agreement with the reconstruction of the palaeoposition of the Indian plate and the age of the ocean floors, right from the early stage of its break-up and the opening of the Indian ocean and the Arabian sea[35-37]. According to this reconstruction, it is found that southern India spent a longer time in the equatorial zone i.e. between 53 m.y. and < 32 m.y. It has been discovered that the initial speed of drifting of the Indian plate was very fast, 17 cm/year total rate, it decelerated and then stopped around 56 m.y. ago and again started drifting with a much slower rate[38]. This has been possibly attributed to its leading edge having reached the subduction zone in the Tethys sea to the north. This must be the only logical reason to explain why the southern Indian continental plate was spending a lot of time in the equatorial zone. If this is acceptable, then the size of the Indian continental plate must have been sufficiently big to have its trailing edge in the equatorial region and its leading edge in the Tethys subduction zone. Thus, the shape and size of the Greater Gondwanic India, as suggested by Crawford[39], and approved by many

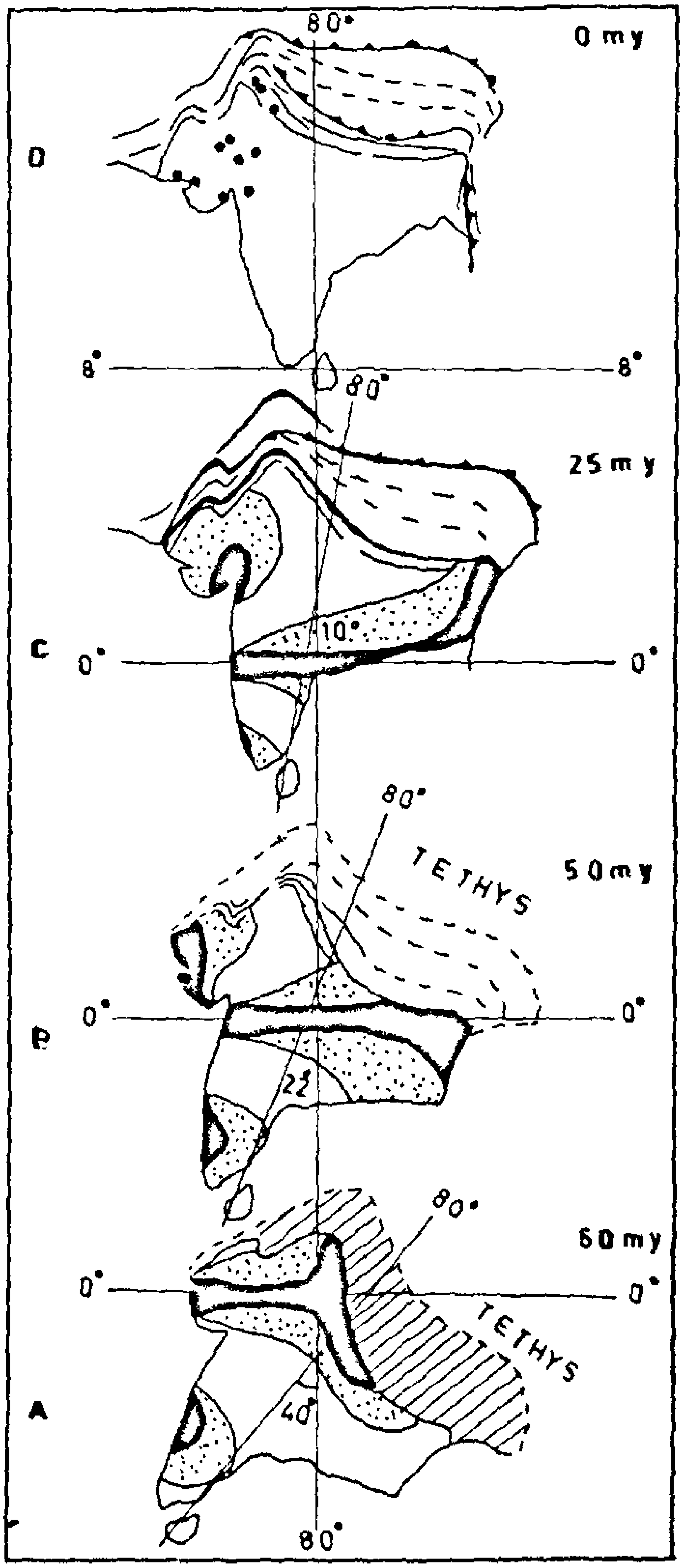

Figure 4. A, B, C. Palaeoclimatic reconstruction of the Indian continental plate during its course of drifting across the equatorial zone. Construction is based on the available laterite and lignite data with respect to the recent wind circulation and climatic classification in terms of precipitation (Early Palaeocene, Early Eocene and Late Oligocene respectively). D. Present-day configuration with the distribution of the northwestern laterite and lignite

belt. Dark area denotes wet climate, suitable for lateritization and thick tropical rain forests; stripped dotted area indicates humid climate with much lesser rainfall; and blank areas represent sub-humid or semi-arid and arid climates. The rotation angles for 50 m.y. and 25 m.y. are approximately calculated based on laterite and lignite data of Central, Southern and Eastern India in comparison with palaeomagnetic results.

workers[40–42], is quite reasonable. In the above age interval, the marine sedimentary facies of the Himalayan and Tibetan regions was terminated at the end of Eocene period (38 m y.). This is evidenced by the disappearance of marine sediments after the numulitic limestones in the lesser Himalayas and by the marine Eocene sediments which pass up into continental deposits in Tibet. Due to the overlapping of several nappes and foldings an estimated crustal shortening of 500 km was developed during the Himalayan orogeny[43]. If the crustal consumption by the subduction of the Indian plate beneath Eurasia and its former leading edge (i.e. Tibet) is also taken into account, then the total amount of shortening increases considerably. This would correspond with the dimension of the Greater Gondwanic India having a leading edge in the Tethys subduction zone and a trailing edge in the equatorial region.

The age of the whole Indian Tertiary laterites and lignites decreases from north to south in concordance with the drift tectonic history of the Indian plate across the equator. Based on these data, the palaeoclimatic reconstruction in this continental plate under equatorial conditions can be suggested following the concept of climatic distribution and precipition over various hypothetical continents of different shapes and sizes in the equatorial zone[44] (figure 4). It is concluded that as a result of the anticlockwise rotation of the Indian plate, the time span for lateritization in Jammu-Kashmir and adjoining Himalayan regions was shorter than in Gujarat and Rajasthan. Thus in terms of volume, the laterites/bauxites and lignites/coals of the Himalayan region are meagre in comparison with those of Gujarat and Rajasthan. The lateritic profiles differ considerably, with mature ones in the south and immature ones in the north. Thus, the position and time span of the Indian plate in the equatorial zone as suggested by Frakes and Kemp[45,46] and Bardossy[47,48] seems to be very generalized, as it does not comply with the ages of laterites and lignites and with the geology of the Himalayas and Tibet as discussed above. But their pioneering attempts in discussing this interesting problem are appreciated.

We acknowledge the encouragement of Profesor S. S. Merh. One of us (SPHS), acknowledges the M. S. Unviersity authorities, especially the Vice-Chancellor Dr B. C. Parekh, for providing a special fund for carrying out this research work.

16 October 1986

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ANNOUNCEMENT

ELEVENTH ALL INDIA CELL BIOLOGY CONFERENCE, DECEMBER 1987

The Eleventh All India Cell Biology Conference will be held at the Department of Zoology, University of Delhi, under the joint auspices of the Centre for Advanced Study in Zoology and the Indian Society of Cell Biology, on 26, 27 and 28 December, 1987. A Symposium on Cell Differentiation will form a part of the Conference. Scientists who wish to participate and present research papers may write to the Convener of the Conference, Department of Zoology, University of Delhi, Delhi 110 007, before June 30, 1987.