

THE STRUCTURAL AND DRAINAGE PATTERNS OF THE WESTERN GHATS IN THE VICINITY OF THE PALGHAT GAP¹

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CONTENTS

	<i>Pages</i>
I. Introduction	104
II. Physiography of the Area	104
III. Climate	106
IV. General Drainage	106
V. Geological Formations	107
VI. Geological Structure	107
VII. Drainage pattern in the Hill Tracts adjoining the Palghat Gap and its possible explanation	109
VIII. The Evolution of the Palghat Gap	113
IX. Bathymetric contours in the Arabian Sea west of the Palghat Gap	115
X. Period of formation of the present West Coast and the probable age of the Palghat Gap	116
XI. References	118

I. INTRODUCTION

The Palghat Gap which lies across the Western Ghats in Malabar, forming the only major break in the continuity of the high hills and connecting the West Coast with the rest of the Madras State, is a noteworthy feature in the physiography of southern India. The nature and the mode of origin of the gap is an interesting problem in the geology of southern India which has hardly received any serious attention. No detailed geological mapping of the area of the gap and the adjoining high hills has been carried out till now.

A study of the one-inch and quarter-inch topographic maps of the region has brought to light the remarkably interesting drainage pattern in the hills immediately to the south of the Palghat Gap. The alignment of certain streams and groups of streams with intervening cols along two or three lines forming straight linear patterns of some considerable extent, would seem to indicate possible lines of shearing or faulting. A careful study of the trend lines in relation to the physiography, drainage and geology of the area reveals many striking facts and has enabled us to arrive at certain tentative conclusions regarding the evolution of the drainage pattern of the area and also the possible origin and the age of the Palghat Gap.

II. PHYSIOGRAPHY OF THE AREA

Physiographically the peninsular area south of Mangalore, with which we are concerned, may be divided into three broad natural divisions, (1) the narrow strip

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Dr. S. L. Hora, Director, Zoological Survey of India, after studying the fish fauna of the hill streams of the Western Ghats, has arrived at certain interesting conclusions regarding their distribution on either side of the Palghat Gap. On discussing with him the geological aspects implied in the distribution of the hill stream fauna, we were stimulated to search for evidence which may throw some light on the structure and the possible age of the Gap.

of coastal plains of South Kanara, Malabar, Cochin and Travancore, (2) the high ranges of the Western Ghats with a narrow gap at Palghat, and (3) the broad undulating plains of South Madras comprising the districts of Coimbatore, Salem, Madura, Trichinopoly, Ramnad and Tinnevely.

(1) *Coastal Plains*.—The plains along the West Coast extend continuously from Bhatkal port north of Mangalore as far as Cape Comorin at the southern tip of the Peninsula. In the Mangalore region, the coastal plain is 5–8 miles in width, but it narrows down to a strip of only 2 miles near Kasargod. South of Cannanore the plain broadens out and in the region between Calicut and Quilon, reaches a width of nearly 15–20 miles. Between Trivandrum and Nagercoil in the south, it again narrows down to 6 or 8 miles. A section across the coastal plain from east to west reveals four sub-divisions, (a) a steeply sloping, partially forested country formed of hills and ridges immediately at the foot of the ghats, followed by, (b) an undulating tract with water-logged paddy fields interspersed with low hillocks and mounds of laterite, succeeded by, (c) a flat raised tract (3–6 miles) capped with laterite and underlain by sub-recent sediments towards the coast, (d) the regions between Ponnani and Cochin, and between the latter and Quilon are marked by the backwaters parallel to the coast.

(2) *Western Ghats*.—The Western Ghats extend as a range of high hills, 15–30 miles in width, over a distance of nearly 450 miles in a NNW-SSE direction from near Karwar on the Bombay border to Cape Comorin in the south. The highest peaks are the following:—

South Kanara: Kodachadri (4,402) and Kuduremukha (6,207).

Coorg: Pushpagiri (5,620).

Nilgiri: Vavulmala (7,673), Doddabetta (8,640), Kolarbetta (5,624).

Nilgiri-Malabar border: Gulkal (8,090), Anginda (7,817), etc.

Cochin: Karimalai Gopuram (4,721).

Anaimalai hills: Anaimudi (8,841), Tanakamalai (8,244), etc.

Kodaikanal hills: Ibex Peak (8,663), Vembadi Shola Peak (8,221), Kodaikanal Peak (7,664).

Andippatti-Varshanad hills: Surulimalai (5,680), Suruliparai (6,221).

North Travancore-Tinnevely border: Kottaimalai (6,624), Sivagirimalai (5,723) and Devarmalai (6,307).

South Travancore-Tinnevely border: Vairattimotti (5,237), Agastiyamalai (6,132) and Mahendragiri (5,427).

The general trend of the ghats is NNW-SSE and there are three more or less arcuate projections extending eastward into the South Madras plains: (a) the Nilgiri range running ENE between the Coimbatore plains and the Mysore plateau, and continued northward into the Satyamangalam-Kollegal hills of Madras and Biligirirangan Hills of Mysore, (b) the Palni range (Kodaikanal hills) running also ENE and continued east and ESE, after a narrow pass at Dindigul, into the Sirumalai-Ammayanayakkanur-Ayyalur hills, and (c) the low Varshanad-Andippatti range running NE towards the Vaigai valley. Lying between the arcuate projections of the Nilgiri range and the Anaimalai-Palni range is the Palghat Gap, with an elevation of 250–1,000 ft., the highest point in the gap being a little over 1,000 ft. near Pollachi.

(3) *Plains of South Madras*.—The plains to the east of the ghats comprising the districts of Coimbatore, Salem, Trichinopoly, Madura, Ramnad and Tinnevely, form a broad undulating region sloping gently to the east and south-east towards the Bay of Bengal and the Gulf of Manaar. These fall into two divisions, (a) the Coimbatore-Salem-Trichinopoly region lying between the Nilgiri-Satyamangalam hills in the north and the Palni hills to the south, and (b) the Madura-Ramnad-Tinnevely region to the south, separated from the northern region by the projection of the Palni-Varshanad-Andippatti ranges. Between the Palni and the Andippatti

hills lies the narrow Kambam valley. The general elevation of the northern plain is between 500 and 1,000 ft., while that of the southern is between 250 and 500 ft.

III. CLIMATE

The area has an equable temperature ranging between 75° and 100°, the mean for the year being 80°–90°. February to May is the hot season when the temperature rises to 90°–100°; between December and January is the cold season with a temperature range of 70°–77°. With regard to rainfall, there is great contrast between the West Coast and the plains to the east of the ghats. The south-west monsoon breaks on the West Coast at the end of May and for three or four months the region is in the full grip of the monsoon. The annual rainfall, which is mostly received during this period, goes up to 200 inches. The South Madras plains, being on the leeward side of the ghats, receive practically no rainfall during the south-west monsoon except around the Palghat Gap and the high passes as in the Kambam valley and around Shencottah. Only strong dry westerly winds prevail here during this period which lower the summer temperature considerably. The rainfall on this side is around 35 inches, the greater portion of which is received during the north-east monsoon in October, November and December. During this period, the coastal region immediately adjoining the Palghat Gap is subjected to dry easterly winds and dust storms.

IV. GENERAL DRAINAGE

The drainage of the region is in conformity with the three physiographic divisions, with the summit of the Western Ghats forming the natural divide between the drainage systems of the West Coast plains and the South Madras plains.

The rivers and streams along the western slope of the ghats flow west and north-west and, on emerging into the coastal plains, run west or south-west into the Arabian Sea within a short distance from their source in the hills. The most important of these rivers are the Netravati and Payaswani in South Kanara, the Valarpattanam, Beypore and Ponnani (Bharata Puzha) in Malabar, the Chalakkudi Ar and Periyar in the Cochin region, and the Manimalai Ar (Pamba Ar), Achankovil Ar and Kodayar in Travancore. Owing to the heavy rainfall along the western slopes of the ghats, the rivers and streams on the West Coast are perennial. Their course from the hill slopes to the sea is short and steep, and they flow rapidly into the sea cutting steep valleys.

The rivers and streams of the South Madras plains have their sources on the steep eastern slopes of the ghats and they flow east or south-east towards the Bay of Bengal, Palk Strait or the Gulf of Manaar. They flow with only moderate currents and have developed long broad valleys. Having their source on the leeward side of the ghats which receives only a low rainfall, the majority of the rivers and streams, except the Cauvery, are dry during the greater part of the year and are flooded only during the monsoon.

In relation to the two sub-divisions of the region, the drainage systems are also quite separable. The chief rivers of northern region are the Bhavani from the Nilgiri hills, the Noyyal from the Coimbatore hills and the Amravati from the Anaimalai hills. These flow east or north-east into the Cauvery which enters this region from the Mysore plateau after cutting through the Kollegal hills and flows south, south-east and east between the districts of Salem, Coimbatore and Trichinopoly.

The important rivers of the southern region are the Vaigai from the Cardamom hills, the Vaippar from the Sivagiri hills, the Chittar from the Tenkasi hills and the Tambraparni from the Papanasam hills. All of them flow south-east into the Gulf of Manaar. The Vaigai is the longest river in the area. Rising from the Periyar

lake on the eastern slopes of the Cardamom hills, as the Suruli Ar, it flows north-east through the Kambam valley for nearly 50 miles and then turns south-east as the Vaigai river flowing through Madura and entering the sea not far from Ramnad town. The details of drainage of the area adjoining the Palghat Gap are given in Sections VII and IX below.

V. GEOLOGICAL FORMATIONS

The geological formations of the area belong to the Pre-Cambrian metamorphic complex with a narrow belt of sedimentaries along the coastal region. The Pre-Cambrian rocks consist of granitoid mica-gneisses and garnetiferous gneisses, with broad massive bands of charnockitic rocks, and thin bands and lenses of hornblende and biotite schists, granular quartzites, crystalline limestones and calc-granulites, and metamorphosed rocks of igneous or sedimentary origin including pyroxene granulites, epidiorites, etc. The northern part of the region, comprising the districts of South Kanara, Malabar, Cochin, Nilgiris, Coimbatore, Salem, Trichinopoly and Madura, shows a more predominant development of granitoid biotite-gneisses, while the area to the south is chiefly composed of garnetiferous gneisses. A few lenses and masses of ultrabasic rocks like pyroxenites, amphibolites and dunites are also found. Pink granites and granitic gneisses of a late age (equivalent to the Closepet granites of Mysore) occur amidst the gneisses of both the regions, but more commonly in the north. With these granites are associated some younger pegmatites and quartz veins which carry at places mica, gemstones and rare-earth minerals like allanite and columbite-tantalite.

The sedimentary formations along the West Coast are of small thickness and of Recent and sub-Recent age, except for the Miocene Warkalai and Quilon beds. The lignites of Beypore and Cannanore are probably also of the same age.

The rocks of the South Madras plains are not weathered to any considerable extent and the country commonly displays good outcrops. The soil and alluvial mantle, except along the river valleys, is very thin, ranging up to 10 feet in thickness. The summits of the Western Ghats and the steep eastern slopes of the range are also composed of barren precipitous rocks with only a thin capping of soil.

Conditions are different on the West Coast and on the western slopes of the ghats, owing to the heavy rainfall and thick vegetation. The soil cover in the West Coast plains is on an average 50 ft. in thickness and there is also a thick capping of laterite in many places, especially on the western slopes of the ghats, the higher regions of the ghats being composed of barren unweathered rocks.

VI. GEOLOGICAL STRUCTURE

(Text-figs. 1 and 2)

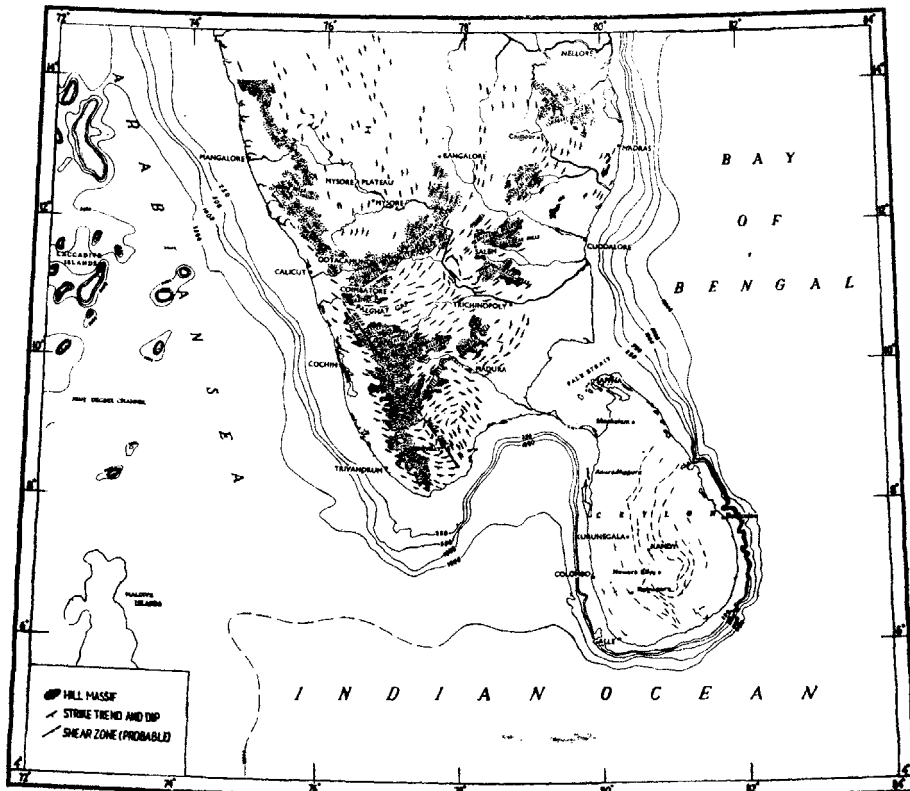
The trend lines of the rocks together with the broad physiographic features and geology are shown in the accompanying sketch map (Text-fig. 1).

The strike of the rocks in the coastal plains and along the western slopes of the ghats is generally NW-SE, varying between NNW-SSE in North Kanara and Coorg, NW-SE in Malabar and North Travancore, and WNW-ESE in the South Travancore region. About a NNW-SSE imaginary line passing through the summit of the Western Ghats, through Coorg, Wynaad, Anaimalai hills, Periyar lake and Tenkasi town, there is a sudden change in the trend of the rocks due to folding about a north-south axis. From a NNW-SSE or NW-SE trend on the western side of the ghats, the strike veers round to the east, ENE and finally to NE on the eastern side. The strike of the North Malabar-Coorg rocks continues into the Nilgiri range in a ENE direction. This is continued further on into the NNE (and occasional

northerly strikes) of the Satyamangalam-Biligirirangan-Kollegal hills along the Mysore border. The rocks of the Palghat Gap region continue similarly into the Coimbatore plains and turn gradually with a NE strike into the Salem region. This north-easterly trend extends from the Shevaroy-Karayan hill tracts of Salem into the Javadi-Yelagiri hills of South Arcot and is continued into the neighbourhood of Chingleput and Madras city. Similarly the NW-SE strike of the South Malabar-Cochin rocks continues east and ENE into the Anaimalai and Palni hills and further up into the Trichinopoly-North Madura region in a NE directions, beyond which it is concealed by younger rocks. The NW-SE strike of the North Travancore rocks turns round to the NE into the Kambam valley, Andippatti-Varshanad hills and West Ramnad plains beyond which the Archaeans are covered by Tertiary sediments. The NW-SE and WNW-ESE trends of South Travancore extend into the South Tinnevely plains and gradually curve round to an easterly direction towards the coast where they become concealed underneath the sub-recent coastal deposits.

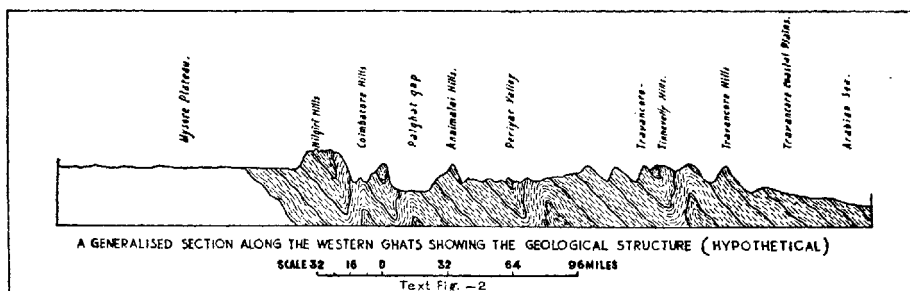
The general regional trend of the rocks in South Madras plains some distance east of the Western Ghats is thus NE-SW. But about a roughly north-south irregular line passing through Erode, Dindigal, Madura city, Virudhunagar and Kovilpatti, there is a northerly loop in the strike of the rocks due to folding of the strata about a north-south axis, similar to the one noticed along the Western Ghats (Text-fig. 1).

TEXT FIG. 1-PROVISIONAL TECTONIC MAP (PRE-CAMBRIAN) OF PARTS OF PENINSULAR INDIA AND CEYLON
SCALE IN S 20 40 60 80 100 120 140 MILES



The general regional dip of the rocks is to the WSW, SW and SSW in the West Coast region, which changes to south, SSE and SE in the South Madras plains. Opposing northerly dips, i.e., to the NW, NNW, north, NE and ENE, are often found along certain areas as a result of local folding. Along the north-south fold axis in the region of Erode-Madura-Kovilpatti, the dips are rather confusing due to the variations in the nature of the folding at different places. The dip is generally steep to moderate. In the West Coast region, it varies from 80°-60° in South Kanara, Coorg and Malabar to 60°-50° in Travancore. In the South Madras plains the dip ranges from nearly vertical to about 50°-60°, and as in the West Coast region, there appears to be slight flattening of the dips as we proceed southward.

The rocks of the Mysore Plateau on the northern side of this region strike NNW-SSE. The Dharwarian schists form linear belts amidst the gneissic and granitic rocks as north-pitching synclinal folds with the intervening anticlinals eroded away. Structurally this region appears to represent the eroded portion of a main anticlinorium.



A careful study of the map seems to indicate that the strike trends of the rocks of South Madras closely follow those of the Dharwar schist belts. The schistose formations thus seem to form the basal portion of the Dharwar schists which may probably rest on older formations. The general structure of the region is that of a series of major anticlines and synclines with minor folds on the limbs of the major ones. In conformity with the Dharwar synclines, these folds should also plunge to the north. The southerly loop in the strike of the rocks about the Western Ghats and in the vicinity of the Palghat Gap thus appears to be a north pitching synclinal fold and the northerly loop about Erode, Madura and Kovilpatti is a north-pitching anticlinal.

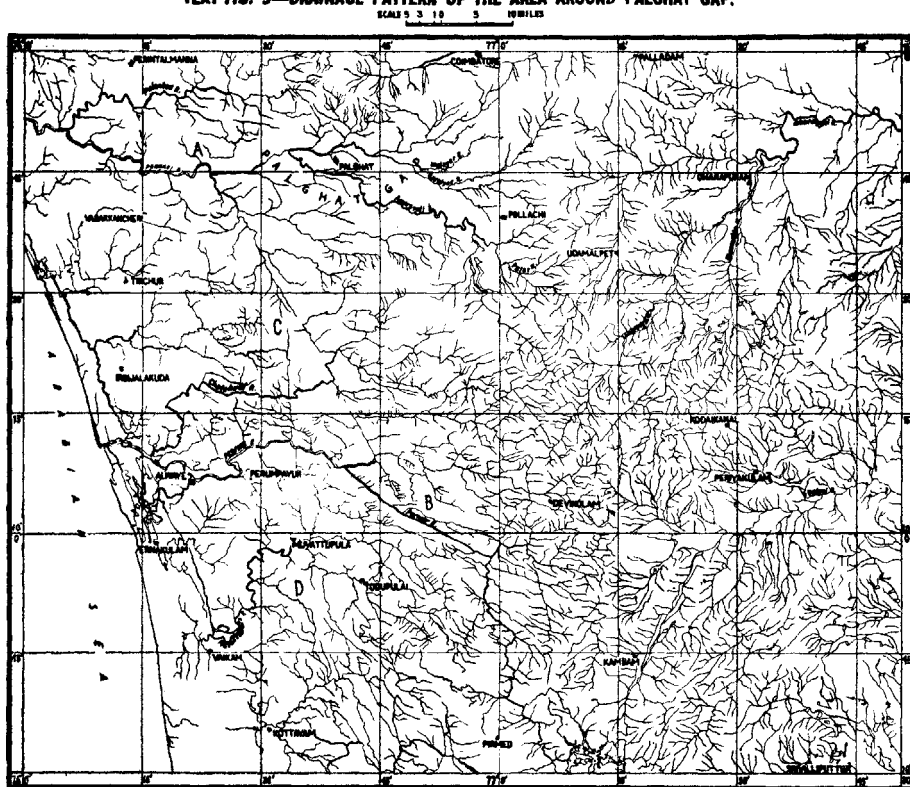
VII. DRAINAGE PATTERN IN THE HILL TRACTS ADJOINING THE PALGHAT GAP AND ITS POSSIBLE EXPLANATION

(Text-figs. 3-6)

A study of the topographic maps of the West Coast and the western slopes of the ghats of this region reveals that the majority of the rivers and the larger streams flow in a general westerly and north-westerly direction in their course through the hills following the strike of the rocks. In the coastal plains which are covered with a thick mantle of alluvium and laterite and sub-Recent formations, the streams have a low gradient towards the sea, preferring no particular directions.

In contrast with the general direction of flow of these main streams, are other smaller streams and tributaries which join the main drainage at high angles cutting across the general trend of the hills and the direction of strike of the rocks. The hill tracts of South Malabar and Cochin lying immediately to the south of the Palghat Gap are of interest in this respect (Text-fig. 3).

TEXT FIG. 3—DRAINAGE PATTERN OF THE AREA AROUND PALGHAT GAP.



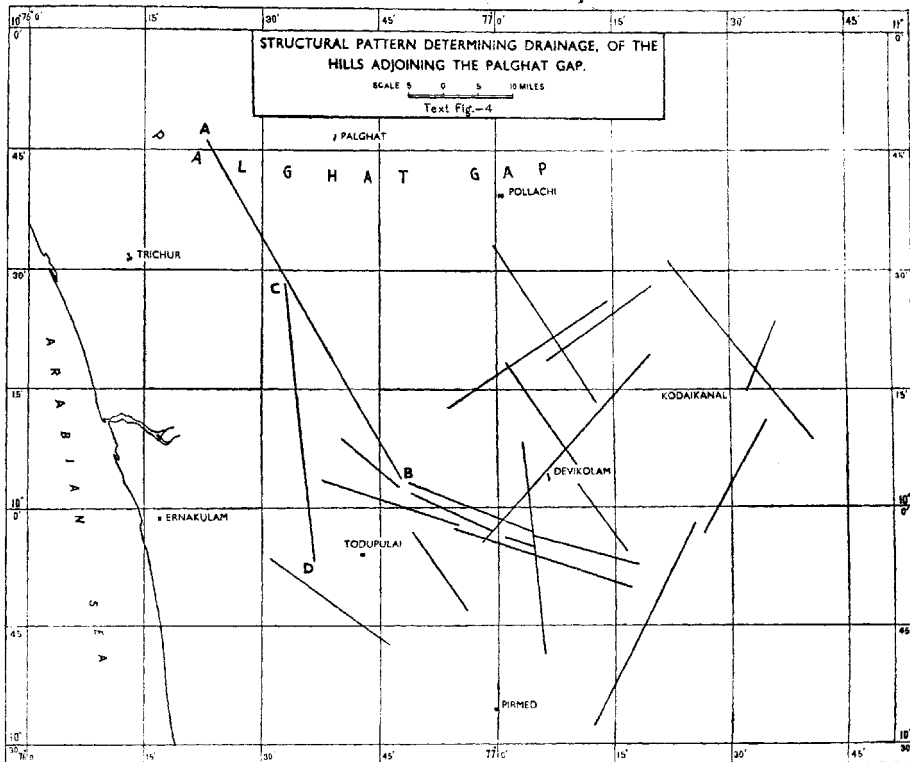
The main streams in this region running west and north-west are (1) the Bharata Puzha in the Palghat Gap, (2) the Mappili Puzha and Parambikolam Ar (along the sides of which the government timber tram line runs), (3) the Chalakudi Ar, (4) the Yedamalai Ar, (5) the Puyankutti Ar and (6) the Periyar.

Meeting these rivers at fairly wide angles are two sets of prominent tributaries, (1) the Gavitri Puzha, the Karappara Ar, the connecting streams between Parambikolam Ar and the Chalakudi Ar and between the northern and southern sections of the Yedamalai Ar and a few others extending in a NW-SE line between the Bharata Puzha and the Periyar; (2) the Kannankuzhi Todu, Perum Todu, Kottapara Todu and a few others running in a N-S line. The courses of the main streams are also marked occasionally by sharp bends which offset the streams for short distances. Groups of waterfalls and cascades are found not only along the main streams but also in the tributaries, particularly near their junctions.

The remarkably straight alignment of the tributary streams (A-B, C-D; in Text-figs. 3, 4) mentioned above is very striking. These are streams (with intervening cols) which take part in the linear patterns. One set lies in a NW-SE direction extending for nearly 64 miles (A-B, Text-figs. 3, 4) and the other in a N-S direction running for a distance of 32 miles (C-D, Text-figs. 3, 4). The two sets converge at the western end of the Palghat Gap area. They probably represent certain well defined structural features.

The northern ends of both may be traced to the actual gap where the height above mean sea-level is only 500 ft. As the straight river patterns are developed between altitudes of 500 ft. and 5,000 ft. above sea-level, it is not improbable, as

Auden (1951, p. 35) pointed out, that the structural features are of great lateral extent, and are developed through a considerable vertical range. In the case of a NE-SW linear pattern extending for nearly 40 miles and which passes near Mattupatti dam site in Travancore, Auden estimates a vertical range of 6,200 ft.



Similar straight alignments, but less striking, are also noticed in the upper reaches of the Yedamalai Ar and Puyankutti Ar, and also at places in the Anaimalai-Devikulam hills. As seen in Text-figure 4, four major directions may be recognized in the linear stream patterns developed in the region to the south of the Gap.

The first impression conveyed by these linear patterns is that they are possibly fault planes. A careful examination of the valleys along the Mappili Puzha and Parambikolam Ar during a traverse along the timber tram line has, however, not indicated the presence of such later faulting. The rocks here are foliated and banded gneisses with charnockitic bands, and have a general WNW-ESE, E-W and ENE-WSW trend with low dips of about 20°-30° generally to the south. The gneissic and charnockitic bands are clearly seen traversing the beds of these tributaries without any lateral shifting or other signs of disturbance. No indication of any fault could be noticed in the vicinity of Ottappalam along the Bharata Puzha west of Palghat where the NW-SE line appears to terminate.

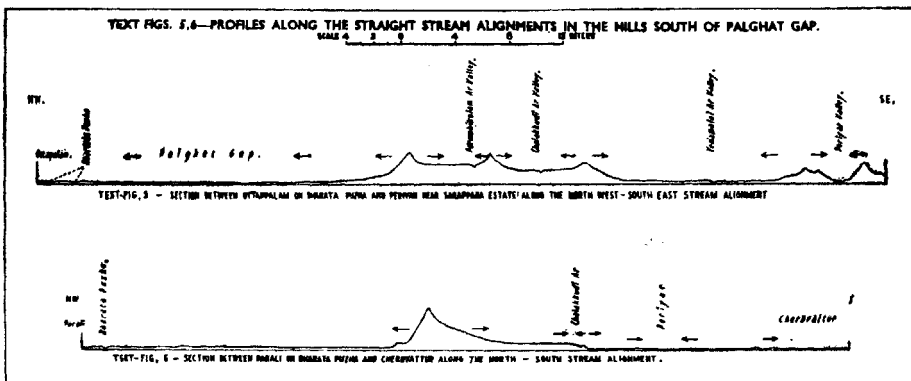
Auden (51) had, however, observed a shear zone about 70 ft. in width near the Mattupatti dam site through which a NE-SW linear pattern runs. He could not find any convincing evidence of major fault offsets having taken place along this zone.

A careful study of the map reveals that the linear patterns (A-B, CD, in Text-figs. 3, 4) are more or less at right angles to the strike directions of the rocks and they occur in greater numbers at the north-pitching synclinal fold, where the strike of the rocks changes from NW-SE and WNW-ESE to E-W and ENE-WSW. It is possible, therefore, that the linear patterns may be the result of shearing.

Shearing may occur more or less uniformly along a straight boundary for considerable length. It may also follow the easiest planes of weakness in the rocks which, in this case, are at right angles to the strike. Such shear fractures most probably determined the straight courses of the tributaries in contrast with the courses of the main streams which follow the strike of the rocks. Elsewhere, these fractures might have encouraged block-faulting, so that one may reasonably expect to find them indicated by long straight segments of streams begun or ended by abrupt bends. If one examines carefully the other parts of the Western Ghats, more examples may come to light. In this connection the recent papers by Radhakrishna (1952) and Radhakrishna and Ghouse (1951) may be seen. An extended study of the stream patterns, particularly of the region south of the gap, should be worthwhile.

It may be pointed out here that during the course of systematic mapping in the Tinnevely district, a 'thrust' zone of presumably Pre-Cambrian age has been recognized by one of us (S.N.) running in a NW-SE direction for a distance of over 120 miles (Text-fig. 1). This zone is traced from the Tambraparni river near Srivaikuntam up to the foot of the Western Ghats north of Srivilliputhur. Except for a slight lateral shift in its alignment in the hills near the Periyar lake region, the 'thrust' zone recognized here apparently extends in continuation of the major shear line (Text-fig. 4, A-B; Text-fig. 1) noticed in the Palghat Gap region.

To our mind an alternative explanation of the linear stream patterns immediately to the south of the Gap is to consider them as remnants of an original drainage much older than the main streams. The present west and north-west flowing streams like the Periyar, Chalakkudi Ar, Bharata Puzha, etc. are apparently subsequent to the faulting of the West Coast region and these have followed the strike directions of the rocks. The direction of flow of the tributaries which make the straight line patterns appears to have no definite relation to the main streams which they join. The sections shown in Text-figs. 5, 6 are drawn along the lines of tributaries extending south-east



and south from the Bharata Puzha to the Periyar. A study of these profiles shows that the divides between the opposing pairs of tributaries gradually decrease in elevation as one proceeds southward, and the south-flowing tributaries are much longer than the north-flowing ones. These features perhaps indicate the possible existence in the past of south-east and south flowing main streams which occupied

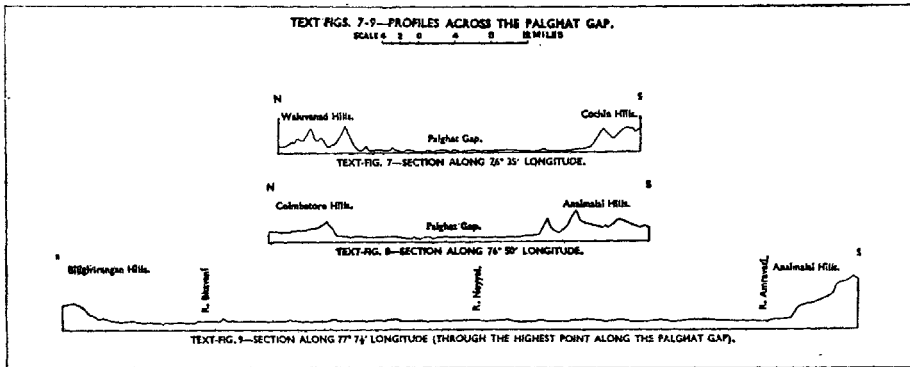
these valleys at a much higher elevation than at present. They were consequent upon the original slope of the terrain. Subsequent to the faulting and tilting of the West Coast region, these streams might have considerably dwindled in size, probably because the sea encroached upon the area to the west stimulating the development of west-flowing streams. They now occupy the position of the old valleys as tributaries meeting the west and north-west flowing main streams formed at a later period.

A recent paper by West (1951) has come to our notice wherein the author mentions having recognized paired shear fractures *en echelon* over a wide area in Alaska, which at times determine straight stream directions. The author has also attempted to determine the direction of inferred force. In the case of the shear fractures recognized in parts of South India we are at present not in a position to determine the direction of force without additional data.

VIII. THE EVOLUTION OF THE PALGHAT GAP

(Text-figs. 1, 4, 7-9)

As mentioned in an earlier section, the Palghat Gap is a fairly undulating pass extending east to west with an average width of eight miles (Text-figs. 1, 7-9). The elevation of the gap ranges from 250 ft. near Palghat to a little over 1,000 ft. at Pollachi (Text-figs. 7-9). The hills on either side rise abruptly as steep precipitous scarps reaching to heights of over 3,000 ft. The almost straight direction of the



hills and their steepness on either side of the gap, especially to the south, might suggest that faulting in an E-W or NE-SW line was responsible for the formation of the gap. A study of the strike trends and other features apparently does not support such a suggestion for the origin of the Palghat Gap. No trace of faulting has been noticed in the rocks of the Coimbatore region immediately to the east of the gap. From a NW-SE trend on the West Coast the rocks turn eastwards through the gap and run east and ENE into the Coimbatore region. It appears, therefore, that evidence for the evolution of the gap has to be searched for in the physiography and the drainage features of the area.

The river Cauvery which forms the main drainage basin here, flows to the south-east and east through the Coimbatore-Trichinopoly plains, between the Nilgiri-Satyamangalam-Salem hill tracts in the north and the Palni-Dindigal hills to the south. The rivers Bhavani, Noyyal and Aravati are the main tributaries which enter the Cauvery from the western side after draining the Coimbatore plains. The combined basin of these tributaries is a broad undulating peneplain.

The major portion of the area receives a low rainfall and the rivers are flooded only for a short period during the rainy season. It is really difficult to conceive of such a broad peneplain developed by denudation by these rivers alone. The shape and size of the basin and its general slope towards the east seem to suggest that it was once occupied by a larger stream flowing eastwards right from the Palghat Gap and receiving a much greater flow of water from the hills to the west.

A study of the contours also indicates that this stream probably occupied the course of the present Amravati river between Karur and Dharapuram, and the Uppar Odai between Dharapuram and Pollachi. The course of the stream further west was probably through the centre of the Palghat Gap with a gradual northerly turn towards its source just above the region of Anangamalai (Δ 1291). The Bhavani and the Noyyal were probably its tributaries which entered the main river from the north.

After the faulting and the subsequent tilting of the West Coast region resulting in the diminution of the water supply from the hills to the west, this Ur-Cauvery might have become considerably dried up. Depending on the degree and direction of tilting, the ancient Cauvery appears to have captured the present stream from the Mysore plateau after cutting its way through the Kollegal-Biligirirangan hills.

The existence of deep gorges like the Mekedatu and waterfalls like Sivasamudram and Hoganakal seems to point to the still youthful stage of the Cauvery in this region. The alternate straight courses of the river following the strike of the rocks, followed by sharp bends cutting across the strikes with deep gorges and waterfalls, apparently indicate a subsequent drainage.

The original east flowing river might have gradually dwindled in size leaving only a steep-sided wind gap in the Palghat region. The profile section across the gap (Text-figs. 7-9) reveals steep and almost precipitous slopes on either side down to 1,000 ft., below which occurs the almost flat valley of the Bharata Puzha.

In addition to the easterly drainage, the probable presence of a large westerly flowing drainage system with its source very close to the Palghat region is indicated by the landward curvature of the bathymetric contours in the region of the Arabian Sea opposite to the gap and continued WSW to a deep channel, 'the Nine-Degree Channel', between the Laccadive and the Maldiva groups of islands (Text-fig. 1). The significance of this submarine depression which may possibly indicate a submerged river valley is discussed in Section IX below. Medlicott and Blanford (1893, p. 495) had postulated the possible existence of a large westerly flowing river running through the Palghat Gap area, its main drainage having been reversed by earth movements which 'raised' the Western Ghats. They suggested that probably these movements considerably reduced the former westerly flowing river into the much smaller stream, the present Bharata Puzha, while the major part of the drainage was diverted to the east.

In explaining the accumulation of the ancient alluvium in the plains of the Narbada, of Berar and of the upper Godavari, Vredenburg (1906, pp. 38, 39), on the other hand, postulates the formation of a shallow anticlinal ridge running west of the western termination of the Narbada and Purna plains with a strike slightly east of north, instead of a general tilting of the western side of the Peninsula. Warping, as suggested here by Vredenburg, cannot explain many other remarkable features on the West Coast. No doubt there are evidences of warping in the western half of the Peninsula, but we feel that tilting has also taken place to some extent. In our opinion tilting and warping of the western parts of the Peninsula followed the block faulting.

The drainage systems mentioned above followed the general slope of the land, and their direction had, therefore, been to the east, south and west. Subsequent to the faulting on the West Coast, a new set of west-flowing streams developed from the steep western slopes of the ghats. These streams followed the weak planes of the rocks which now naturally lie along the strike, viz., to the west and NW.

The Bharata Puzha is one such subsequent stream which has developed along the old gap in the Palghat region. It is now cutting headward into the gap and on to the Coimbatore plains, and its tributaries have their origin from the slopes of the Anaimalai hills south of Pollachi. As may be seen from the section in Text-fig. 9, the only remnants of the original east-sloping valley floor which have withstood erosion and occur as isolated stumps are: (1) the 1,250 ft. high-ground ENE of Pollachi, and probably (2) the ridge Anangamalai (1,500 ft.) to the NE of Shoranur.

In a recent contribution by King (1950, pp. 109-111) on the study of the world's plainlands, the author suggests the existence of three cyclic erosion surfaces in the Indian Peninsular region. In southern India he recognizes a 'Gondwana Cycle' of levelled residuals of Gondwana age in parts of the Nilgiri and Cardamom hills, rising above the general plateau ('Indian Cycle') which he considers to be younger. According to him, the 'Gondwana' land surface is pre-Cretaceous while the 'Indian' land surface is Cretaceous-Middle Tertiary. The Palghat Gap area is shown in his map as 'post-Indian' land surface of late Tertiary-Recent age. In our opinion, King's views require scrutiny before they can be accepted. However, it is of interest to note that the N-S and NW-SE linear drainage patterns observed in the Palghat Gap area cut across the 'Indian' (Cretaceous-Middle Tertiary) and 'post-Indian' (late Tertiary-Recent) land surfaces. To those who find King's views acceptable, it may appear that any shearing that might have been responsible for these linear patterns, probably took place not earlier than the late Tertiary. On the other hand, it is not unlikely that a more ancient feature of the land was rejuvenated in comparatively recent time.

IX. BATHYMETRIC CONTOURS IN THE ARABIAN SEA WEST OF THE PALGHAT GAP

(Text-fig 1)

It is noteworthy that in the region due west of the Palghat Gap in the Arabian Sea, the 200, 500, 1,000 and 5,000 ft. bathymetric contours take a more or less sharp bend towards the coast, thereby suggesting that in this region a submarine valley exists (Text-fig. 1). Further west, between the Laccadives and the Maldives this valley probably extends in a WSW direction as the 'Nine-Degree Channel'. The alignment of this channel and the prominent deflection of the bathymetric contours towards the region of the coast west of the gap, is approximately in the ENE-WSW direction.

This interesting feature may at first suggest the existence of a submerged valley formed by a large river which once took its course through the gap (as postulated in an earlier chapter) in a WSW direction and extending into the region of the Arabian Sea.

It would appear that the Pleistocene changes of sea-level owing to the repeated formation on land of thick ice sheets and their melting, would only account for an oscillation of sea-level of about 300 ft. It is possible that during the low sea-levels of the Pleistocene Ice Age the upper parts of the submarine valley were incised when the shelf surface was largely situated at or above sea-level.

According to Bourcart (1938), continental flexure has apparently taken place along their margins causing periodical marginal flexure or bowing upwards of the borders of the continents, accompanied by submergence of the margins resulting in rejuvenation of the continental border relief. Jessen (1934) has also supported this idea. Such rejuvenation has been a characteristic feature of comparatively recent geological times. But these movements caused by subsidence of the shelf areas and the uplift of the coastal regions can only be small in amplitude.

On the other hand, if we assume a N-S coastal block faulting with crustal subsidence from a normal level, we shall have to postulate a downthrow of at least

5,000 ft. magnitude to account for an erosion base at that depth. It may be that the theories based on sub-aerial origin alone, explaining the present level of the submarine valley, will have to be abandoned.

In a subsequent section, we have attempted to adduce evidence for the Lower Miocene faulting of the West Coast, although some hold the view that this event took place in the Pliocene or Pleistocene times which may be true of only the Mekran Coast.

Though the faulting is of Miocene age, it would seem that the submerged land had preserved some of its erosional features such as the postulated ENE-WSW drowned river valley extending from the Palghat Gap area towards the 'Nine-Degree Channel'. In the present state of our knowledge, it is difficult to decide whether to consider this feature as a mere submerged river valley or as something else. However, as Kuenen (1950) has pointed out, 'Conditions under water may possibly tend to encourage the development of forms that are destroyed on land. The absence of weathering and to a large degree of the creep of surface layers on the sea floor should allow bold forms to persist almost indefinitely that would soon crumble away under the influence of atmospheric attack'. It is therefore quite possible that gullies and valleys of a former land surface may persist under submarine conditions for a much longer period than similar features on the land. Hence the submarine surface features now seen may reflect those present on the land surface in the Miocene just before the land was faulted down.

The Laccadives and the Maldives which for the most part arise from two separate plateaus (Sewell, 1935, p. 42) with the former at a depth of about 1,000 fathoms and the latter about 1,900 fathoms (Gardiner, 1902, p. 296), are not exactly in the same alignment; the latter group of islands lie slightly displaced to the east from a perfect N-S alignment. The 'Nine-Degree Channel' between the two groups of islands may possibly represent a drowned valley occupying a zone of an ancient fault line, the displacement extending ENE opposite to the Palghat Gap area. It has also been suggested by Davis (1928, p. 525) that the Laccadive and the Maldive atolls and reefs are perched on the tops of fault blocks (Sewell, 1935, p. 435).

In our opinion, major changes in sea-levels on the West Coast were caused by several factors including subsidence of land after the block faulting, eustatic changes during the Pleistocene as a result of the formation and melting of large sheets of land ice mostly in the northern continents, and possibly also continental flexure.

X. PERIOD OF FORMATION OF THE PRESENT WEST COAST AND THE PROBABLE AGE OF THE PALGHAT GAP

Subsequent to the faulting along the West Coast of the Peninsula, subsidence took place accompanied by brief incursions of the sea into the land. At that time the present West Coast region was worn back and a wave-cut platform resulted with the formation of wave-built terrace in front. If this surmise is correct the present plains lying immediately at the foot of the ghats represent the wave-cut platform and the laterite uplands towards the coast underlain by the marine sediments, the wave-built terrace. As the trend lines of the rocks are nearly transverse to the coast, drowning and marine denudation have resulted in long promontories alternating with narrow estuaries. This may be seen from the projecting ridges of harder rocks alternating with low narrow valleys at the foot of the ghats. As already pointed out by Medlicott and Blanford (1893, p. 11), the sea probably extended as a bay into the Palghat Gap thus augmenting the steepening of the walls of the gap.

These events were followed by the emergence of the West Coast which then began to expose the sediments deposited in the previous period.

From fossil evidence, the age of the Quilon beds on the West Coast is believed to be Burdigalian (Lower Miocene; Jacob and Sastri, 1951; Eames, 1950). The

characteristic Lower Miocene foraminifer, *Austrorillina howchini* recently found in the Quilon beds (Jacob and Sastri, 1951) also occur in the Miocene of Broach on the Bombay coast (Rao, 1941). It is believed that the two patches are most probably of the same age (Lower Miocene). Near Ratnagiri also, between Quilon and Broach, marine Miocene sediments have been reported although their exact horizon is not definitely known. It would appear, therefore, that the faulting along the West Coast took place before the Burdigalian followed by marine incursion. The later emergence of the coast was in all probability post-Burdigalian.

Profiles drawn at intervals (1) from north to south across the Palghat Gap, and (2) from east to west along the West Coast plains from the sea to the Western Ghats seem to indicate some minor accordance of levels below 2,000 ft. altitude (Text-figs. 5, 6). These levels roughly correspond to elevations of 1,000 ft., 750 ft., 400 ft., and at intervals of 100 ft., between 400 ft. and the sea-level. The possibility cannot be overlooked that these levels may indicate different stages of emergence of the coast. The presence of groups of waterfalls along certain intermittent elevations inside the ghats also seems to have some relation with the suggested emergence in stages (Text-figs. 7-9). Further detailed study in the field will be necessary before any definite views may be expressed on the periods of emergence and other related phenomena.

In the preceding pages we have discussed at some length the possible significance of linear drainage patterns noticed in the Palghat Gap area, in the hope that it may focus attention on the desirability of taking up similar studies in other parts of India. Much of this paper is somewhat speculative. If, however, the views put forward, right or wrong, serve as a stimulus for further observations its purpose has been fulfilled.

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SUMMARY

The Palghat Gap which lies across the Western Ghats in Malabar, forming the only major break in the continuity of the high hills and connecting the West Coast with the rest of the Madras State, is a noteworthy feature in the physiography of southern India.

The physiography, general drainage, climate and the degree of weathering of the region are first described.

The geological formations of the area belong chiefly to the Pre-Cambrian metamorphic complex with a narrow belt of sedimentaries along the coastal region. The Pre-Cambrian rocks consist of granitoid mica-gneisses and garnetiferous gneisses traversed by broad massive bands and lenses of hornblende and biotite schists, granular quartzites, crystalline limestones and calc-granulites, all of which represent intensely folded granitized and metamorphosed remnants of original sediments and basic intrusive and effusive rocks.

The strike and dip of the rocks of south Madras closely follow the trend lines of the Dharwarian schist belts. The gneissic and charnockitic formations with the associated highly metamorphic rocks probably rest on older formation and have suffered the same degree of deformation as the latter. The general geological structure of the region is that of a series of major compressed anticlines and synclines, with minor folds on the limbs of the major ones. In conformity with the Dharwarian rocks, the synclinal folds in these rocks also plunge to the north. The southerly loop in the strike of the rocks about the Western Ghats in the vicinity of the Palghat Gap thus appears to be a north-pitching synclinal fold and the northerly loop about Erode, Madura and Kovilpatti is a north-pitching anticlinal.

In regard to the drainage pattern, the remarkably straight alignment of the tributary streams immediately to the south of the Palghat Gap area with associated waterfalls is very striking. One set of these lines lies in a NW-SE direction extending for nearly 64 miles and the other in a N-S direction running for a distance of 32 miles. They run more or less at right angles to the strike direction of the rocks at each place, and occur in greater numbers in the

north-pitching synclinal fold where the strike of the rocks changes from NW-SE and WNW-ESE to E-W and ENE-WSW direction. The two sets converge at the western end of the Palghat Gap area. It is surmised that there existed south-east and south flowing main streams which occupied these valleys at a much higher elevation than at present. They were probably consequent upon the original slope of the terrain. Subsequent to the faulting and tilting of the West Coast region, these streams might have considerably dwindled in size, probably because the sea encroached upon the area to the west. They now occupy the position of what are thought to be the old valleys of tributaries meeting the west and north-west flowing main streams formed at a later period.

It is suggested that the combined basin of the Bhavani, Noyyal and Amravati which join the Cauvery, is a broad undulating peneplain, once occupied by a larger stream flowing eastwards from the Palghat Gap and receiving a much greater flow of water from the hills to the west. After the faulting and the subsequent tilting of the West Coast region there was a diminution in the supply of water to this Ur-Cauvery. The original east-flowing river probably left only a steep-sided wind gap. In addition to the pronounced easterly drainage, the probable presence of a large westerly flowing drainage system with its source very close to the Palghat region seems to be indicated by the landward curvature of the bathymetric contours in the region of the Arabian Sea opposite to the gap and continued WSW to a deep channel, 'the Nine-Degree Channel', between the Laccadive and the Maldive groups of islands. This submarine depression may therefore indicate a submerged river valley. The combined head erosion of these two opposite flowing streams in the Palghat Gap region might have augmented the formation of the low saddle in the gap.

The evolution of the Palghat Gap may be said to have commenced from the time of block faulting of the West Coast and the possible incursion of the sea into the region. This, in all likelihood, took place earlier than the Middle Miocene, and if this surmise is correct, the age of the gap is not later than the Lower Miocene.

Much of this paper is somewhat speculative. If, however, the views put forward, right or wrong, serve as a stimulus for further observations its purpose has been fulfilled.

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