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*The Editor takes no responsibility for the views expressed in the Journal.
Authors alone are responsible for their respective statements.*

THE INDUSTRIAL GEOGRAPHY OF THE KARACHI AREA

By

AKHTAR HUSAIN SIDDIQI, B.A. (Hons.) Alig., M.A. (London).

The Karachi area,* which lies about 60 miles to the west of the Indus delta, is bounded by the river Hab, in the west, and the Malir river in the east. The Kohistan region, a sparsely populated mountainous area, forms the northern frontier, and in the south, the waters of the Arabian Sea wash its coast line. The Lower Indus Basin (Sind) forms a natural immediate hinterland to the port of Karachi. There is railway communication northward to Sind, the Punjab, Baluchistan and North-West Frontier Province.

The object of this paper is a geographical interpretation of the present distribution of the industries in the Karachi area, as well as an assessment, from the geographical point of view, of the opportunities for the further industrial development of the area.

PHYSICAL SETTING

The rocks of the Karachi area are mostly tertiary, and are very gently folded. There is little in the way of mineral wealth. The rocks found in the area belong to the Upper Tertiary age. The oldest strata belong to the Nari series of the Oligocene system, and outcrops in the range of low hills trending N.E. from Cape Monze to the Mangho Pir region and thence further northwards. These sand-stones and lime-stones are frequently fossiliferous. The Gaj series of the Middle and Lower Miocene are also found in the region as buff-coloured sand-stones and lime-stones. To the south-east, the Gaj rocks again dip under alluvium and Manchhar sand-stone, in the Malir valley.

Physiographically, a greater part of the area is a plain of marine deposits, combined with the plain of sub-aerial denudation of the neighbouring hills. The valleys have been filled up with the alluvium brought down by the rivers. The Karachi coast mostly consists of lime-stone and sand-stone

* The Karachi Administration, which has been termed as the Karachi Area, came into existence on July 23, 1948, after the separation of Karachi from Sind. The Administration covers an area of 812 sq. miles.

rocks, in which many creeks, bays and inlets have been formed due to the encroachment of the sea in this region of the coast. Near Manora and the island of Keamari the work of the sea erosion is most active, resulting in the formation of a natural harbour of Keamari.

Though the streams of Lyari and Malir are dry for the greater part of the year, yet they are a very prominent feature of the land-scape of the area. The dry, sandy and gravelly bed of the Malir river has been interesting to Karachi from the point of view of its water supply. Not only this, but the drift soil derived from the native rocks also supports good vegetation and a number of wells were sunk on both the banks in this part of the valley.

The region is mostly devoid of vegetation, except in the river valleys, where the sub-soil water and the soil support some vegetative cover. Along the coast various kinds of sea-weeds and tall grasses are seen. In the dry hills of the area, especially the Drigh Road area, a large number of perennial herbs having medicinal value grow.

The climate of the Karachi Area, which is in every direction open to sea breeze, possesses a superiority over that found in Sind as a whole. Humidity is high, and both the annual and diurnal ranges of temperature are low. The annual rainfall is more than 7". The mean annual temperature is about 90° F. May and June are the hottest months. The humidity is high but not depressing. In the south-west monsoon season along the coast of Karachi, the wind speed is greater, but the diurnal variations are less marked. During the retreating monsoon period, October to December, Karachi is the only place in the plains where the mean wind speed is 6 m.p.h. or over throughout the day. Karachi stands foremost with 90% of the days in the year having 10 or more hours of such winds, while nearly 60% have 20 hours or more; the number of days with 20 hours or more rises to about 95% in the monsoon season. The maximum duration is found in the monsoon months as at Karachi, and high values are also present in May.

In Karachi, it will be found that wind power, if not absolutely ideal, is by far the cheapest and most convenient motive power available.

Table I, gives the average mean maximum, mean minimum temperatures, humidity, rainfall and the wind velocity at Karachi.

TABLE I.

Month.	Maximum Temp. (°F.)	Minimum Temp. (°F.)	Humidity (p.c.)	Rainfall.	Velocity of Wind (m.p.h.)
January	78.1	46.0	61	0.46	6.4
February	82.4	51.3	67	0.44	7.4
March	88.9	57.0	71	0.29	9.2
April	97.7	64.8	76	0.15	11.4
May	106.0	73.6	78	0.06	13.1
June	105.6	80.4	79	0.72	14.6
July	100.8	80.7	82	3.20	14.9
August	99.2	77.7	84	1.56	13.7
September	99.4	73.6	82	0.52	10.7
October	99.7	63.3	74	0.02	7.6
November	92.9	53.5	62	0.08	5.9
December	83.3	49.0	58	0.20	6.2

Total Rainfall—7.7.

Average Velocity of Wind (m.p.h.)—10.3.

INDUSTRIAL RESOURCES

In a study of the industrial aspect of the Karachi Area, the natural and other resources of the area conveniently fall into the following:

(a) The Mineral Resources, (b) The opportunities for the production of the industrial raw materials by Agriculture in its immediate hinterland, (c) Marine resources, (d) Animal products, (e) Man Power.

It should be borne in mind that some of the industries of the area depend not only on the local products, but also upon the agricultural and non-agricultural products of the whole of West Pakistan and materials imported from overseas.

(a) Though the rocks of Karachi contain no important economic minerals, yet they can be used for several industrial purposes. Most of the hilly area is composed of rocks of lime-stone interbedded with sand-stone, clay and shales. The rocks could be used commercially and they are of potential economic value. Besides the abovesaid minerals, Karachi is in a natural position to use many economic minerals found and produced in Sind and Baluchistan. Chief minerals of Sind and Baluchistan are sulphur, alum, gypsum, barite, bauxite, celestite and silica sand which are to be investigated and properly used for the industrial purposes.

(b) The hinterland of Karachi has several agricultural products, which are raw materials for industry. These products include (i) food crops which are the raw materials for processing industries, such as wheat for flour milling and (ii) crops other than food crops, e.g. cotton, oil-seeds, tobacco, etc.

(c) The sea coast of Karachi offers opportunities for the production of salt and the industries based on it. The fish and fish products offer unlimited possibilities for various industries to be set up at Karachi. Several sea-weeds can be used for cottage industries and for the preparation of iodine.

(d) Animal products also form important raw materials for various industries in the Karachi Area, as there is an ample supply of cattle in the plain region, specially in Sind, which is purely an agricultural zone. Milch cattle, hides and skins, and bones, are the important industrial raw materials of this group.

MAN POWER

Before 1872 Karachi did not show any appreciable increase in its population; but in the year 1901 the population of Karachi increased from 53,500 souls to 116,660. This increase was due to the advent of the North-Western Railways and the consequent development of the port. Since 1911 the population of Karachi has shown a very rapid increase, as is shown in the table given below:

Year.	Population.	Year.	Population.
1872	53,526	1921	201,691
1881	68,322	1931	247,691
1891	105,199	1941	386,655
1901	116,663	1951	1,085,000
1911	140,511		

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This rise in the population is always due to the rapid development of trade and the demand of labour in connection with the port and the construction of buildings in the Karachi Area. The decade from 1891 to 1901 was one of the most important decades in the economic history and the development of the Karachi Area. This decade may be called the decade of the beginning of industrial enterprise within the town of Karachi. During these years flour milling, cotton pressing, ice making, bone crushing and iron workshops were started in the town. After the separation of the province of Sind in 1936 from the Bombay Presidency, Karachi became the capital of the Province, which led to the migration of people from suburbs and other provinces to Karachi. Karachi also took first steps towards industrialization by opening some new factories and reorganising the old ones and fishing trade. The clearing and forwarding business, which was the important occupation of the city in those days, also increased. These were the most important factors for the increase in the population of the city till 1941. In 1951, the population of Karachi has increased more than three times of its former strength owing to the mass migration of Muslims from the Indian Union. It is estimated that since partition of 1947 approximately 6,00,000 have migrated from the different parts of the Union and settled in the Karachi Area. During the last fifty years Karachi port has attained a leading position as a centre of commerce and trade, and having lately been given the status of a federal capital the population of the town has increased to three times its previous size during the last decade.

The main occupation of the people has ever since its existence been commerce and trade for which no statistical information is available to deal with satisfactorily. The second main occupation of the area was industry. These main occupations of the town dwellers have been fluctuating from decade to decade. These fluctuations or variations in number were mainly due to the uncertain nature of agriculture in its immediate hinterland, which was caused by variations in the irrigation facilities in the Lower Indus Basin or by some economic improvements bringing back a good number of people to their occupation. At the end of the year 1892 about 1,894 people were working in the power-driven factories and besides, a good number of people, of which no statistical records are available, were engaged in various cottage industries in the Karachi Area. In the year 1949, the strength of the workers employed daily in the power-driven factories may roughly be estimated about 22,000. The table given in the next page gives the number of workers employed daily in the factories of the Karachi Area from 1892 to 1949.

The figures for these various years are not, however, strictly comparable, the increase in the number of factory workers being due to the extension of the scope of the Factory Act to smaller undertakings, as well as the increase in the number of larger factories or of persons employed therein.

It is difficult to give any estimate of the numbers engaged in various occupations and most particularly the industrial occupation, and no attempt can be made to give a comparative idea as the census figures of the previous decades are inadequate in this case. Also, due to the unsettled conditions of the refugees, and due to the fact that many of them have been changing their occupations, it seems difficult to show what is the actual strength of the migrated labour, unless when the conditions are settled some systematic occupational census is taken. It can safely be said that the area is never short of a supply of manual labour and even those industries which require cheap large unskilled labour force may easily be set up in the area. Some skilled

and semi-skilled labour, which can easily be employed in various industries, such as textile, leather goods, glass works, etc., has already arrived, after having migrated from the Indian Union and has compensated this deficiency to a small extent.

Year.	Daily Workers employed.	Year.	Daily Workers employed.
1892	.. 1,894	1915	.. 4,021
1893	.. 1,781	1916	.. 3,860
1894	.. 2,272	1917	.. 3,702
1895	.. 2,273	1918	.. 4,162
1896	.. 2,347	1919	.. 4,672
1897	.. 2,426	1920	.. 5,442
1898	.. 2,361	1921	.. 5,933
1899	.. 2,731	1922	.. 5,908
1900	.. 2,603	1923	.. 6,159
1901	.. 2,617	1924	.. 6,468
1902	.. 2,927	1925	.. 6,985
1903	.. 2,715	1926	.. 6,823
1904	.. 3,135	1927	.. 6,614
1905	.. 3,467	1928	.. 5,784
1906	.. 3,983	1929	.. 5,442
1907	.. 4,464	1930	.. 5,442
1908	.. 4,352	1931	.. 3,923
1909	.. 3,842	1932-43	(Figures not available separately)
1910	.. 3,910	1944	.. 13,578
1911	.. 3,977	1945-47	(Figures not available)
1912	.. 3,965	1948	.. 20,768
1913	.. 4,334	1949	.. 21,652
1914	.. 4,040		

MOTIVE POWER

Karachi is very poorly developed, as far as its power resources are concerned. The normal sources of power of the city are oil and electricity. A good number of factories in Karachi are run by diesel oil. In conversation with the author, a few proprietors of power-driven factories in the Karachi Area stated that formerly they fixed their boilers with imported coal but that

they have found it economically well worth-while to convert their boilers in order to use oil fuel. At the present time oil prospecting in West Pakistan is being undertaken energetically. There is already some indication that considerable resources of mineral oil exist and that Pakistan can look forward to substantial home products.

The production of thermo-electricity in Karachi is at present very poor and far short of its domestic and industrial needs. At the moment, power is being generated in Karachi at 6,600 volts. The new sets are designed for 11,000, which is now the standard voltage in the world. The maximum generating capacity of the Karachi Electric Supply Corporation at present is 10,500 K.W. Government have decided to place orders in the near future for two 15,000 K.W. steam sets for installation at Karachi and have already ordered two 5,000 K.W. steam sets, one 2,800 H.P. diesel engine and one 1,900 K.W. diesel set to augment the existing supply of electricity. The West Wharf steam generating station, which is capable of expansion to 100,000 K.W. will soon be inadequate to meet the mounting demand for power. As the city is expanding towards the east, Government are therefore planning a second power station at Landhi or Malir. This will be designed for an ultimate capacity of 100,000 K.W. Government are also investigating the possibilities of utilising Jhimpir coal, for raising steam at this proposed power house. All these plants shall generate power required not only for the present use of the city but also to the Karachi industrial estates.

Besides the above power resources, in order to produce cheap electric power, a hydel scheme has been investigated on the Kalri Baghar Feeder. It is to be developed on a 20 feet fall at the down stream and of the lake formed by diverting Kalri feeder into the Sonhera, Kinjra and Kuhi lakes. The scheme would produce 81 million units gross annually. The hydel station will generate 12,000 K.W. and will serve areas in the Lower Sind and Karachi. In this way the area has scope for industrial development in the near future.

WATER SUPPLY

Since the establishment of the town of Karachi the water problem has been taxing the minds of the water engineers. Many attempts have been made for the solution of this problem, but the supply cannot be called assured even now. But with the working of the Lower Sind Barrage (Kotri Barrage) the position will change, as the present source will be replaced by the water from the Kalri canal, about 52 miles from Karachi on the Karachi-Kotri road. This supply will be led by a canal two miles long, up to a convenient point of the Halaji conduit, which is the present water source of Karachi.

EXISTING INDUSTRIES

Karachi is primarily a port and as such it has been working as a transit city, exporting and importing goods of various kinds in and out of Western Pakistan, being the only available port in this zone. There has been very little industrial development in the Karachi Area in the past, and even to-day it is in its primary stages. The Area is suffering from an acute shortage of motive power to run the factories. The lack of energy and initiative among the 'Sindhis' is another reason which has hindered the industrialization of the area. A few existing industries have sprung up during the last few decades. After the division of the sub-continent, because of the arrival of a large number of refugees, most of whom are from the working class and some of whom were industrialists, a few new industries have been started. Though most of the present industries are on a small scale, and produce very little, they still show promising future.

The important industries of the area may be classified into the following groups* :

- I. *Industries based on locally extracted materials*, such as Cement Works ; Cement Tile Works and Cement Drainage Pipe Works.
- II. *Industries based on agricultural products*, e.g., Flour Milling ; Oil Milling and Cotton Pressing.
- III. *Manufacturing Industries* : (a) *Metal Industries*, e.g., Iron Works and Repair Shops ; Wire Netting ; Tin-box Works ; Aluminium Hollow Ware ; and (b) *Other Industries*—such as Electric Bulb Factory ; Rubber manufactures ; Biscuit making and Confectionery ; Ice making Plants ; Carbon Paper making ; Sodium Silicate Works ; Soap making ; Plastic Works ; Oxygen Acetylene and Sulphuric Acid.
- IV. *Industries based on marine products*—e.g. Salt Works and Fishing.
- V. *Industries based on animal products*—e.g. Dairy ; Bone Mills and Tanning.
- VI. *Industries based on forest products*—e.g. Saw Mills and Boat making.
- VII. *Cottage Industries.*

CEMENT WORKS

The cement factory, known as Dalmia Cement Ltd., Karachi, was established in the neighbourhood of Drigh Road of the Karachi Area, in the year 1938. The factory possesses plants which can produce 750 tons of cement a day.

The presence of abundant deposits of high quality lime-stone and clay in hills within a short distance from the factory has helped the development of cement manufacture within the area. The factory is situated in an ideal position with stone quarries adjoining the factory premises and with sidings of North-Western Railways entering the factory.

Lime-stone and clay are the two important raw materials on which the entire manufacture depends. Extensive deposits of lime-stone are found in the Drigh Road Hills and are very suitable in composition. The quarries are open and generally shallow in depth. The lime-stone found at Mangho Pir, is quarried extensively for the cement manufacture. Clay is also found in very large quantity near the cement factory, and is of high quality. In the chemical analyses made in the laboratory of the factory results obtained have proved the suitability of the clay and lime-stone for the manufacture of cement. The chemical analyses, taken from the Karachi Cement Factory, of lime-stone and clay quarried near the cement mill are as follows :

	Loss	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	CaO	MgO	Alkalis	
P. C. 36-38.2	7-12	—	1.3	46-49.7	4.7-	—	—	Lime-stone
P. C. 17-21	35-46	14.5-16.4	5.2	11.5-18	2.5-2.75	—	—	Clay

* The above grouping of the industries is based on the nature of raw materials they use.

Clays are associated with lime-stone in the Gaj beds. Extensive deposits of clay also occur in the Manchhar series. Gypsum is another important raw material required, though it is used in very small quantities. Almost all the gypsum is imported by rail into Karachi from Melting, a quarry in West Sind or from West Punjab.

The annual output of the factory is estimated about 264,000 tons, and about 1,000 men and women are employed daily in the factory. The table given below gives the annual production of cement in Karachi from 1939 to 1950 :

Year.	Tons.	Year.	Tons.
1939	130,996	1943	105,545
1940	132,416	1944	125,713
1941	171,171	1945	174,443
1942	124,955	1950	264,000

The variations in the annual output of cement are the result of the variable nature of the demand for the commodity. The fall in production during the years 1942 and 1943 is said to be due to shortage of coal, as well as due to wear and tear of plants which have been overworked during war. Since 1947 the out-put has been increased due to the heavy programme of building construction in the area, as well as in other parts of Sind and Baluchistan.

CEMENT TILE WORKS

Floor tile manufacture is an industry which gained momentum following an early start at Karachi. The industry was started in the year 1908. This industry has been sufficiently developed on modern lines and commands a good market within the country. Karachi possesses four modern tile factories equipped with modern machinery. Nearly 300 persons are daily employed in these factories and 50% of them are skilled. Besides these works, there are 12 small-scale factories, which are run on a cottage basis. These works besides tile making also make bricks and blocks of sand.

CEMENT DRAINAGE PIPE WORKS

During the last 12 years, due to the programme of building construction, the extension in the city, and the efforts made towards the improvement of the drainage system of Karachi, cement pipes have been manufactured in the city of Karachi. There are four factories which undertake this work. Thus pipes manufactured here are reinforced cement concrete pipes. Hume pipes are also used for culverts, irrigation, drainage and for sundry uses. The raw materials required for the manufacture of such pipes are cement, steel plates and rods. Owing to the shortage of steel, cast iron and other substitutes are also used. The factories consume local raw materials such as sand and cement, which are found in abundance in the neighbourhood of Karachi. The number of labourers depends on the amount of work to be done, but at present there are 240—280 men and women working daily in all the four factories and produce 500—600 pipes of varying sizes in a day.

FLOUR MILLING

Before 1894 there was no large or small scale flour mill for any wheat product in Sind ; but the idea of starting a flour mill came to the minds of the Parsee industrialists, who were working as exporters and importers at that time. The first large-scale flour mill was started in the year 1894 and later on three more large scale flour mills were started in the Karachi area. These four large scale flour mills at Karachi were established between 1894-1936.

The growth of flour milling in Karachi is one of the outstanding aspects of the industrial development of recent times. Karachi's large-scale flour roller mills now have a daily capacity of about 650 tons per day. Besides these large-scale mills, there are about 10 small-scale flour mills and about 60 small unit flour grinding stone mills, run by power, locally known as *Chakkis*, working for the local retail demand.

Flour milling within the area is a direct result of the function which the town has been performing as the trade centre. The entire wheat export of the Indus Plain is carried on through the port of Karachi. Besides, there is a tendency to start a power driven '*Chakki*' for the quite simple reason that the machinery used can easily be handled. For this reason a good number of stone mills (*Chakkis*) have been started in the town. The wheat which is brought to Karachi, a portion of it is ground there, and flour, after being packed in bags, is exported to different countries overseas. About 700 tons of wheat flour is produced daily by all the large and small scale flour mills of Karachi. Wheat constitutes the basic raw material for the flour milling industry. '*Triticum Vulgar*' are common wheats grown in the plains and used in large quantities by the milling industry for the manufacture of flour. In the flour milling industry about 1,000 men are employed daily.

The figures given below only relate to the large-scale flour mills of the area from 1912-1950 and show that there was always a sudden increase or decrease in the average number of persons employed daily each year which is due to the variations in the yield of wheat produced in the plain area.

TABLE II.

Year	No. of Mills.	Persons daily employed.	Year	No. of Mills.	Persons daily employed.
1912	2	191	1926	7	393
1913	3	262	1927	6	387
1914	3	363	1928	—	—
1915	3	261	1929	6	393
1916	3	292	1930	6	393
1917	3	305	1931	—	—
1918	3	325	1932	10	507
1919	3	419	1933	11	440
1920	3	375	1934	11	626
1921	3	339	1935	10	546
1922	3	340	1937	8	706
1923	3	325	1944	9	538
1924	4	372	1949	12	820
1925	5	361			

OIL MILLING

The oil milling industry was started in the year 1922 in Karachi. At first, this work was started on a very small scale; but later on, it was expanded, and now has attained a considerable size from the point of view of oil production. At present, there are about 26 mills, large and small scale, with 65 expellers and 7 oil refining plants. The majority of these oil mills crush coconut, which is imported from Ceylon. The chief raw materials in the oil mills in order of importance are coconut, cotton seed and other oil seeds, which are being crushed. The annual crushing capacity of all the oil mills is estimated about 1,512,000 maunds.

There is full scope for the extension of vegetable oil industry in the Karachi area from the standpoint of the availability of raw materials. Oil-cakes are the valuable by-product of this industry. They are rich in organic matter and serve as food for cattle. They are superior to inorganic fertilisers on account of the humus which they contain. The industrial utilization of oils in Karachi is soap manufacture and production of the edible vegetable oils.

Besides the power-driven oil mills in the area, there are about 60 oil *ghanis*, i.e. the indigenous oil mills, and produce a large quantity of oil from oil-seeds, if they are collectively taken into consideration. In this way, the Karachi area is one of the most important oil-seed crushing centres. This is due in part to the availability of oil-seeds in abundance in its immediate hinterland and in part to a heavy local demand.

COTTON PRESSES

Cotton Pressing is an old industrial work of the city and is the outcome of the cotton export. Since 1865 up to 1922 three important cotton presses were established in the city of Karachi. At present, all these presses turn out 1,000 bales of cotton, wool and hides a day and employ about 350 persons daily.

IRON WORKS AND REPAIR SHOPS

Iron works, which entirely depend on imported raw materials, were started in the year 1883 in the form of a repair shop. Gradually, it got the status of a small-scale factory and started foundry work and later on the preparation of steel goods of various description on a small-scale. From 1901 to 1917 two more engineering works were started in the Karachi area. All these engineering workshops are situated in the Keamari area of Karachi, where they do most of the ship repair work. Besides ship repairing, they are preparing pressed steel tanks, geared pulley blocks, steel wire ropes, garden rollers, storage sheds, petrol tanks and other structural materials, due to the heavy demand for building materials.

During the past two World Wars, the people of Karachi got another chance to start a few more iron re-rolling factories and workshops in Karachi. These factories, no doubt on a very small-scale, were started in the western section of the city, as it was considered to be on the outskirts; but later the labour class settled in this area, due to the availability of cheap land in this sector of this city. The most remarkable thing in the city of Karachi, as regards industrial expansion, is the location of a large number of small-scale engineering workshops and metal works along the length of the Lawrence Road. In all there are about 30 iron works and repair shops which employ about 3,000 persons daily. The foundries of the workshops generally do melting and remoulding of cast and pig-iron. A few of them consume a small quantity of steel for the preparation of hardware. All these factories get very limited quantities of raw materials, so they cannot produce anything on a

large-scale. The machines are generally run partly by electric power and partly by diesel oil engines. As very little coal is supplied by the Government to the foundries, some of these factories have been converted into oil consuming foundries, which are considered economic, as well as effective.

Karachi has one wire netting factory, which was started in the year 1942. At present factory produces 500 ft. by 3 ft. of netting per day and employs about 15 men daily.

TIN-BOX WORKS

Tin works is an old industry in Karachi. In the first instance, oil agencies in Karachi started three tin-box making factories for their own requirements. Later on, three more factories were set up for doing the work for the public. The establishment of confectionery factories and oil mills has already created a huge demand for the tin-boxes in the Karachi area. About 800 persons are employed daily in all the six tin works of Karachi. There is a great scope for increased demand for tin-boxes for packing vegetable oils, biscuits, confectionery, etc. A few factories have already undertaken the work of making cooking utensils and other aluminium hollow-ware.

ALUMINIUM HOLLOW-WARE

This industry was started in the year 1948 on a small-scale. The factory consumes tin and aluminium sheets, which are imported from the United Kingdom. At present only hollow-ware are made. The daily out-put ranges from 250 to 350 lbs.

ELECTRIC BULB FACTORY

An Electric Bulb manufacturing factory was set up in Karachi in the year 1945. It is the only electric bulb manufacturing factory in Pakistan. The factory consumes almost entirely imported raw materials, such as glass tubes, glass rods, filament, copper and chemicals, which are imported from the United Kingdom and Belgium. The total output of the factory ranges from 6,000—7,000 electric bulbs a day and approximately 100 men are employed daily.

RUBBER MANUFACTURE

The manufacture of rubber goods in Karachi was started in the year 1941-42, and at present Karachi possesses two factories which produce various rubber articles. The rubber goods industry is working on the imported raw rubber which generally comes from Singapore. Besides raw rubber, chemicals and rubber dyes are imported from the United Kingdom and the U.S.A. At present these factories are producing play-balls, horn bulbs, tyres, cycle tubes, sanitary fittings, rubber mats, corks, door silencers, soles and heels, etc. Both the factories employ about 160 men daily.

PLASTIC WORKS

In pre-partition days there was only one plastic factory at Karachi. In view of the ease with which finished products can be marketed, simplicity of process, and moderate capital requirements, this industry has attracted a large number of industrialists. To-day in Karachi, there are more than a dozen medium size plastic factories fitted with electrically operated machines. Besides, there are large number of units which function on a cottage scale using hand operated machines. In Karachi, production has been established in respect of certain simple varieties of plastic goods such as combs, bangles, pen-holders, ball point pens, door handles, tooth brushes and the like.

SULPHURIC ACID

An acid plant with a capacity of ten tons per day has been installed. This plant, which came into production in August 1950, has raised the sulphuric acid capacity of the country to more than 3,000 tons per annum.

Besides, to meet the requirements of the country, M/s. Pakistan Oxygen and Acetylene Ltd. installed in Karachi a unit with a capacity of 1,000 cubic feet each of oxygen and acetylene per hour in 1949. They have increased the capacity of their oxygen unit recently by another 1,000 cubic feet per hour. The chief raw materials to manufacture ammonium sulphate or sulphuric acid are sulphur and gypsum. Fortunately gypsum is available in large quantities in West Pakistan. Though the country lacks in the large quantities of sulphur, yet the recently discovered sulphur deposits of Baluchistan and Sind may be used for this industry.

SOAP MAKING

Soap making is a very common cottage industry in the Karachi area. The process of manufacture is easy and a great demand for soap exists in the area. Since the partition, the industry has made remarkable progress both as regards quality and quantity, particularly in the production of washing soap. Even in toilet soap and superior quality washing soap in respect of which there was no production before, some progress has been made. Two soap factories in the area produce toilet soap and other varieties by the full boiling process. Their annual production capacity is 2,100 tons. The chief raw materials for soap making are caustic soda, cotton seed oil, resin, aniline dyes, oils essential for perfuming toilet soap. With the exception of oil all raw materials are imported from the United Kingdom or the United States of America.

TEXTILE INDUSTRY

Cotton forms the most important commodity of export, since the large scale production of good cotton and especially the introduction of long staple American cotton in its hinterland, from the port of Karachi. The cotton textile industry, being a most promising and prospective industry, needs better planning and development in the area. Most of the long staple cotton of the country is exported in a raw state which may also be consumed locally. Karachi being the only port, all the cotton is brought to Karachi for export, and so there are better prospects of starting some large-scale textile mills on modern lines. It has already been said that the climatic conditions of Karachi are fairly suitable, and secondly, with the help of scientific controls moisture conditions may easily be artificially maintained to start such work. The shortage of the skilled labour may hinder progress, but with the co-operation of the Government, trained hands may be had from outside who may train the local hands in spinning, weaving and in other branches of textile industry.

Along the industrial venture in the area, Karachi is fortunate enough to have little planning in the way of industrial development of the area. So far, five textile mills in the industrial estates of Karachi have been located.

The table given below gives the number of textile mills and the number of spindles and looms already working in the Karachi area since 1946 :

Year	No. of mills.	No. of spindles.	No. of looms.
1946	..	1	1,500
1948	..	1	1,500
1949	..	2	27,900
1950	..	3	27,900
1951	..	5	58,100

Besides, there are two hosiery making factories, and a few spooling factories, which make vests, underwear, socks, silken, woollen goods, as well as folding yarn and making sewing thread.

BONE MILL

At present, the Karachi area possesses two bone crushing factories. The first one was started nearly 40 years ago in Karachi proper and the second factory was erected at some time in the year 1930, nearly 20 miles from Karachi, near the railway station of Landhi.

The bones collected from the different parts of the region form the only raw material to be crushed by the crushing plants. The Karachi bone mill is run by electric power, while Landhi bone mill is run by diesel power. In both the factories about 570 men and women are employed daily, and the mills crush about 100 tons of bones a day. In the Karachi area bones are only crushed and exported to overseas, without being of any importance to the country itself.

FISHING INDUSTRY

The Western-coast of the Indo-Pakistan sub-continent has a well established reputation for its fishery and fishing grounds. The greater part of the year, the local fishermen of the Karachi area are found catching fish which are of a large size and are of great economic value. Such fish often migrate northwards from the open sea and reach the Sind-Karachi coast in search of food.

The fishing industry has been carried on near the Karachi coast from time immemorial on a scale so much in excess of local requirements that the salting of fish for export has also become a source of livelihood.

Along the coast, there are a good number of creeks, which are shallow and silted up every day by the action of the waves. There are many numbers of edible fish and prawns within these creeks. There is an excellent submarine bank, only a few fathoms deep near the Indus river delta, which is most suitable for a fishing ground. This area is very congenial for tropical fish and suitable breeding grounds are also found in the lagoons and mangrove swamps. The river silt is rich in mineral and fish food. There are besides extensive prolific fishing grounds north of Cape Monze which is said to be not affected by the south-west monsoon and consequently the sea is said to be much calmer and hence fishable even during the monsoon. Thus the entire coast has conditions which favour the development of a fishing industry. Palla Indian shed, Jhinga Sanmiani, Dhawan, Ranwas, Indian salmon, sea breams and mackerel are the best fish of the area.

In spite of the fact that most of the fishing areas are unexplored and virgin grounds, the total catch of fish on the Karachi coast is about 4,000 tons a year. It may be interesting to note that fish in Karachi waters are mostly of a great size, weighing 20-40 lbs. each and oil producing shark contains Vitamin A of highest potency. A large amount of the fish load is dried with salt on the coast and exported, packed in bales. This is indigenous system of fish curing and needs the attention of the authorities. The fishing industry in Karachi is, however, still in the primitive stage. Fishermen using small country craft and sailing boats are averse to the employment of modern power-driven fishing gear.

SALT WORKS

The salt industry is a large-scale industry on the coast of Karachi, and it has been concentrated at Maripur. The salt industry was started in a well organized form in the year 1922. Within the last thirty years five salt works have been established in Karachi for manufacturing salt on a large scale.

The existence and the development of salt manufacture in Karachi is not only due to the nearness of the coast-line, but also due to the other favourable geographical conditions. In particular the dry climatic conditions of the area play an important role in the development of this industry. The selection of the site and the direction of the high tides, near the coast, are other factors. The Maripur area particularly has vast open levelled spaces where a fairly large number of pans may easily be constructed. The pans are of varying sizes. The largest salt works have nearly 169 pans of three hundred feet by one hundred feet in size, while the others cover a lesser area and have a smaller size in pans.

In some salt works crude method of salt manufacture is used. In the old method, pits are dug and the water is taken from the sub-soil. But now according to the modern methods the water is taken from the high tides and is pumped into pans. This method is adopted in the large size salt works. The output of salt per pan depends upon the addition of the brine. The pan is filled with brine many times and each time crystals are formed after evaporation. After 25 days crystals of salts are removed by means of hand from the pan and are dumped in a heap and that heap remains in the sun for another 15 days for further drying. In order to remove the smallest percentage of sand or mud from the ordinary salt, it is again refined by a chemical process. The salt is washed by the brine solution again, till it becomes free from every impurity. Then it is again dried by electrical machines. The five principal salt works in the Karachi area which are situated mainly in the Maripur area produce about 4,000,000 maunds of ordinary salt a year. Salt is used for several useful purposes. Besides cooking, table salt, and as preservative, it is also used in curing fish, dairying and in other industries, such as glass, leather, soap, oil purification, refrigeration, etc. It is expected that the industrial use of salt will go up as a result of attempts to produce sodium compounds within the country.

COTTAGE INDUSTRIES

Besides the power-driven industries, the cottage industries also occupy an important place even today in the economic structure of the area. They consist of those small-scale industries which are carried on throughout the area on a cottage basis and supply the needs mostly of the local population. In spite of the fact that in recent times machine-made goods are in great demand, such artisans of the area are still the most important of the industrial workers. The industries exist in the area because of a considerable proportion of raw materials, all the artisans and the market exist in the area itself. The most important are Ghahi oil, hand-loom, dyeing and printing, carpet-making, soap-making, leather works, wood works, cane works, etc. For the development of these industries improved implements would have to be introduced and new methods taught to the craftsmen. In many of the handicrafts, process also requires to be considerably improved.

INDUSTRIAL ESTATE

Industrial Trading Estate was established in Karachi in 1947. It has been sited in an area which is at a distance of about 3 miles from the city,

and yet it is sufficiently close for the workers to derive the advantage of local amenities. The entire industrial estate covers an area of 2,400 acres of land with a further 2,645 acres reserved for possible future expansion. The entire area has been reserved for setting up 400 factories. The Karachi Trading Estate has been designed to enter for the following Trades :—

1. Textile—Hand-loom, power-loom, and wool picking.
2. Foodstuffs—Edible oil, biscuits and confectionery, flour mills, etc.
3. Obnoxious Trade—Leather and bone crushing.
4. General Trade—Matches, rubber goods, paints, etc.
5. Engineering Works.
6. Chemicals.
7. Pharmaceuticals and 87 specially projected industries.

At present 5,000 workers are employed on the Trading Estate and it is expected that by the time the present tenants develop their factories to the full, there will be employment available for about 15,000 workers.

CONCLUSIONS AND SUGGESTIONS

A study of the published material on the industrial development of the Karachi area, together with the fieldwork carried on by the author in the year 1949-50 reveals that the area contains very few industries in the sense that these words are understood in the western countries. With the notable exception of some of the cement, salt, flour milling and oil milling, the industries of the Karachi area are developed on a small-scale. No complete production figures for most of the industries of the area are available, but the study of the output figures of a number of factories, which were gathered by the author by personal visits from time to time, shows that the total industrial production is very small. The main reasons for this small output are the shortage of raw materials for various existing manufacturing industries, and secondly, the deficiency of capital and equipment, neither of which could easily be imported or procured in the country.

The area has a large supply of unskilled manual labour and some skilled labour. At present, the area is short of industrial water supplies and motive power, but with the completion of the Lower Sind Barrage, these difficulties will in part be overcome. Most of the raw materials of the manufacturing industries must be brought from elsewhere in Western Pakistan or from overseas. The only local mineral resources are lime-stone and clay.

Industries that depend upon imported raw materials have already been set up in the Karachi area; and further have been sited in the trading estate of the area. They may easily be further developed, if skilled labour and cheap motive power are provided; but their products would need Government protection to enable them to compete with imported goods in the local market. This area is best suited for the industries based on imported raw materials, as well as industries based on locally extracted materials and marine products.

At present, Karachi cannot claim to be an industrial city, as nobody tried to develop it as such. It has been all these decades a 'transit city'. Most of the existing industries of the area are ill-equipped and are on a small scale and need planning of some kind. The present industries of Karachi are

lacking in a number of essentials, and with an exception of a few, such as cement, salt, oil milling and flour milling, Karachi possesses only small-scale industries. In fact, they cannot produce enough to cope with the local demand.

The greatest drawback is the lack of proper selection of sites. A number of factories have been set up in the heart of the city, haphazardly. Thus, atmospheric pollution is the greatest enemy of the city dweller's health. In Karachi, however, its effects are greatly felt, because the geographical position of the city promotes dew fall, the prevailing direction of the winds being southerly and south-westerly also affects the whole city badly by spreading smoke, etc. For this, it is necessary that all the factories, lying within the limits of the city, should be grouped under two heads :

- (a) The factories, which can and should be kept within the city limits,
- (b) The factories, which should be removed elsewhere in the interest of civic life in the city.

All those factories which are run by electric power can be kept as they are, till they make any improvement and expand this work. All the cottage industries, such as hand-looms, shoe-making, and other cottage works should be kept within the city, as they do not injure the public health. Those factories which are lying at present on the outskirts of the city and are run by electric power or oil, yet have taken measures to avoid smoke nuisance, may also be kept as they are. Among these flour mills and cotton presses are to be noted.

The other group of industries, which is the real cause of pollution of the city, for its obnoxious nature, should be removed from the city limits. These factories have been causing two troubles, which are unbearable (1) noise, and (2) smoke. The factories which are a perpetual nuisance for the city, like ice factories and oil mills are almost in the heart of the city. All such factories can easily be located at some other suitable places outside the city.

Lastly, but not the least, zoning should be done within the area. The factory zones of the area should not be allowed for residential purposes. This protective measure is to be adopted in the Karachi area, as the city is badly suffering from this defect and a good number of factories are found in the midst of the residential localities. In the Karachi area, there are good chances of developing some localities industrially, provided that water and the motive power are supplied at a cheap rate. Besides the Karachi Industrial Trading Estate, which includes parts of the suburbs of Mangho Pir and Mariapur area, there are few other localities which could be developed as industrial sites: Dalmia Nagar, Malir, West Wharf, Gazri, Landhi and Drigh Road. Fortunately, the Government planners have also included these localities for the planning of the area under the Greater Karachi Scheme.

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THE COASTS OF INDIA *

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"India for its extent has one of the shortest coastlines of any important country bordering the ocean. Its outline is scarcely broken by a single inlet in its 5,000 miles of sea-coast."¹ Even this short stretch of coastline is remarkably uniform and straight and characterised by a general absence of deep indentations. Therefore there is a general paucity in the number of good harbours; this being most marked on the east or Coromandel coast of India: this is indeed the more striking in view of the many large rivers that discharge into the Bay of Bengal on that side. The reason is not, however, far to seek, since these same big rivers tend to build up bars at their mouths, thus shallowing up the channels, as to ultimately make them altogether unsuitable for navigation.

The lack of suitable harbours is also to "be found to mark the coast of Africa, Western Australia and what are by some thought to be the other remnants of the supposed ancient Equatorial continent, the Gondwanaland."² Such similarity of features exhibited by such now-widely-separated land-masses is naturally to be ascribed to their ancient history and subsequent evolution. According to Ed. Suess, there was a hypothetical southern Palaeozoic continent known as the Gondwanaland, which included practically the whole of 'Africa, Madagascar, Peninsular India, Australia, Tasmania, Antarctica, Falklands and all South America except the extreme west and north-west'³; this continent finally broke up during the late cretaceous times. This hypothetical continent so to say, embraced all the southern rigid masses.⁴ These ancient nuclei (the rigid masses) have been stable dry earth blocks above the sea, for vast lengths of geological time. This latter cause, more than any other, accounts for the paucity of good harbours in them. The other striking feature about the Indian coast is the small number of Islands around them.

The seas around the coasts are nowhere deep, the 100 fathom line running parallel to both the Arabian and Coromandel coasts; this combined with the flat and sandy nature of the sea-bottom makes navigation extremely difficult. On the western sea-board one does not encounter the abrupt deeps, so usual on the eastern coast wherein the sea-board becomes abruptly deeper, a short distance off the coast. *The coasts of India belong mainly to the Atlantic type and are non-embayed, reefless and continental in nature.* A few exceptions to this general observation are however known, especially from the Malabar Coast.

* Published with the permission of the Director, Geological Survey of India, Calcutta.

¹ Morrison, C.—*Scot. Geographical Mag.* XXI (1905), p. 457.

² Frew, David—"A Regional Geography of the Indian Empire." (Blackie, 1925) p. 176.

³ Quoted from the article in the *Encyclopædia Britannica*, 14th Edition, p. 514.

⁴ Steers, J. A.—"Unstable Earth" (Methuen), p. 12.

The continental shelf is fairly well-developed; on the east coast, the best development of a continental shelf being at the mouths of the Ganges. Well-marked coastal plains are noticeable around the coasts of India. The western coastal plain is not so wide as the eastern strip; the eastern coastal strip attains its maximum width towards the south.

THE COASTAL STRIPS

On both the eastern and western sides, running parallel to the sea-coast, lie the Eastern and Western Ghats. There is a well-marked coastal plain between the Ghats and sea. "The coast plain to the west of these hills is rugged and narrow, with a fringe of alluvial formation enclosing long lagoons or backwaters, which admit of continuous inland navigation for long distances. The eastern coastal plain, that of the Carnatic, is of variable width, averaging about 80 miles and where narrowest to the North of Madras, 30 miles across. It consists of alluvial flats around the low course of the rivers that descends from the Eastern Ghats and nearly continuous along that coast."⁵ The western coastal plain, is made up "entirely of gravels and sands and clays, the latter often mixed up with Kankur".⁶ "The eastern and western coast strips have been formed by the wearing down of the edges of this (ancient peninsular) tableland into narrow alluvial coast plains. The edges of these coasts have at the same time slowly sunk or been dipped beneath the sea. Thus along the east coast strip, Engineers, while boring for wells, have in several places, come to old sea-beaches near Madras, beds of Oyster shells have been found nearly 100' below the surface."⁷

According to Burrard the plumb line deflections go to indicate that these coastal strips mark the zones of sub-crustal weakness parallel to the coasts and now since filled up by the river-borne detrita; he concludes 'that it is a zone of subterranean deficiency, a zone of fracture and subsidence like that of the Gangetic plains'. "The evidence of present configuration, confirmed by tradition, point as to an ancient submergence of a vast extension of the continent on the west."⁸ This lends additional support to Sclater's belief in a 'Lemuria' connecting India through Madagascar with South Africa.

Fermor, in his latest study of the Deccan Trap escarpment arrives at a similar conclusion. He affirms that the earth movements which "led to the foundering of the Deccan Traps over what is now the Arabian Sea" affected also the coastal belt by leaving a block of small width at an intermediate level between the great depressed submarine area to the west and the great elevated plateau of the Deccan to the east.⁹

THE WESTERN COAST-LINE OF INDIA

This coast-line extends from the Gulf of Cambay to Cape Comorin and is known as the Konkan in the northern half and the Malabar coast in the south. The strip of coast from the Gulf of Oman to the Gulf of Cambay is structurally similar, though petrologically distinct.

"From the Gulf of Oman to Karachi and along the coast of India as far as Bombay that is a generally reefless shelf, from 50 to 80 or 100 miles wide and about 50 fathoms deep at its outer border; a few fringing reefs

⁵ Blanford, H. F.—*India, Burma & Ceylon* (Macmillan, 1904), p. 153.

⁶ Frew, D.—*Op. Cit.*, p. 109.

⁷ Morrison, C.—*New Geography of the Indian Empire and Ceylon*, p. 27.

⁸ Burrard, Sir S. G.—*The Plains of Northern India and their relationship to the Himalayan mountains.* J. A. S. B. XII, N.S. 1916, p.

⁹ Burrard, Sir S. G.—*The Plains of Northern India and their relationship to the Himalayan mountains.* J. A. S. B. XII, N.S. 1916, p.

follow the shore. South of Bombay, where the shelf narrows to 50 or 30 miles, the coast is still beached and reefless although it has a few embayments."⁹

Petrologically considered the Coast of Mekran is as different from the Bombay coast as the latter is from the Malabar coast further to the south. The coast of Mekran (ancient Gedrosia) is made up of a monotonous series of unfossiliferous sedimentary rocks, chiefly pale greenish shales and light-coloured sandstones, corresponding to the so-called "Flysch" of Europe. The argillaceous rocks are "in the state of a friable clay, scarcely differing from the marine ooze which originally constituted them."¹⁰ The clays or shales are exposed in a series of elongated anticlines trending parallel to the sea-coast.

On the west coast proper "there is naturally a considerable difference of physical aspect to be noticed between the low flat lands bordering the Indian Ocean to the north of the Narbada and those of the long strip of Bombay coast."¹¹ North of Narbada, land growth into sea is general, though not universal. "South of the Tapti River along the length of the Bombay coast, no very recent land growth is visible."¹² North of the Narbada, the coast is made up of marine sediments, neither very old, nor well consolidated.

The Bombay coast is composed of basic lava extravasations—the Deccan Traps. According to Medlicott and Blandford, a larger land than that of peninsular India alone, presumably of moderate relief and altitude, was over-spread with a heavy series of lavafloes, the so-called Deccan Traps in Cretaceous time. The peninsular part of the lava-covered area, now raised to highland altitude is limited on the west by a dissected slope known as the Western Ghats, where descent is made to the Konkan lowland bordering the Arabian Sea. These experienced geologists stated that "the Western Ghats rise from the Konkan in an almost unbroken wall, varying in height from 2,000' to 4,000', cut back in places preserving throughout a singular resemblance to sea cliffs."¹³ From this it is apparent that the recent downfaulting of the Arabian Sea floor (which took place during the late Cretaceous times when the ancient Gondwana continent broke up) has its counterpart in the recent elevation of the Deccan plateau. If this be the correct view, Burrard's suggestion about the younger age of the Western Ghats can be accepted. In this connection Burrard notes the decided curve of the Ghats about Bombay Harbour and also of the fact that at this curve, the Deccan Traps rises to its highest point, Kalsubai. He suggested that a crack in the sub-crust has extended from Cape Comorin to Cambay and that as this crack has occurred the Western Ghats has been elevated.—The Western Ghats have been elevated after the Deccan lavas had become solidified into surface rocks. Their elevation has taken place in the Tertiary age."¹⁴

THE MALABAR COAST

As contrasted with the Bombay coast described above, this is made up of an ancient system of metamorphic rocks, highly indurated and crushed. As a result of the incessant labours of the short swift streams, coursing headlong down the slopes to the sea, numerous alluvial fans have been formed here.

⁹ The Imperial Gazetteer, Vol. I, p. 37.

¹⁰ Fermer, L. L.—Quoted by Davis, W. M. in his "The Coral Reef Problem", p. 53.

¹¹ Davis, W. M.—The Coral Reef Problem (1928), p. 227.

¹² Vredenburg, E. W.—Report on the Geology of Saravan, Jhalayan, Mekran etc. Rec. G.S.I. XXXVIII, Part 3 (1909), p. 202.

¹³ Medlicott & Blandford.—Manual of the Geology of India. Vol. I, p. 378. Quoted by Davis, W. M.—The Coral Reef Problem. pp. 528-29.

¹⁴ Burrard, S. G.—Op. Cit., pp. XCI-XCII.

Again due to the constant lashing of the coast by the waves, and especially more so during the S.W. Monsoon season, numerous sand-dunes have been formed along the coastal strip.

The geological history of this coast is the same as that of the Bombay coast. The only difference is in the occurrence of numerous inlets of water—a number of lakes, lagoons or backwaters. There are also numerous mangrove swamps, especially in the tidal estuaries along the coast.

"Around the southern extremity of India and thence north-eastward to Ceylon, the continental shelf is well-developed, its border being 50 or more fathoms in depth; no islands rise from it. The shore is generally reefless, except that Ceylon has discontinuous fringing reefs and that¹⁵ submerged barrier reefs rise 15 or 20 miles off its south-east side. Adam's bridge, is a wave and current built shoal and this connects Ceylon with the mainland.

THE MADRAS COAST

"An excellent example of a reefless continental coast of emergence is the Madras coast. The unconsolidated deposits of a former sea-floor have been partly laid here. Mature sea-cliffs, from which the deposits were largely derived during a former period of lower stand and long-continued abrasion, now rise several miles inland."¹⁶

The "cliffing took place during a reef free period, probably introduced by upheaval when a coastal plain of sea-floor sediments was laid bare."¹⁷ "In the absence of protecting coral reefs, a long cordon of offshore sand reefs, alternating here and there with deltas has been built up by the Surf."¹⁸

The Madras coast appears to have "suffered a second uplift revealing a second coastal plain and therefore remains reef-free."¹⁹ Above the uplifted plane of marine denudation, "rise numerous unconsumed remnants of Quartzite, the bases of these former islands or 'Stacks' not infrequently being marked by sea-caves."²⁰ The other features of this coast have already been referred to elsewhere.

Further north, "the northern shore of the Bay of Bengal, is largely occupied with deltas (the deltas of the Ganges and the Brahmaputra) which have been built out by great rivers in spite of possible subsidence and of strong wave attack; the deltas are extended seaward in a broad shelf. This low stretch is wholly reefless and is in this respect like the mid-southern coast of New Guinea, where the delta of the Fly River forms extensive flats and shoals."²¹

THE INLETS OF WATER AND THE STRAITS ON THE INDIAN COAST

The more important inlets of water are situated on the west coast of India, especially on the Malabar coast. The only inlets of water on the east coast, the Pulicat, Kolar and Chilka lakes are merely inland lakes, connected with the sea by channels.

¹⁵ Davis, W. M.—Op. Cit., p. 227.

¹⁶ Davis, W. M.—Op. Cit., p. 227.

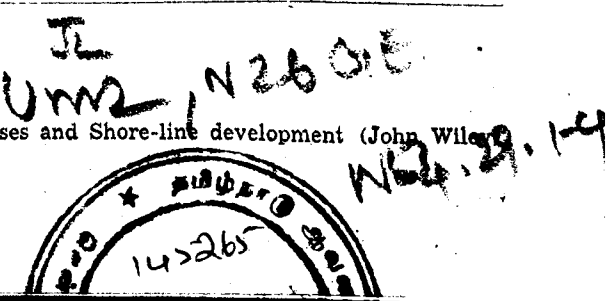
¹⁷ Davis, W. M.—Op. Cit., p. 274.

¹⁸ Davis, W. M.—Op. Cit., p. 227.

¹⁹ Davis, W. M.—Op. Cit., p. 275.

²⁰ Johnson, D. W.—Shore-line processes and Shore-line development (John Wiley & Sons, 1919), p. 231.

²¹ Davis, W. M.—Op. Cit., p. 228.



On the west coast of India, we find²² the Rann of Cutch, the Gulf of Cutch, the Gulf of Cambay and the backwaters of Cochin and Malabar. Of these, The Rann of Cutch is the largest and occupies an area of over 9,000 sq. miles, part of which is however permanently or for the part of the year submerged under water. Like the others it is also very shallow. "The backwaters of Cochin and Malabar are lagoons connected together and joining some small rivers on the coasts, with outlets to the sea."²³ To the South of India lie the Gulf of Manaar and the Palk Straits—inlets of water connecting the island of Ceylon with the mainland of India. The surf adds up its load of silt from the coast yearly and the small waterways are now being gradually silted up.

CHANGES IN SEA-LEVEL

Though in general, the east coast of India bears the impress of recent elevatory movements, apparent from the presence of sea-cliffs bearing sea-caves and the signs of marine erosion, yet signs are not wanting in a few places (cf. Pondicherry) as to the recent submergence of the land.

The oscillations of the sea-level have been much more complex on the west coast. Whereas the Kathiawar coast bears unmistakable signs of land uplift, and specially so in the Rann of Cutch (where it has been mainly due to seismic activity; the earthquake of 1897 tended to raise up a large plot of land—the Allah Bund—though there was also the concomitant submergence of a strip in the neighbourhood), the Bombay and Malabar coasts, on the other hand show unmistakable signs of submergence (cf. the submerged forests on the coast of Malabar and Bombay).

CONCLUSION

The coasts of India have not been properly studied. Years of extensive research, should elapse before any true conclusions could be drawn, regarding the structures of the coast-lines and their relations with similar earth-features elsewhere.

RAINFALL IN THE CENTRAL ZONE OF THE MADRAS STATE

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INTRODUCTION :

The Central Zone of the Madras State comprises five districts of Chittoor, North Arcot, Salem, Coimbatore and Tiruchirapalli. With the exception of Tiruchirapalli, the other four districts contain extensive hills. There are no big rivers in the hilly districts of Chittoor and North Arcot. Salem may also be grouped with these two districts, perhaps with the exception of the Namakkal taluk. In Coimbatore there are two fairly dependable rivers, namely, the Bhavani and the Amaravathi. The other river Noyyal in the Coimbatore district has no doubt a course of 108 miles in length, but it has to be classified only as a jungle stream. In Tiruchirapalli there are the two big rivers, namely, the Cauvery and the Coleroon. Certain taluks in this district get the benefit of the Amaravathi also. A careful study of the natural dependable irrigational facilities of these five districts indicates that no district in this zone can be compared with the districts like the East Godavari, West Godavari and Krishna in the Circars and Tanjore in the South. With the exception of a major portion of Tiruchirapalli the entire central zone has only minor irrigation systems like tanks or wells. It is said that the North Arcot district is the only district in the Madras State with the maximum number of wells.

An examination of these details will reveal that the success or otherwise in agriculture in these five districts depends mainly on the adequate and appropriate receipt of the monsoonal showers. In view of the agricultural importance of rainfall in this zone the available rainfall data have been made use of for statistical analysis.

MATERIALS AND METHODS :

The rainfall data collected on district-wise basis in a period of 82 years—1870 to 1951—were taken up for a statistical scrutiny to gain an insight into the nature of behaviour of both the monsoons in these five districts.

In regard to method the usual statistical methods of working out the different types of correlations existing between the showers received in periods like months, seasons and year were followed. Graphs were also drawn to bring out the nature of relationship existing between the main monsoonal showers and the periodicity of failures of either anyone or both of the two main monsoons, namely the South-West Monsoon and North-East Monsoon.

DISCUSSION :

(a) Particulars regarding the nature of monthly, seasonal and annual precipitations characteristic of everyone of the five districts constituting the Central Zone of the Madras State are given in Table No. I. They indicate that the first three months of January, February and March are the driest

²² New Geography of the Indian Empire and Ceylon of Morrison, p. 29.

²³ Morrison, Cameron.—Op. Cit., p. 29.

months. Conditions improve considerably in the next three months. The South-West monsoon showers are received in July and August. The rainiest season commences in September and continues for three months. In December only moderate showers can be expected. In this zone only 34" of rain can be normally expected with the exceptions of North Arcot and Coimbatore which have respectively 38" and 28" as their annual normals. In short, the data presented in Table I point out that these five districts constituting the Central Zone have practically the same pattern of rainfall.

(b) Sixty-six inter-monthly correlations were worked out for every one of these five districts. From these correlations it looked as though that no tangible conclusion could be drawn. Ten inter-seasonal correlations were worked out for every one of these five districts. Details regarding these correlations are given in Table II. From this table the following tentative inferences may be drawn :—

- (i) If the rains received in the hot weather period of April and May are above normal, it is an indication that the total rainfall in that year will also be above normal.
- (ii) A similar inference seems to be possible with regard to the rains received in the South-West monsoon and the North-East monsoon periods.
- (iii) Both the monsoons appear to be important from the agriculturist's point of view. Practically equal amounts of rainfall may be expected in both the monsoon periods in the Chittoor district. In North Arcot and Salem the South-west monsoon period is likely to record more rains than the North-East monsoon period. In the last two districts of this zone, namely, Coimbatore and Tiruchirapalli the North-East monsoon is expected to give more rains than the South-West monsoon. These small differences are important only from the farmer's point of view. Broadly it may be mentioned that these five districts have almost a similar pattern of rainfall.
- (iv) Generally a negative correlation may be expected with these two monsoons, i.e., if the showers received in the South-West monsoon is far above normal, the showers recorded in the North-East monsoon period will be only below normal in the same year.

(c) The graphs drawn separately for these five districts, making use of the entire available data collected in a period of 82 years confirm the inferences detailed above.

(d) Details regarding the failures of the monsoons and also the total annual rainfall are given in Table III. The general inferences, barring of course a few deviations here and there, are that the pattern of rainfall is practically alike in all these five districts and that the two monsoons are almost negatively correlated in a significant manner.

CONCLUSION :

The annual rainfall in the Central districts of the Madras State is only meagre. Further, its distribution is practically scattered equally between the two important monsoon periods. Indication is there to lead the ryots to the

inference that if the first monsoon, i.e., the South-West monsoon is above Normal, the North-East monsoon will be generally below Normal. There is not much to choose between these two monsoons by the farmers in these two districts though the showers received in the North-East monsoon period are slightly of more agricultural importance in the districts of Coimbatore and Tiruchirapalli than the showers recorded in the South-West monsoon period.

In conclusion it is to be recorded that in a good portion of area in these five districts agriculture still continues to be a gamble with the monsoons. Mountainous regions with fairly good forests are plenty in these districts. These geographical features are meteorologically associated with natural cloud formations. It may, therefore, be mentioned that the Central portion of the Madras State, constituted by these five districts, should form an ideal locality for all the experiments on artificial rain production, which is so much in the air now-a-days.

ACKNOWLEDGMENT :

The author is highly grateful to Sri M. B. V. Narasinga Rao, Paddy Specialist, for his valuable guidance in the preparation of this paper. His thanks are due to Kumari T. P. Anna for her assistance in the analysis of the data and also to all those, who are responsible for the collection of the rainfall data.

TABLE I

DETAILS REGARDING THE RAINFALL PATTERN

S. No.	Month.	Chittoor.	North Arcot.	Salem.	Coimbatore.	Tiruchirapalli.
1.	January ..	0.7	0.8	0.4	0.5	0.8
2.	February ..	0.3	0.4	0.3	0.4	0.4
3.	March ..	0.4	0.4	0.5	0.6	0.5
4.	April ..	0.9	0.9	1.6	2.2	1.7
5.	May ..	2.5	2.9	4.2	3.4	3.3
6.	June ..	2.4	2.5	2.2	1.5	1.3
7.	July ..	3.1	3.4	2.7	1.7	1.6
8.	August ..	4.2	5.2	4.4	2.3	3.9
9.	September	5.2	6.4	5.6	3.0	4.7
10.	October ..	6.2	6.5	6.1	6.4	7.0
11.	November	5.9	6.0	3.9	4.4	5.7
12.	December	2.0	2.3	1.3	1.4	2.5
13.	Annual ..	33.8	37.7	33.2	27.8	33.4
14.	Dry Weather Period ..	1.4	1.6	1.3	1.5	1.2
15.	Hot Weather Period ..	3.4	3.8	5.8	5.6	5.4
16.	South-West Monsoon	14.9	17.4	14.8	8.5	11.6
17.	North-East Monsoon	14.1	14.9	11.3	12.2	15.2

TABLE II
INTER-SEASONAL CORRELATION OF RAINFALL

S. No.	Details of the correlation	Chittoor	N. Arcot	Salem	Coimbatore	Tiruchirappalli	Remarks
1.	Dry weather period and Hot weather period.	+N	+N	-N	-N	-N	N = Not Significant Y = Significant
2.	Dry weather period and South-west monsoon period.	+N	-N	+N	-N	-N	
3.	Dry weather period and North-east monsoon period.	-N	-N	+N	+N	-N	
4.	Dry weather period and annual.	+Y	+N	+N	+Y	+N	
5.	Hot weather period and South-west monsoon period.	-N	+N	-N	-N	+N	
6.	Hot weather period and North-east monsoon period.	+N	+N	+N	+N	-N	
7.	Hot weather period and annual.	+Y	+Y	+Y	+Y	+Y	
8.	South-west monsoon and North-east monsoon period.	-N	-Y	-N	-N	-Y	
9.	South-west monsoon and annual.	+Y	+Y	+Y	+Y	+Y	
10.	North-east monsoon and annual.	+Y	+Y	+Y	+Y	+Y	

TABLE III
DETAILS REGARDING THE FAILURES OF THE MONSOONS

S. No.	South-west monsoon					North-east monsoon					Total Annual				
	I	II	III	IV	V	I	II	III	IV	V	I	II	III	IV	V
1.	4-6	5-5	6-4	6-4	5-5	3-7	3-7	3-7	2-8	3-7	4-6	4-6	5-5	2-8	4-6
2.	4-6	4-6	2-8	4-6	2-8	7-3	7-3	5-5	6-4	6-4	7-3	7-3	4-6	5-5	3-7
3.	4-6	5-5	5-5	4-6	4-6	3-7	3-7	3-7	5-5	4-6	3-7	3-7	4-6	4-6	4-6
4.	4-6	4-6	5-5	4-6	7-3	3-7	4-6	3-7	4-6	4-6	4-6	5-5	5-5	7-3	6-4
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7.	5-5	3-7	3-7	4-6	6-4	4-6	7-3	6-4	6-4	8-2	6-4	5-5	6-4	6-4	7-3
8.	4-8	4-8	5-7	3-9	4-8	5-7	5-7	6-6	8-4	6-6	5-7	4-8	5-7	7-5	5-7

N.B.—(i) First figures indicate the years above normal in a period of 10 years.

(ii) Last figures indicate the years below normal in the same period of 10 years.

(iii) The data given in the last column comprise a period of 12 years.

NOTES AND REVIEWS

"THE MEANING OF LANDSCAPE IN GEOGRAPHY"*

Dr. Richard Hartshorne, in his "Nature of Geography", considers at length the significance of the term Landscape in the study of Geography. He points out the extent to which the term has been loosely used by geographers. In any science the students need to learn precision; whether one is speaking or writing or doing, scientific procedure demands precision. To achieve this, one important step is to understand the scope and content of technical terms. Landscape, in Geography, is a technical term and demands universal understanding as to its scope; if Geographers are agreed on what it means, they will be able to avoid confusion and misconception.

The English term Landscape is akin to the German *Landschaft* which has been used with different connotations by German Geographers. Since the foundations of modern Geography were laid in Germany by the German Geographers, it seems obvious that some amount of the vagueness associated with the English term Landscape is derived from liberal translations of German works. The meaning of *Landschaft* in German works, is dependent on the context and the writers expression as to its connotation. The same need not be true in English works on Geography. Landscape, by general acceptance, has come to mean something definite; it is this that this brief note will try to explain.

Many Indian Geographers have given little attention to the scope of the term Landscape. It has been used freely to refer to small and large areas, as well as to specific characteristics as giving colour to the said areas; the term has also been used as a substitute for the more appropriate term "region" with reference to areas marked by certain degree of homogeneity in natural and cultural conditions. A definition of what is Landscape is necessary.

W. Hellpach of Germany considered *Landschaft* to refer to "the total impression aroused in us by a piece of the Earth's surface and the corresponding section of the sky"; his definition seems to include the aesthetic values also. Here one finds the artist's reaction included in a scientist's observation. It is obvious, at this stage, that Hellpach's definition needs to be modified; landscape, in Geography, can refer only to features that exist; aesthetic impressions gained by the observer cannot, by themselves, find a place in the geographic connotation of the term 'Landscape'.

Omitting aesthetic reactions and impressions, does Landscape include all objects that can be observed; if so, over what area? With reference to the first aspect of this question, it is necessary to point out here that the Geographer must be careful to avoid what is implied by observable features; for example, the presence of oil-derricks show, to the Geographer, the presence

of oil below, and the possible structure of the rocks below; these, however, cannot be included in the landscape; open-pit mines will be included in landscape while deep ones will be excluded. The area within which the features are to be recorded should be that which can normally be observed by the Geographer.

Some Geographers have objected to the recording of the movable objects within the landscape; this is obviously wrong; movable objects that are present must be included in the landscape; the Calcutta landscape, including the Hooghly Bridge, must necessarily include the steamers and boats that are ever present on the Hooghly; similarly a Dum Dum landscape cannot avoid the many aeroplanes that are landing and taking-off.

Landscape, in short, must include all that is visible to the Geographer in a particular area, which he is studying. While it will include everything present in the area, including the amount of sky and clouds that are visible, it cannot include what had happened in that area before, or what could happen later. Some of the major items that would come under landscape are:—

- the land, sea and sky (including clouds) that can be seen by the observer at the time of his observation;
- the movable objects within the above fields, including human beings, animals, birds, reptiles and vehicles;
- plants, trees, buildings, hills, mountains and all other land-forms; (including rivers, tanks etc., etc.);
- the forms and colours of the above;
- the activity observable within the area, like the farmers ploughing the fields, porters moving luggage, so on.

Landscape is, thus, a mass of reality. It is the starting point of geographic investigation and interpretation. Many observations would lead to a chain of landscapes, which, in its turn, would lead to an understanding of the Geography of the area studied; thus would emerge a regional geography.

It may not be out of place, here, to refer to the terms 'Natural Landscape' and 'Cultural Landscape', which are freely used by geographers. The first of these is supposed to refer to a landscape marked by natural forces only, where human efforts have made no impression at all; such a Natural Landscape, to-day, is essentially a theoretical conception and could best be avoided. Cultural Landscape refers to the remarkable extent of human efforts expressed in a landscape; most landscapes, to-day, are of this type. If both these terms are to be used they need to be used with very great care; it would be best to avoid using these terms; the character of landscape will come out at the interpretative stage without all this advance aids.

In conclusion, very briefly, Landscape may be defined as a mass of observed reality over a limited observable area on the surface of the Earth including its atmosphere.

V. S. GANANATHAN,
Geography Department, Poona University.

*1. *The Nature of Geography*—Richard Hartshorne, Annals of the Association of American Geographers, 1946.

2. *Landscape and Society*—Robert E. Dickinson. Scott. Geog. Magazine, 55 (1939).

3. *Geography among the Earth's Sciences*—Albrecht Penck, Proceed. Amer. Phil. Soc. 66, (1927).

TRANSACTIONS AND PAPERS 1951. Pp. 165. The Institute of British Geographers. Publication 17. 21s. 0d. net. London: George Philip & Son, Ltd., 1952.

The Institute of British Geographers is too well-known to the profession of Geography to need any introduction. The publications of the Institute have always been looked upon as models for research work both by the scholars and the teachers of Geography.

The Publication No. 17—Transactions and Papers, 1951—edited by Mr. R. W. Steel includes the following eight papers representing, as usual, the wide range of research being carried out by British Geographers, and is well documented by notes, references, maps and diagrams.

The necessity for determinism: A metaphysical problem confronting Geographers.—By A. F. Martin.

Three new Climatic Maps.—By A. Austin Miller.

Wind and Weather in the Equatorial Zone.—By P. R. Crowe.

Weather-crop Relationships: Forecasting and Spring-wheat yield in the Northern Great Plains of the United States.—By E. M. Frisby.

The Movement of Coal in Belgium, with special reference to the Kempen Coalfield.—By F. J. Monkhouse.

The Influence of Inclosure on the Form and Pattern of Rural Settlement in Denmark.—By H. Thorpe.

Coke Manufacture in Great Britain: A Study in Industrial Geography.—By S. H. Beaver.

The Industrial and Urban Development of the North Staffordshire Conurbation.—By H. A. Moisley.

Martin discusses the problem of cause and effect in Geography, and examines some metaphysical problems confronting Geographers. He asserts that Possibilism should be rejected and Determinism accepted—not the crude determinism of the earlier writers—as a working hypothesis, chiefly because, Possibilism cannot be philosophically substantiated and it is, also self-contradictory.

Miller presents three new climatic maps of the world, using simple combination of rainfall and temperature or summer warmth, Map 1 showing $\frac{T}{R}$ as an index of humidity, Map 2 duration of temperature seasons and Map 3 accumulated temperatures (month-degrees above 43° F.). Any classification to be of great value, must be definite yet not too complex. It is true, classification by simple methods may not bear a very close relationship to vegetational distributions but delimitation and correlation on a broad basis are possible.

Crowe makes a detailed analysis of the *Doldrums*. His paper seeks to relate the character and movement of the zone to the annual sequence of equatorial and sub-equatorial weather, as it is reflected in long period rainfall statistics.

Frisby's paper is a border topic with many frontiers, and Frisby rightly points out that neither the Climatologist nor the Agricultural Scientist is engaging himself on the aspect of crop-yield forecasts, and it has become the Statisticians job, who is neither a Climatologist nor an Agricultural Scientist. It is claimed that there is scope for the imagination of the Geographer. The method adopted by Frisby for arriving at Spring-wheat relationships in the Northern Great Plains of the U.S.A., is geographical cum statistical in that the approach is geographical while the technique of yield forecasting is statistical. This is really a promising line of investigation and Geographers should pursue it. Of course in India, to get the required and the representative data will be the problem of first order.

Dual purpose is served by Monkhouse's paper, as a contribution towards cartographic method and regional economic geography. The paper is a 'dynamic' summary in map form, dealing with the movement of combustibles *solides*, a specific freight category.

Thorpe's paper 'describes the significant changes which occurred in the form, pattern and economy of rural settlement in Denmark between the inclosure of the common fields at the end of the 18th century and the present day, with particular reference to the township of Osterstillinge in South-Western Sjaelland'.

Beaver traces the developments in the processes of coke-making in Britain and gives an account of the geographical distribution of coke-industry, while Moisley's paper deals with the industrial and urban development of the North Staffordshire conurbation. Urban industrialism is one of the evils characterising the present day civilization, and when it springs up from coal as in the case of Britain, the problem becomes all the more complicated. Congestion in the 'core', rehabilitation of the derelict land and swallowing-up of good agricultural land are some of the chief problems of any conurbation and North-Staffordshire is no exception to this. From Moisley's study, it becomes quite evident how the problems of conurbation relate mainly to questions of land-use.

V. L. S. P.

THE ANDHRA AGRICULTURAL JOURNAL. Vol. 1. Inaugural Number, 26th January 1954. No. 1. Pp. 82. Published by the Andhra Agricultural Union, Agricultural College, Bapatla (Guntur District), Andhra State. Annual subscription: Inland Rs. 6/-, Foreign Rs. 7/-. Single copy Re. 1/-.

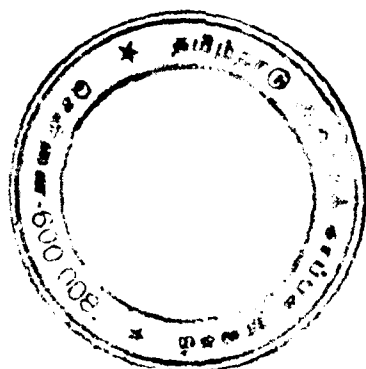
The Andhra Agricultural Journal is a bi-monthly, and is the official organ of the Andhra Agricultural Union, consisting chiefly of the members

of the Department of Agriculture, Andhra. This first Number gives more or less a cross-section of the activities of the Andhra Agricultural Department, Bapatla, Agricultural College and its Farm.

In the first article, an account of the Agricultural College at Bapatla (starting of the college—courses, strength, etc.) is given, and this is followed by Agronomy, Agricultural Economics, Agricultural Botany, Plant Physiology, Agricultural Chemistry, Entomology, Mycology, Rice, Millets, Cotton, Sugar-cane, Oil-seeds, Chillies, Horticulture, Agricultural Extension in the State, Agricultural Marketing and Agricultural Engineering. These short articles give an indication of the work in progress and future schemes contemplated by the Agricultural College and the Department. The author of the note on Agricultural Economics (p. 8) gives a hint about the economic surveys of villages, undertaken by the students under the guidance of the staff, and we hope that the results of the surveys will be published in the Journal, and thus make available for those interested.

The journal has covered almost all aspects of Agriculture excepting Agricultural Geography. We wish the journal all success.

V. L. S. P.



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GEOMORPHOLOGY

There is at present a world-wide interest in Geomorphology, as if there is a revival, but it must be said that the field of Indian Geomorphology is still untouched specially at the regional and local levels. The expressions 'Geological Geomorphology', 'Geographical Geomorphology', and 'Ideal' or 'Pure Geomorphology' reveal different points of view. Science has no water-tight compartments, and there is no need to consider the claims and counter-claims of the Geologists and the Geographers as to their jurisdiction in Geomorphology. It is quite natural that the Geographer's point of view is different from that of the Geologist, who tends to think in terms of vertical cross-sections and traces the historical development of land forms. The Geographer describes and analyses the present distributional patterns of land-forms, and is concerned with their geometrical characteristics (size, shape and nature of surface materials) and their significance to man.

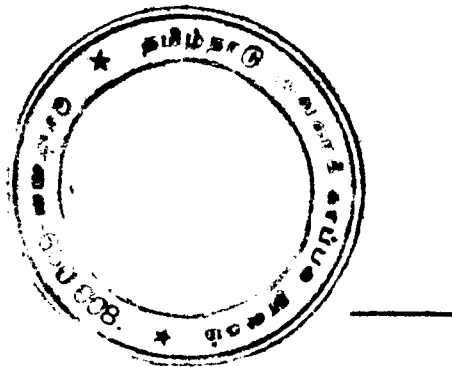
Now Geomorphology is emerging as a discipline by itself with its own methods of investigation both on the map and in the field, may be that some of the methods are traditionally associated with Geology and Archaeology. There is scope for contribution not only for the Geologists and Geographers but also soil scientists, plant ecologists, hydrologists and others. The recent contributions from the surveys of Edelman and Tavernier to the Geomorphology of Netherlands and Belgium support this point. It may be mentioned that Edelman's survey employs a full-time historical geographer.

Geomorphology is dynamic like any other scientific discipline. Progress of research is being recorded along several lines. The application of Geomorphology to civil engineering, soils and archaeology is really of special interest. New approaches are being made. L. C. King in his studies of the world's plainlands envisages the failure of the Davisian Concept of Penepla-

nation to explain the principal African land-surfaces, and puts forth a hypothesis with Penkian flavour: the horizontal work of *pediplanation*, the process of scarp retreat and the formation of *pediments*. Any investigator of Planation Surfaces should give due consideration to all recent trends both in approaches and techniques.

Morphometric analysis is very important in preliminary investigations, and of course, the results depend on the scale of the map. Large-scale topographical maps provide a good frame-work for the reconnaissance phases of landscape study, or for generalised analysis of wide areas, though for detailed work, the map analysis must be supplemented by observation and measurement in the field. The British six inch (1/10,560) and the new 2½ inch (1/25,000) maps are proving as valuable tools for Geomorphic studies in Britain. Air photographs are also being increasingly used. In contrast there are only the one inch (1/63,360) Survey of India topo-sheets, readily available to the Indian student, who should make the best use of them in his preliminary investigations.

Pioneering macroscopic work in Indian Geomorphology is not altogether lacking, and with the one-inch topo-sheet, the Indian Geographers can make a modest beginning in geomorphic studies in different regions of India, of course, as far as the map permits. For facilitating studies in Indian Geomorphology, the Geography Departments of the different Indian Universities should offer Geomorphology as a special subject at the post-graduate level, and train students, who in their turn will become specialist teachers and research workers.



THE UPPER PANCHAGANGA BASIN: A STUDY IN THE GEOMORPHOLOGY OF THE DECCAN TRAPS

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It is well known that although the Deccan Traps belong to one geological formation, there are several regional variations in petrological characters as well as in the landscape the Traps develop. Geologists have drawn attention to the petrological aspects and have shown that 'the fact still remains that much of the stratigraphical field work on the Traps and the associated sedimentaries is old, and it is very desirable to restudy them'.¹ This paper examines the landscape aspect of the Deccan Traps with reference to (a) a description of the main morphological features, (b) the processes involved in the shaping of these features, and (c) a possible genetic consideration of the same. It is necessary to emphasise that the conclusions reached are of a tentative nature and may require modification in the light of further field work in other regions of the Deccan Lavas.

1. *The area and its main physical features.*—The Upper Panchaganga Basin is a triangular region of about 800 square miles belonging to the upper

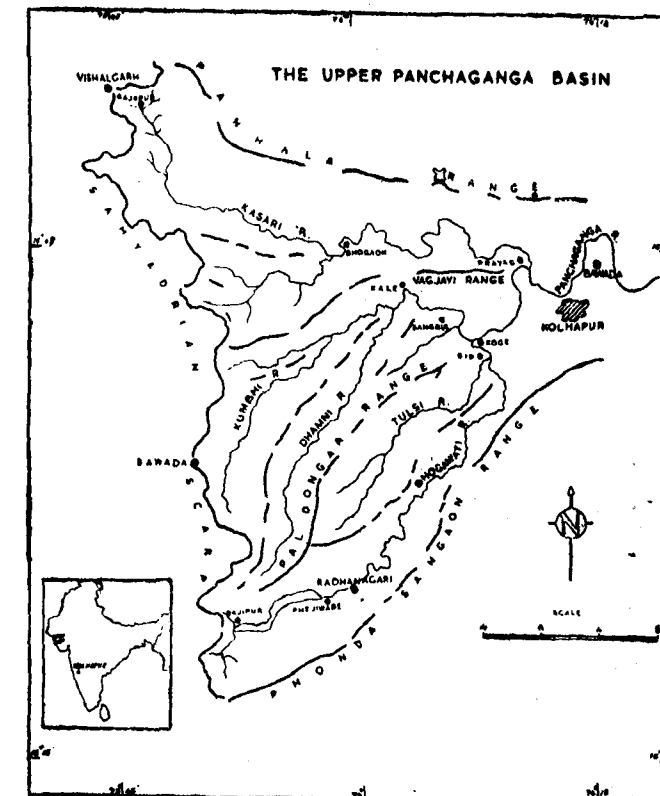


Fig. 1

drainage waters of the Panchaganga river, a tributary of the Krishna (Fig. 1). On the west the Sahyadrian watershed marks it off from the Konkan belt, to

¹Krishnan, M. S.—Geology of India and Burma, Geological Survey of India (Madras, 1949), p. 433.

the north the Panhala range and to the south the Phonda-Sangaon range separate it from the neighbouring drainage basins of the Varna and the Dud-ganga respectively. The basin proper is drained by four streams—the Kasari, Kumbhi, Tulsi and Bhogawati—which a little to the west of Kolhapur, combine to form the Panchaganga river.² (Fig. 1 above.) The dominant features of landscape are thus (a) the residual hill ranges, and (b) the intermediate

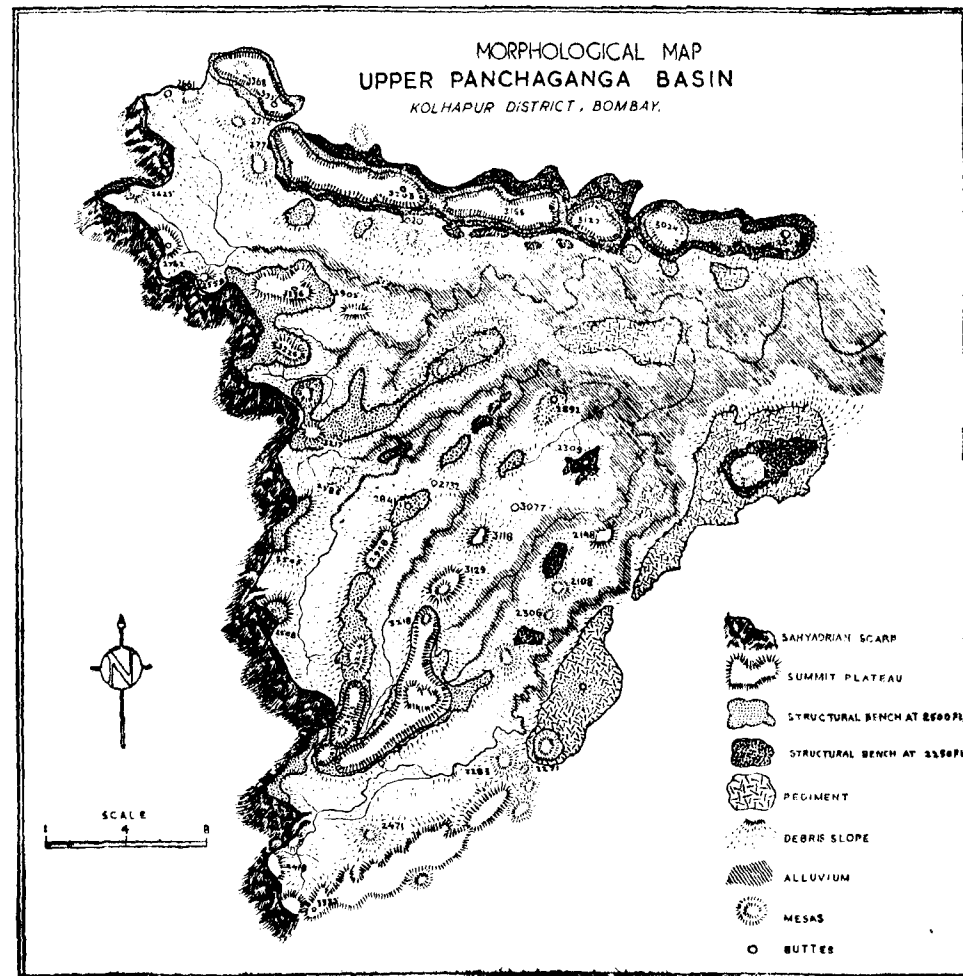


Fig. 2

river basins. A closer examination, however, reveals a landscape pattern that is characterised by (i) a rapidly retreating watershed of the Sahyadries, (ii) transverse hill ranges of the plateau adorned by buttes, summit flats, basaltic scarps, concave debris slopes, river basins drained by meandering streams, "incised" in the alluvium, alluvial flanks and flood-plain terraces, and sub-duced plateau forms which simulate pediment characteristics. (Fig. 2.)

2. *Structure and Process.*—These landscape features are capable of being well interpreted in terms of the influence of the process on the structure, though such interpretation would evidently remain incomplete until the genetic aspect is thoroughly enquired into. Structurally, this portion of the

² Survey of India Topographical Maps: No. 47 L. & H.

Deccan Traps participates in almost all the general characteristics of the lava flows. Flat-topped hill ranges with structural benches is the general feature of the landscape. The thickness of the individual flows varies between 300 and 400 feet. They show a gentle dip East-north-eastward. It is possible to divide the lava flows of this region into the lower, middle and upper flows; the lower flows are dominantly basaltic; the middle are more of amygdular nature, while the upper are basaltic and extensively capped by laterite.³ (Fig. 3.) Ash beds are often seen to separate the major flows. From the

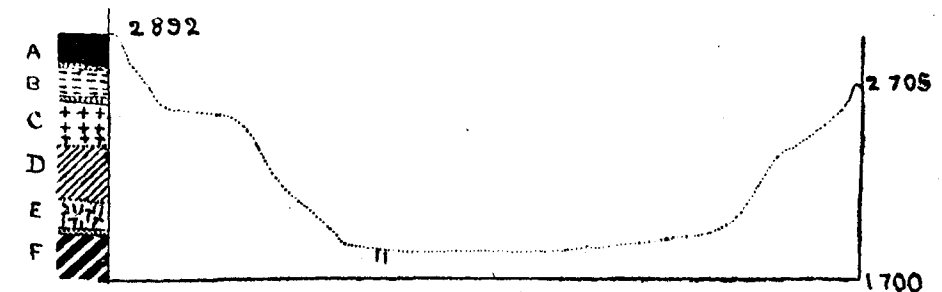


Fig. 3. Section across the Kumbhi Valley.

morphological point of view these major variations in the lithological characters of the lava flows are noteworthy. But far more important is the weathering action and erosive processes which under Tropical Monsoonal conditions exert a significant influence on the landscape. The devastating nature of chemical action under hot humid conditions even on heavy and compact rock material has been often emphasised by Woolridge and Morgan and others.⁴ In this region, the processes of oxidation, carbonation and leaching all contribute in an abundant manner to the disintegration of the exposed rock and the supply of mantle waste. Weathering, as may be expected, starts at two planes: vertically along the columnar jointing of the basalts, and laterally along the base of lava flows (Figs. 4 and 5) particularly where ash bed deposits are prominent. The basalts, as in the Bavada Fort, show the effect of weathering on vertical joints in the shape of stacks. The basaltic material is thus broken away from the main flow, slips off the plane that is next below and rolls down the slope under the action of gravity. Spheroidal weathering hastens the rolling down of such blocks, and a boulder strewn slope-face is a common sight in this region. (Fig. 6.) It is important to note that this columnar jointing accelerates the weathering process and therefore explains the wall-like scarps all along the edge of such flows. (Fig. 7.) Amygdular flows, on the other hand, yield more easily to weathering and in the absence of regular joints often develop concave slopes. (Fig. 8.) A final feature of note about weathering is its action on summit flats; here, the lava flows disintegrated under the normal influences producing soils and sub-soil features, but under a heavy rainfall the surface soils were leached out, exposing lateritic formations which on account of their increased resistance to weathering all the more preserve the extremely level character of the summit flats. (Fig. 8 above.)

3. *Fluvial Action.*—Of equal importance in landscape is the erosion pattern developed by the flow of water in this region. The monsoonal regime

³ Bruce Foote, R.—Memoirs of Geological Survey of India, Vol. XII (Calcutta, 1876), p. 173.

⁴ Woolridge, S. W. and Morgan, R. S.—The Physical Basis of Geography, Geomorphology. (Longmans Green and Co.) London, New York (Toronto 1945), p. 150.

of rainfall exerts a fundamental influence in this respect. The first onset of the monsoonal downpour is largely utilised in saturating the parched terrain, though there is some surface runoff. The weathering processes on hill slopes are, as the rainy season advances, strengthened by the action of gullies and rills, particularly along joints, almost all along the weaker vesicular beds. This erosion produces alluvial cones at the base, below the boulder strewn debris rolled down under gravity, in the fashion of an apron. Far more interesting than this gully erosion is the work of the major streams: their regime is basically influenced by the monsoonal rainfall; but the rock structure and the aspect of the Sahyadrian crestline have undoubtedly aggravated the seasonal rhythm of their flow. After about 20 to 30 days from the first 'burst' of the monsoons, these rivers suddenly develop wide floods, when there is a tremendous movement of eroded debris either rolled down along the bed or more often carried in suspension in the form of mud. This phenomenon is not only due to the heavy monsoonal fall, but due to the large catchment areas that have been developed in the upper reaches by these rivers. Further it is worthwhile noting that the upper catchment areas serve as large water collecting basins through which water is forced down the main streams where waters are confined to a valley plain by the residual ranges. The consequences of this climatic and structural arrangement are morphologically very significant. This explains (i) the sudden onrush of floods, experienced in the lower reaches of all these valleys, (ii) the heavy flood time corrosion and sheet erosion in the valley; and (iii) the formation of the flood terraces. Lastly, the periodicity of the water flow is in itself a factor in moulding local landscapes: (i) During flood, the flood sheet itself acts as a local base level to tributaries, so that there is deposition of silt on the marginal belts of flooded areas; (ii) With the subsidence of floods—and in many cases this is quite as sudden as its appearance—'scouring' action of the streams begins with the lowering of the local base level with possibly the formation of flood terraces and (iii) During the cold weather season, green vegetation cover slows down the weathering process which, however, is later on accelerated under the parching summer heat acting on a bare and dry landscape.

This complex working of weathering and erosion on the structure of the lava flows of the Upper Panchaganga Basin can be studied in greater detail with reference to its morphological features. (Fig. 2 above.)

4. *The Sahyadrian Scarp*.—The two striking features of this portion of the Sahyadrian Scarp are (i) its sinuosity and (ii) the low general height of the escarpment proper, the higher elevations occurring well away from it, towards the east. (Fig. 2 above.) The sinuous nature of the scarp is apparently due to its extraordinary retreat from the Konkan side and the consequent abstraction of the plateau topography. (Figs. 9 and 10). The primary factor is the rapid weathering of the basaltic beds and the removal of the decayed and disintegrated material by the monsoonal downpour. (See above.) This rapid scarp retreat has created vast amphitheatres through which are fed the Konkan rivers of Rajapur-Jayatapur, Vaghotan and Gad. It is necessary to observe three significant features of this scarp retreat: (i) the retreating scarp leaves behind it some remnant bosses of hard core—bornhardts (Fig. 11) such are for instance pts. 1775, 2330, 2268. The Bavada Fort is obviously the latest example of a boss being left by the escarpment, (ii) the scarp leaves behind a trail of minor ranges of a transverse nature. Apparently these are the connecting 'necks' that have escaped major erosional attack; and (iii) 'Abstraction' of the sub-mature plateau landscape is a significant feature. Its most striking form occurs where the scarp is abstracting the entire vertical walls of a plateau surface, as in the neighbourhood of



Fig. 4. Weathering along the columnar joints of basalt (Panhala)



Fig. 5. Note the horizontal weathering at the junction of two flows differing in resistance (Bawadar).

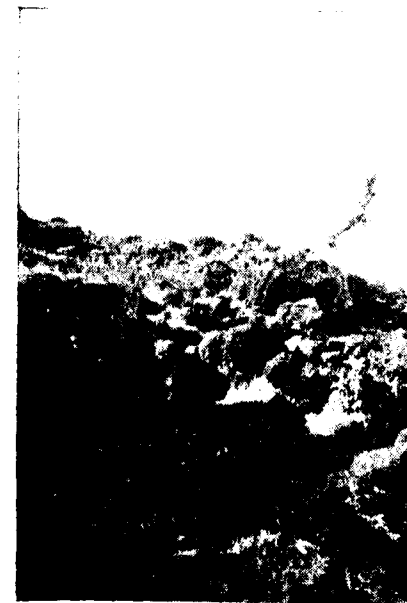


Fig. 6. Boulder strewn rock surface, (Kumbhi Valley).



Fig. 7. The upper part is the fort wall of the Panhala while the lower portion indicates the wall—like scarp.

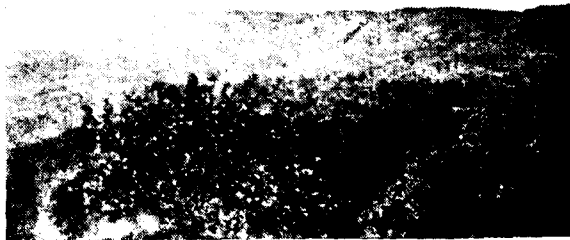


Fig. 8. The western part of the Panhala range. Note the extreme level character of the coast line.

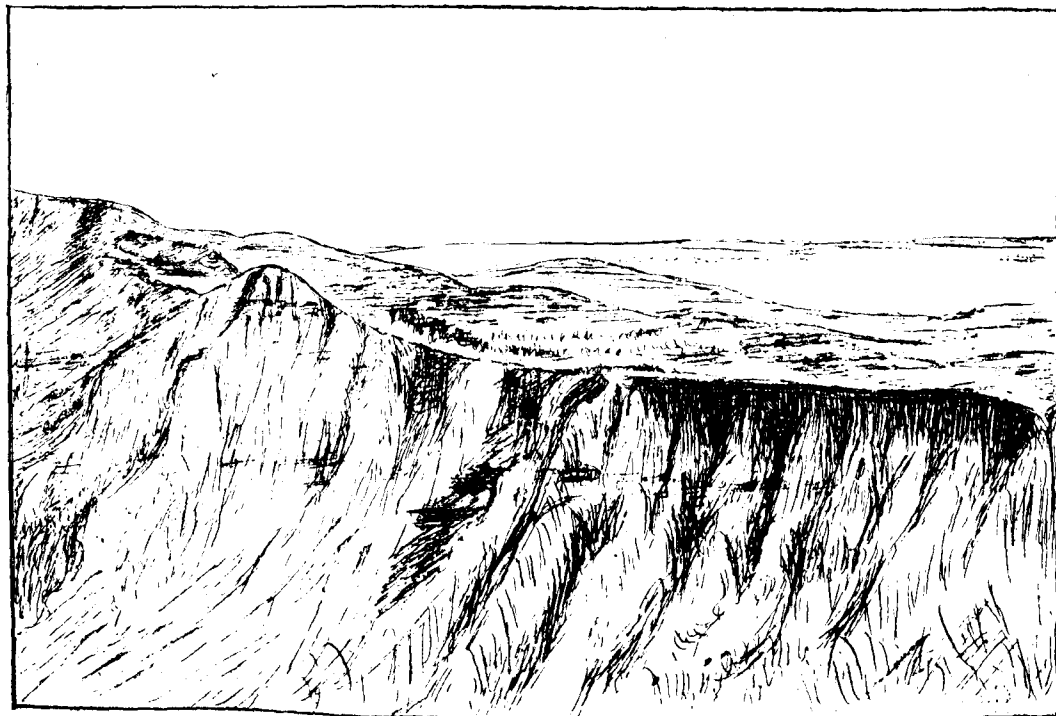
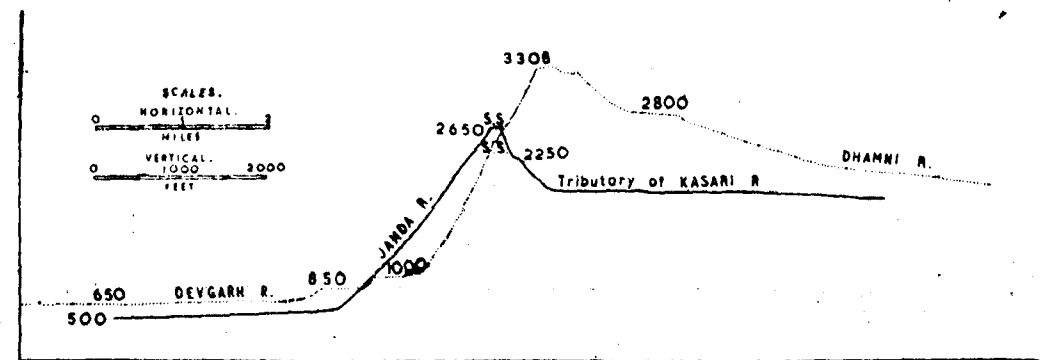


Fig. 9. The abstraction of Sahyadrian scarp. (Sketch).

Bavada, where the base of the 2,500 feet plateau level is being joined with the scarp below. The Sahyadrian scarp of this region affords several magnificent examples of this process which produces a truly majestic landscape of a high terraced wall with buttresses, if seen from the Konkan side. The other aspect of this scarp retreat is the abstraction of the valley forms previously developed by the eastern rivers as a part of the plateau landscape. The scarp retreat produces in many places 'gaps' in the crestline which in most cases have become the well-known passes through which the routes from the plateau area traverse the Sahyadries to reach Konkan, the most prominent being the Amba, the Bavada and the Phonda passes. (Fig. 2 above.)

This rapid retreat of the Sahyadrian scarp and its uniform advance over the uneven plateau topography explains the sinuous nature of its crest-line, its basaltic ramparts, and the gaps produced by the truncated valley courses. It is possible to make two further significant observations, the validity of which will have to be tested by field-work in other areas of the Deccan Traps : (i) the height of the crest-line would increase or decrease according to the



LONG PROFILES OF THE RIVERS FLOWING ON EITHER SIDE OF THE SAHYADRIAN SCARP (S.S.)

Fig. 12

elevated surfaces of the plateau area abstracted, the general base levelling process operating on the entire Peninsula remaining insignificant in comparison. (ii) It would appear from a study of residual heights in the Konkan belt, that there are two levels : one adjoining the scarp at an altitude varying round about 1,200 feet above sea level and the other round about 600 feet. (Fig. 12.) The drainage abruptly changes in direction at the junction of these two levels. It is possible that this junction marks the main fault zone that has created the Sahyadries, and that, land west of the junction is a piedmont plateau slightly dipping towards the coastline.

5. *The Residual Hill Ranges of the Plateau.*—The first noteworthy feature is that the maximum heights lie well away from the main watershed, the highest being point 3386 in the Panhala Range. Secondly, lava flows at 3000, 2700, 2500 and 2200 levels develop marked level surfaces. (Figs. 2 and 14.) These clearly indicate the position of the more resistant lava flows that have withstood weathering and fluvial action. The form of residual hills is conditioned by the structure of the underlying lava bands, weathering of slopes and rill flows, in the same order of importance. The cumulative action

of these factors on landscape may be well studied with reference to a specific hill range, namely the Panhala, which extends from the crest-line to a length of about fifty miles. An initial distinction is apparent in its western and eastern halves; in the west, the range is considerably influenced by heavy rainfall and consequently stream erosion appears to be a more important factor than wasting of slopes under weathering and gravity. In the drier

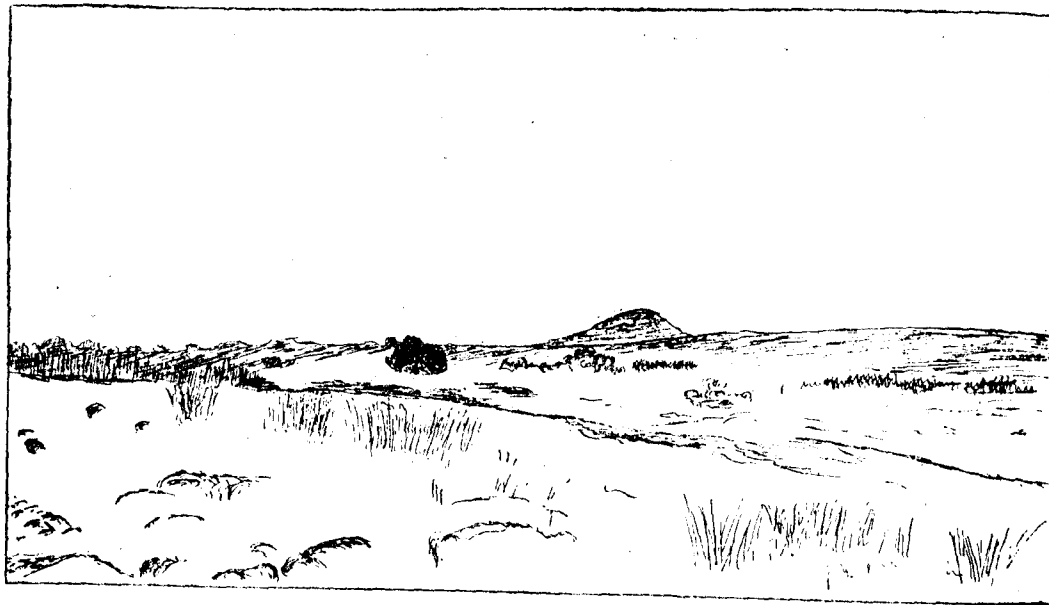


Fig. 13. The occurrence of Buttes. (sketch.)

east, the slope retreat is clearer and gives a slightly different aspect to the landscape. Studying the wetter part in a greater detail, it can be seen that the top-most lava flows appear in remnant forms as buttes which crown the broader basaltic-plateau stretches, which mark the crest-line of the Panhala range. (Fig. 13.) This rounded conical appearance is a typical feature in the lova topography. The plateau surfaces too have been attacked by scarp retreat and intense gully erosion which hardly allow the former to develop well defined structural benches below the rapidly shrinking summit planes,

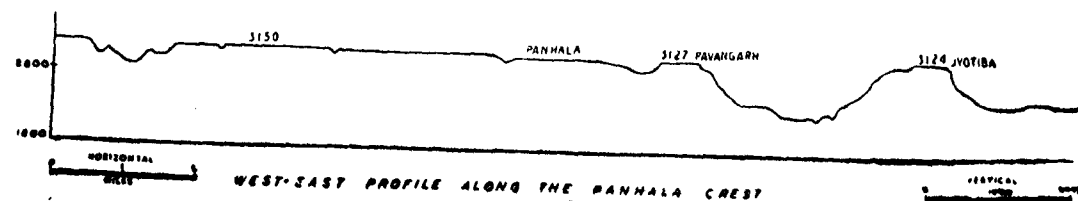


Fig. 14. Note the level character of West line.

so that the structural benches appear more like circular fans with deep dents made by numerous streams. At the foot hill the debris is partly rolled down under gravity but mainly transported by streams to develop talus cones. The slopes thus present a subdued convex curve in the upper parts and slightly



Fig. 10. Note the natural scarp face and the plateau proper. (Bawada Fort).

Fig. 11. Remnants of hard core that have resisted weathering, and hence left behind by the retreating scarp. (Bawada Fort).

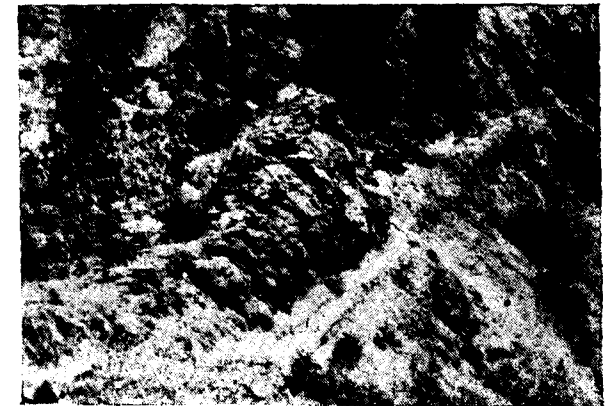


Fig. 15. Formation of a Mesa (Chambukhadi Hill).

Fig. 16. Pediment formations in the drier east.
(Near Sangrui—Fig. 1)



Fig. 17. Rounded nature
of the slopes in the
drier east.

Fig. 19. Narrow flood plain
terrace of 25' to 35' width
covered with grass
and 'makka' (maize).



concave, if not straight curve in the lower, with abrupt notches at the basaltic scarp edges. This is true of the western part and the low hills in the east. These generally are the sites of the joint plane water falls. The eastern parts of the Panhala, however, offer a contrast in that the slopes show a definite step-like aspect under drier climatic condition with a sharp concave edge all round (Fig. 14.)

6. *Mesas and Pediments.*—In the eastern margins of the Upper Panchaganga Basin, all the hill ranges lose their height, some of them abruptly and others through an intermediate stage of spur knobs and knolls to develop more open expanses that are well above the valley levels. In places, as for example the Chambukhali Hill (Fig. 15), these rolling expanses develop mesas. This change in the general landscape can be explained as due to scarp recession under drier conditions creating a pediment topography. (Fig. 16.) Pedimentation is due to scarp recession, but often becomes coincidental with the lateral planes of lava flows. The main reason why the traps develop a rolling topography here, not scarps as in the western parts, seems to be (a) greater aridity which prevents heavy fluvial erosion and (b) very low gradients of the pediment slopes in relation to the local base levels. As is well-known the lower the angle of slope the greater is the time required to erode the slope face, so that a mature landscape takes much greater time in further peneplanation of pediplanation⁶. In this area, the pediment slopes are a result of scarp retreat and weathered debris that cannot be easily removed either by water erosion or by the action of gravity (Fig. 17). This in other words is a development where the waning slope and waxing slope merge with each other and further reduction of the landform becomes very difficult.

7. *Form of River Valleys.*—The long profiles of all the major streams of the basin are marked by extremely low gradients, attended by one or two steps (Fig. 18) while the cross profiles exhibit progressively widening valleys with flat floors and 'shoulders' of structural benches on the flanks. The long profile clearly shows (i) that down cutting is practically absent, (ii) the 'steps' are evidently due to differential local erosion in the lava flow where the river leaves one flow for the next lower one, (iii) the main valley is truncated by the advancing Sahyadrian scarp (see above), (iv) the drainage pattern of the rivers and their main tributaries shows a graded condition. This in contrast with the gully and rill flows running at right angles to the main stream, which almost invariably show steep and ungraded profiles and have discordant junctions with the main stream. A closer study of the valley floors, reveal the following features: (i) a heavily filled in basin of fine alluvium, (ii) bordered on both sides by talus cones at the junction of the side streams and gullies, (iii) meandering course incised below 1750 feet level to develop well marked terraces (Fig. 19), and (iv) rocky river beds. The morphological significance of these features is gathered by the processes of a main stream, its tributaries in the upper reaches, and the rill flows on the main valley slopes. The junctions of the main stream and the tributaries are accordant, but a great discordance marks the junction of the rills with these main and tributary streams. This contrast can be explained as follows: (a) the main valleys are largely due to scarp retreat although stream erosion is a contributory factor in the wetter reaches; (b) the graded main streams—especially from the middle reaches downwards,—collect the watershed debris and alluvium from the upper reaches and the valley sides, and attempt to transport it down-stream. But the excessive supply of the debris coupled with low gradient is directed downstream along a single valley, to create

⁶ King, L. C.—South African Scenery, p. 25.

heavily filled in alluvial floors. This explains the meandering course of the main stream, its flood plain full of alluvium and its flood plain terraces (Fig. 19 above). The flood plain terraces appear to originate as a result of two forces: (a) the monsoonal flood regime of the streams which periodically

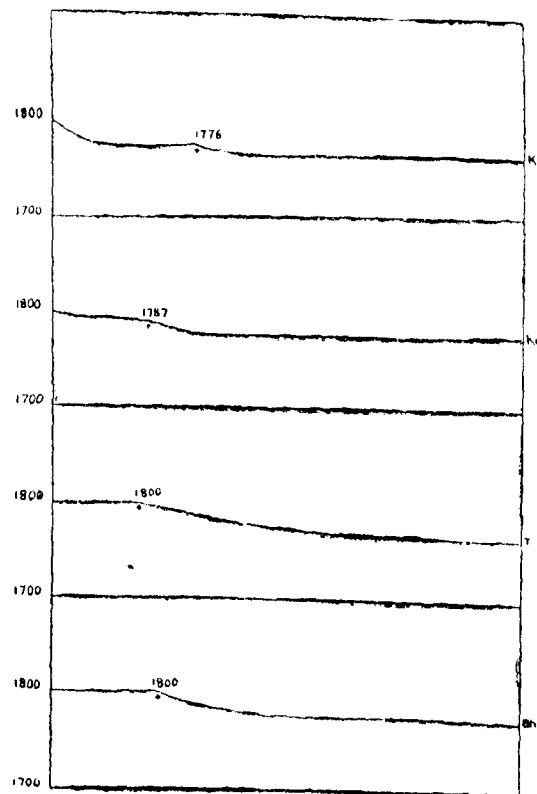


Fig. 18

forces its waters through loose alluvium and the heavy "scouring" which comes as a sequel, after the subsidence of floods and (b) local knick-points created by the outcrops of harder lava flows (Fig. 18 above).

In the eastern margins of this region the valley plains of the four rivers merge to create a confluence plain (Fig. 2 above). This is due to a complementary process of scarp retreat and pedimentation, and a corresponding widening of alluvial basins. There are indications of developing cut-off spurs and meander cores.

A final feature worth noting in this descriptive survey is the triangular pattern of drainage with the head waters region as the base and the exit-end of the stream as the apex shown in each of the streams, by the Upper Panchaganga in aggregate, and by the upper Krishna as the master stream controlling the entire drainage of this region. This may possibly be due to the particular denudational characteristics of the Deccan Trap area and the influence of very humid conditions in the west and progressively drier conditions towards the east.

8. *The Genetic Aspect.*—Morphological study, as Wooldridge and Morgan point out, cannot be complete without a study of its genetic form, although this of necessity must be the most difficult aspect of investigation⁷. A surer interpretation of the evolution of the landscape of the Deccan Traps must await detailed geological mapping of the Traps and field studies in their different parts. But it is possible to make certain tentative observations with a view to testing them in the field: (a) the Traps are sub-aerially formed, and the present landscape too is an evolution of epigene action; (b) the manner of their formation appears to be in a morphological sense, identical with the slow uplift of a mature surface, so that it simulates "a sub-mature landform from the birth". The periods of quiescence between successive outpours must have affected landscape formation under sub-aerial action. It is possible, therefore, that some elements of the present landscape are 'exhumed' surfaces. (c) There are two events of great morphological importance: (i) the origin of consequent drainage, and (ii) the faulting of the region to create the Sahyadrian scarp, although local topography may have been modified by intrusions (Basaltic dykes) and minor faulting. (d) A long period of post-Eocene crustal stability in this region is postulated⁸ i.e. barring the eustatic changes, but it is doubtful whether they have materially affected this interior portion and hence the consequent drainage has had a full play.

In the background of the foregoing assumptions, the evolution of the Panchaganga landscape might be attributed to a development of a consequent drainage pattern, that has been controlled by (i) the dip directions of the lava flow, (ii) by joint planes, (iii) by rapid slope retreat and (iv) by means of a series of river captures. It is possible thus, that the three streams, Kumbhi, Tulsi and Bhogawati of the Upper Panchaganga Basin are the original parallel flowing streams which were subsequently captured by the more powerful Kasari, as may be inferred from the difference in their levels and possible sites of river capture. But perhaps, the most striking feature of the Panchaganga landscape is the dramatic contrast between the sub-mature topography of the plateau tract where the very slow operating denudational forces are geared to the grade of the Krishna River and the advancing Sahyadrian Scarp that seems to be literally devouring the more gently carved out plateau forms.

⁷ Wooldridge, S. W. and Morgan, R. S.—*The Physical Basis of Geography, Geomorphology*, p. 187-188.

⁸ Krishnan, M. S.—*Geology of India and Burma*, p. 432.

EROSION SURFACES IN THE GNEISSIC REGION SOUTH OF MADRAS*

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The area chosen for study is the gneissic outcrop lying south of Madras, extending 40 miles from the Adyar valley in the north to the mouth of the Palar river in the south, and 15 miles west to east from the Palar river west of Chingleput to the coastal alluvium. It is confined to the area bounded by the alluvial deposits of the Palar in the north, west and south, and by the marine alluvium of the East Coast along the east. (Fig. 1.) This region was chosen for study because the numerous hills scattered over this area show not only an apparent similarity in height when viewed from the top of Pallavaram hill and St. Thomas Mount, but also appeared to be strikingly similar in shape. They are mostly conical in shape with almost pointed summits and rise steeply from an otherwise almost flat plain. It was also felt that it will be more easily possible to undertake field investigations, if necessary, on account of the proximity of this area to Madras City. The hills form three distinct ridges having a N.N.E. to S.S.W. trend. The three ridges (shown on Fig. 1) tend to converge towards the south-west where the highest peaks are found, for e.g. Kutchi Malai the hill west of Chingleput town, which rises to 782'. Though similar gneissic rocks occur to the south and west of the Palar river, and the hills in these areas also rise steeply from a flat plain, these hillocks do not show this distinct linear arrangement. Hence these ridges serve to differentiate this area from the surrounding regions.

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There are no sediments of any sort in this area, and hence the surface features of the area are due entirely to erosional processes. It is underlain entirely by crystalline rocks belonging to the Peninsular complex, which is shown on the geological map as undifferentiated gneiss. Some of these hills are composed of charnockite rocks, which have been studied in some detail in this area^{1, 2 & 3} as well as in other parts of South India. The charnockite rocks have a wide distribution in the southern and eastern parts of Peninsular India. The outcrops quarried at Pallavaram and St. Thomas Mount are considered to be one of the typical exposures. Two opposed theories have been put forward regarding their origin:—

1. *The Theory of Plutonic origin.*³—According to most authorities there was a localised bathylithic intrusion of some magnitude towards the end of the Archean period when the Peninsular gneiss was formed, resulting in the peculiar suite of rocks termed the charnockites.

* Acknowledgements:—

I am indebted to Prof. B. M. Thirunarayanan for having suggested the topic and for guiding me at every step in the preparation of this paper, and for giving me facilities to do some parts of the work in the Geography Department of the Presidency College.

I am grateful to the Society of Geographers for making a grant towards the cost of preparing blocks for illustrations accompanying this paper.

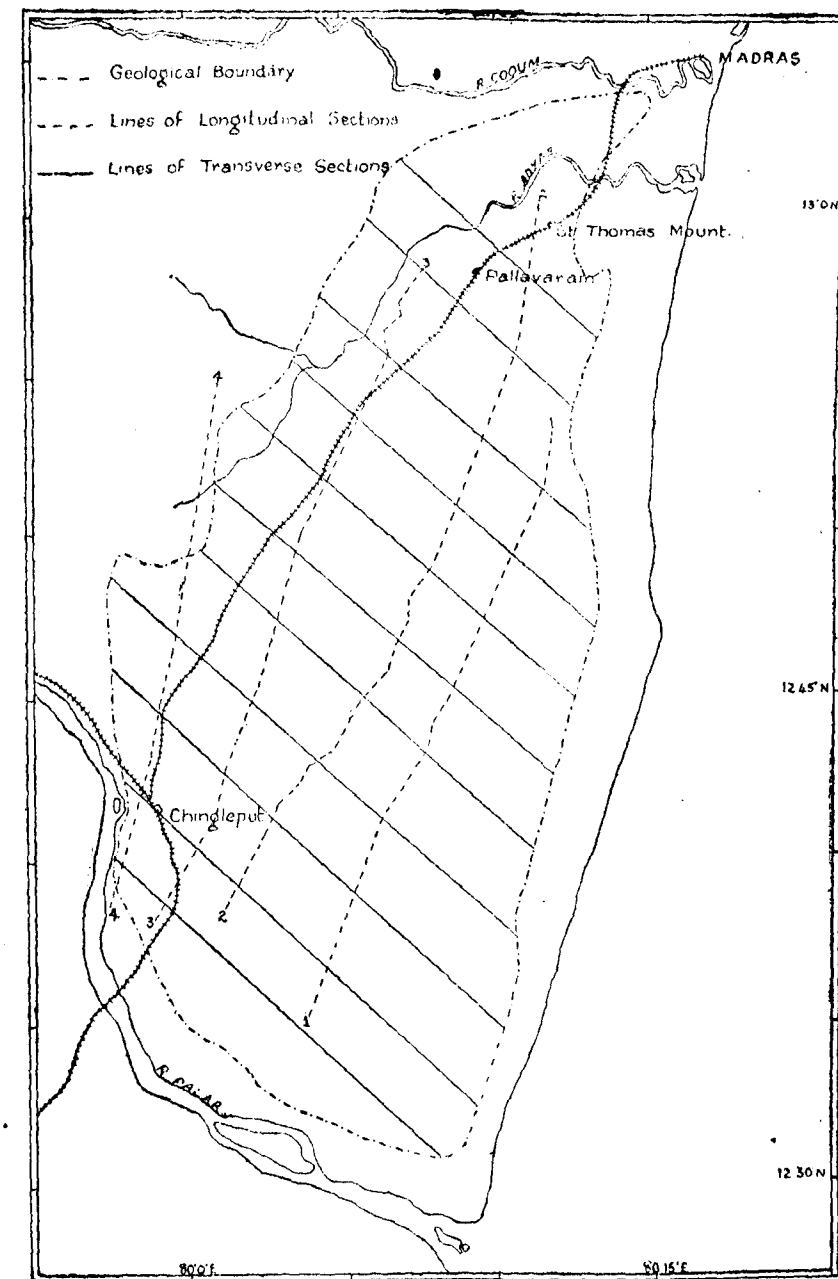


Fig. 1

2. *The Theory of Metamorphic origin.*¹—Recent views suggest that the present day charnockites are essentially reconstructed rocks and have resulted from several phases of recrystallisation due to thermal metamorphism during different periods.

Both these theories imply the removal of a large amount of material in order that these plutonic or metamorphic rocks should be exposed at the surface and be dissected to the extent we now see in this region.

PROCEDURE ADOPTED FOR MORPHOMETRIC ANALYSIS.

1. *Altimetric Frequency Curve.*—These hills are very scattered and also appear to be of similar height when seen from the top of St. Thomas Mount, Pallavaram etc. This suggested the use of the Altimetric Frequency Curve^(4 & 5) to examine the accordance of summit levels. The summit level spot heights were tabulated and grouped and their frequencies plotted against height. (Fig. 2.) The curve thus obtained brings out the prevalence of two levels (a) 150'-250', (b) 300'-400'—which may therefore represent former erosion platforms or peneplanes.

2. *The Hypsometric Curve.*—The Hypsometric Curve^(4 & 5) was also drawn; the area between successive contours was determined and these were shown in a curve as cumulative percentages of the total area (i.e.) the abscissae are proportional to the areas higher than the respective contours. (Fig. 2.) The Hypsometric Curve does not yield positive indications because the areas

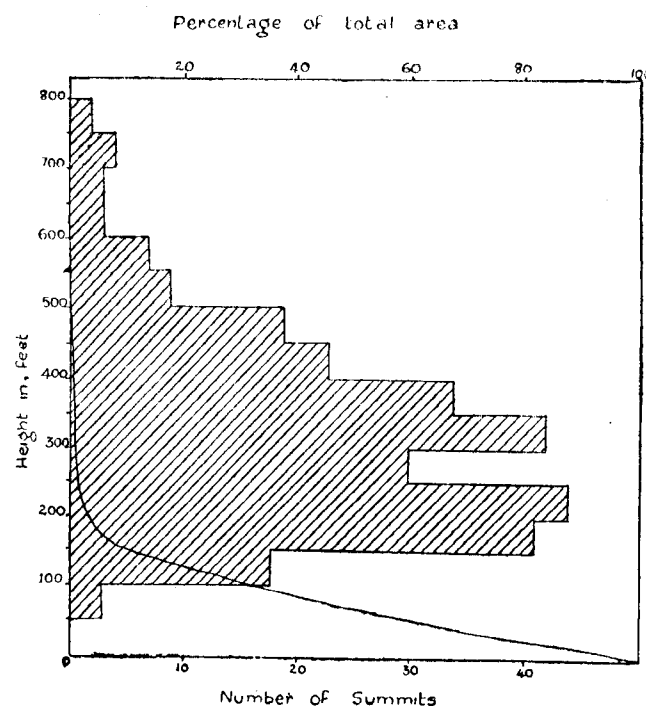


Fig 2

at the heights indicated by the Altimetric Frequency Curve are not significantly larger. This difference between the shapes of the Altimetric Frequency Curve and the Hypsometric Curve may be interpreted as indicating that the peneplanes have been almost completely eroded away, especially the upper ones, and at present only a few summits survive to represent the levels of these peneplanes.

3. *Superimposed Profiles.*—(a) To confirm the existence of accordant summit planes and erosion platforms, and (b) to find out if these peneplanes were horizontal or tilted, a more detailed examination of the region was made

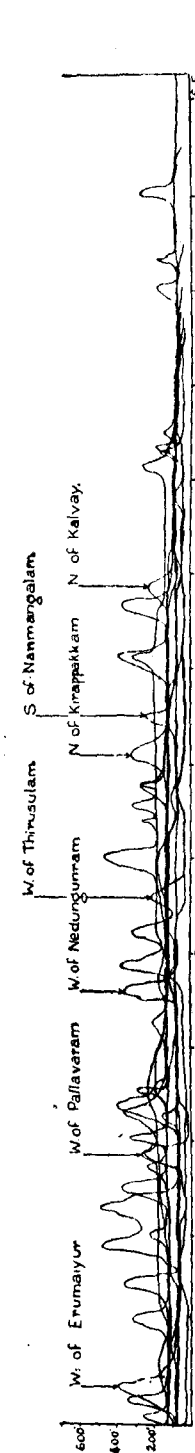


Fig. 3

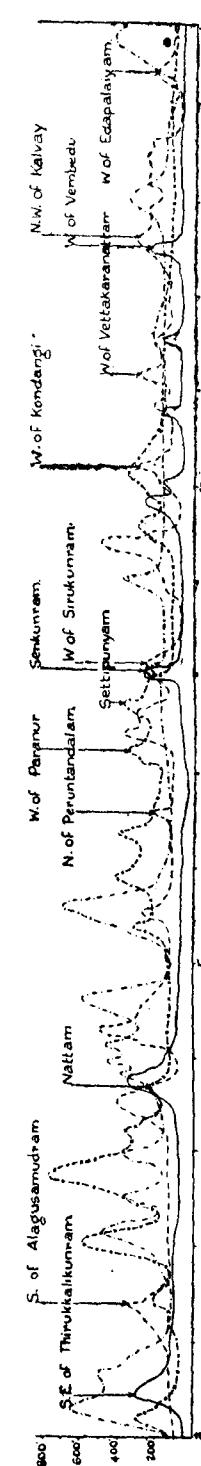


Fig. 4

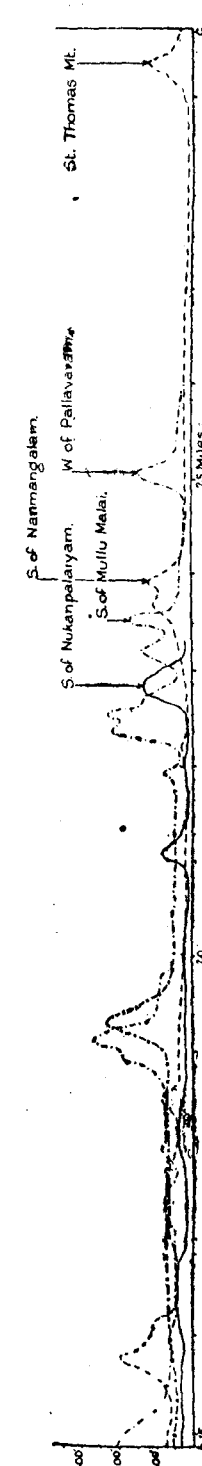


Fig. 4 (a)

by preparing two sets of superimposed profiles^{14 & 51}, one set from S.W. to N.E. (Fig. 3) along the ridge crests, and therefore running parallel to the grain of the region and another set at right angles to the first, along equally spaced lines mostly at two mile intervals running from N.W. to S.E. (Fig. 4). (Both sets of lines along which the sections are drawn are shown in Fig. 1.)

From these profiles we can clearly make out the present peneplane at a height of about 40' to 50', and also the levels of several former peneplanes. A large number of hills have their summit at a height of 200' to 250' and 300' to 350' and thus confirm the inferences drawn from the Altimetric Frequency Curve. For e.g., in the sections transverse to the ridges, the hill west of Pallavaram (66-D/1, Sq. B₁), the hill east of Thirusulam (66-D/1, Sq. B₁), the hill south of Nanmangalam (66-D/1, Sq. C₁) and the hill north of Kalvay (66-D/1, Sq. B₂) represent the lower peneplane. The hill west of Erumaiyur (66-D/1, Sq. A₁), the hill west of Nedungunram (66-D/1, Sq. B₂) and the hill north of Kirapakkam (66-D/1, Sq. B₂) represent the upper peneplane.

In the sections along the ridges, Nattam (57-P/14, Sq. C₁), the hill north of Peruntandalam (66-D/2, Sq. A₁), Senkunram (66-D/2, Sq. A₁), the hill west of Vembudu (66-D/2, Sq. B₁), the hill west of Edapalaiyam (66-D/1, Sq. B₃), the hill south of Nukanpalaiyam (66-D/1, Sq. C₂), the hill south of Nanmangalam (66-D/1, Sq. C₁), the hill west of Pallavaram (66-D/1, Sq. B₁), and St. Thomas Mount (66-C/4, Sq. C₃) represent the lower peneplane; the hill south-west of Thirukkalikunram (66-D/2, Sq. A₁), the hill south of Alagasamudram (66-D/2, Sq. A₂), the hill west of Paranur (57-P/14, Sq. C₁), Settipunyam (57-P/14, Sq. C₁), the hill west of Kondangi (66-D/2, Sq. B₁), the hill west of Vettakaranattam (66-D/1, Sq. B₃), the hill north-west of Kalvay (66-D/1, Sq. B₃), and the hill south of Mullumalai (66-D/1, Sq. B₁) represent the upper peneplanes.

Besides confirming the erosion surfaces revealed by the Altimetric Frequency Curve, the superimposed profiles also bring out very clearly the existence of four other erosion surfaces at (a) 40'-50', for e.g. Narayanapuram (66-D/1, Sq. C₁), Narasankuppam (66-D/2, Sq. B₃), (b) about 75', for e.g. Ichahan-kadu (66-D/1, Sq. B₃), Tiruvancheri (66-D/1, Sq. B₂), (c) 100'-125', for e.g. Hasanapuram (66-D/1, Sq. B₃), Santhakuppam (66-D/2, Sq. A₁), and (d) 150'-200' for e.g. Gudalur (66-D/1, Sq. A₃), Sittamanur (66-D/1, Sq. A₃). The sections incorporated in the superimposed profiles show clearly that these four lower surfaces are still largely intact, unlike the two higher levels previously indicated.

The Altimetric Frequency Curve does not show these still intact lower surfaces, because spot-heights are isolated summits belonging to much dissected surfaces. The lower surfaces appear clearly on the superimposed profiles, because the sections incorporate all the heights along the line of section, and thus the still virtually intact lower surfaces figure prominently as extensive stretches at particular levels.

Earth-movements could have been a possible cause for these numerous peneplanes. Such earth-movements would have ordinarily tended to bring about unequal elevation or subsidence of this region. This would have resulted in a tilting of the surface. But no such tilt is noticeable in any of the peneplanes. Hence the superimposed profiles do not give any indication of tilting of the surface subsequent to the formation of any of the peneplanes.

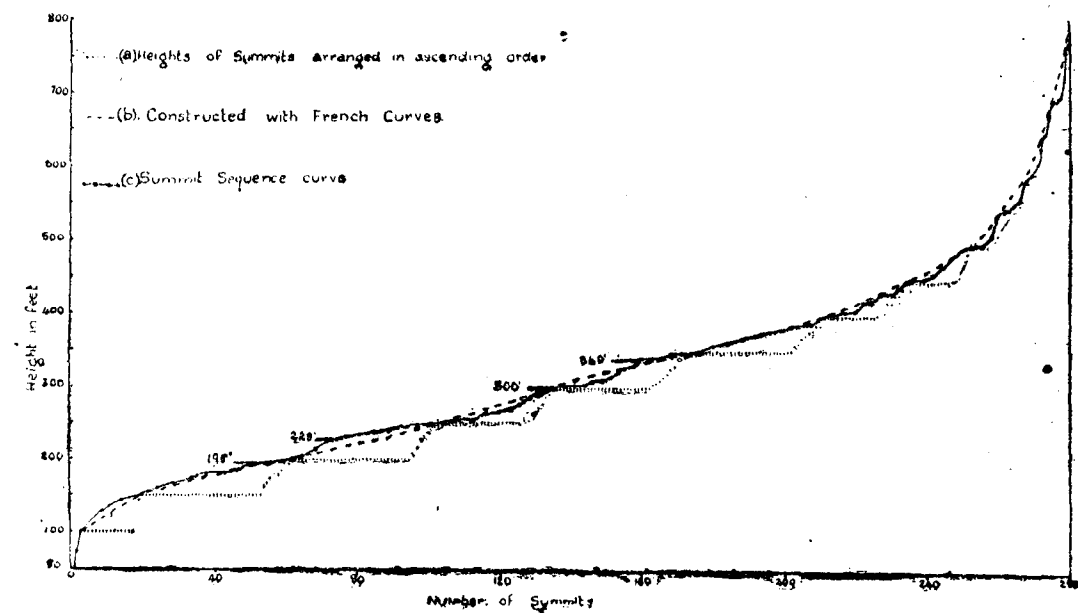


Fig 5

4. *Summit—Sequence Curve.*—In order to fix more accurately the heights of these peneplanes, the summit level spot heights were arranged in ascending order of height and plotted on a graph arranging the summits at one millimeter intervals along the horizontal axis [Fig. 5, curve (a)]. Since the exact height of only a few summits is available from the spot-heights, the heights of the others were inferred, in each case from the highest contour (i.e.) the unknown points were assumed to have the same height as the highest contour.

A smooth curve [as shown in Fig. 5 curve (b)] was then drawn with the aid of French curves. In this curve the heights of known points are not utilised and they are treated as unknown points. For e.g. suppose there are 32 unknown points and 8 points whose exact height is known between the heights of 150' and 200'. Two points are plotted, one at a height of 150' and another at a height of 200', the distance between them on the horizontal axis, being 40 m.m. If there are 25 (known plus unknown) points between 200' and 250' the distance between them on the horizontal axis is 25 m.m. Then a smooth curve was drawn through the 150'-200' and 250' points with the help of French curves. Similarly the other points were plotted and smooth curves drawn through them. These curves show a break of slope at 300'.

The following refinement* was made on the above method. The known spot heights between every pair of contours were first uniformly spaced along the horizontal axis. The unknown points between each pair of contours were then equally distributed between the known points. For e.g. suppose there are 32 unknown points and 8 points whose exact height is known between the heights of 150' and 200'. First the 8 known heights are arranged along

* I am indebted to Mr. V. J. Chacko, Additional Professor of Statistics, Presidency College, for suggesting this refinement on the preceding method.

the horizontal axis uniformly at 5 millimetre intervals, so as to occupy a total length of 40 m.m., since ultimately this length will be needed to accommodate the total of 40 (known plus unknown) points. Each one of these known points is then plotted on the graph at its proper height. They were then joined up and the curve smoothed to yield a number of distinct smooth sections. [Fig. 5, curve (c).] On this curve the unknown points were assumed to lie between the known points occurring at corresponding levels. The form of the curve thus obtained is determined to a greater extent than in the previous case by the heights of the known points.

Since this type of curve shows the sequence of summit levels it seems appropriate to call it a "Summit Sequence Curve". This curve suggests that the region has been affected by 4 or more changes of base level the corresponding heights of sea-level being approximately 340', 300', 230' and 195' above the present sea-level. The lower surfaces do not figure prominently in these summit sequence curves because of the paucity of isolated summits at these lower levels.

ORIGIN OF THE PENEPLANES

The steep sided hills which rise abruptly from the surrounding plain have suggested that these peneplanes are probably due to marine denudation rather than to sub-aerial erosion^(6 & 7). If they are due to marine denudation, the sea most probably encroached upon the land from the east. Therefore we may expect the hills to show steeper slopes on the east, due to undercutting by the waves, and gentler slopes on the west. The hills were hence examined more carefully to see if there was any evidence to support the marine denudation theory. Though some hills, for e.g. the hills east and south-east of Kumili (66-D/1, Sq. B₃), the hill 2½ miles south-west of Peruntandalam (66-D/2, Sq. A₁), the hill west of Pallavaram (66-D/1, Sq. B₁), do show a steeper eastern slope, others have steeper slopes on the west, while most have uniform slopes. But, though we have no positive evidence of marine denudation, it is quite likely that even if cliffs had been formed, they would have been worn back with the passage of time⁸. The sub-aerial erosion subsequent to their formation has probably destroyed all evidence of their marine origin i.e., cliffs and remnant deposits. Five negative changes of base level seem to have occurred before the present position of sea level was attained.

AGE OF THE PENEPLANES

In the adjoining Upper Gondwana deposits the heights range from 800'-100', and even over 1000'. Since these peneplanes occur at heights of less than 350' the elevations at which the Gondwana beds were deposited do not appear to be related to these levels of erosion. These peneplanes were therefore probably formed at a later period than that at which the Upper Gondwana beds were laid down. The Cretaceous deposits in the Trichinopoly area, though much further away from the area under consideration, were also examined as they are the only other important sedimentary formations nearby. These deposits generally occur at heights of over 250', the greatest height being 364' (Map 58-A/4, Sq. B₃). The S.L. during Cretaceous times was therefore probably 360'-370' above the present S.L. The present height of the highest peneplane is 300'-350'. It must have suffered a certain amount of erosion and reduction in height subsequent to its formation. Hence it may have been originally 360'-370' above present S.L., or at the same level as that

of the Cretaceous sea. It could, therefore, have been formed during Cretaceous times by erosion taking place in this area while deposition was taking place near Trichinopoly.

The only other sedimentary formations in or near this area are the recent deposits and the older alluvium and laterite formations of the Palar delta. The Palar delta was therefore examined. Two sets of superimposed profiles were prepared:—

- (1) Along lines of longitude at 5' intervals;
- (2) Along the interfluvies between the distributaries.

Two level stretches at (a) 150'-160' and (b) 250' could be clearly distinguished along both sets of profiles. Other level stretches at about 50', 70-80', 100-110', 125', 175' and 200' could also be distinguished on one or other of the sets of profiles. (Contours could be interpolated at intervals of 10' in this area because there were a sufficient number of spot-heights besides the usual contours at 50' intervals.)

Since there is an accordance of heights between these levels and the erosion surfaces recognised in the gneissic area, these surfaces could have been formed by erosion taking place in this region, while deposition was taking place in the Palar delta. Since the Palar delta consists of alluvial and other deposits which are all of Quaternary age, the lower erosion surfaces were also probably formed during the same period, in relation to successive changes of sea-level. The height of the terrace at Attirambakkam where palaeolithic implements have been found embedded in the strata⁹ is nearly 170' above sea level, and corresponds to the height of the fourth peneplane (i.e.) 150'-200'. Therefore the four still lower surfaces have probably been formed subsequently during the Pleistocene period.

(Summary of Results—See next page.)

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SUMMARY OF RESULTS

Heights	Altimetric Frequency curve	Hypsometric curve	Superimposed Profiles		Summit sequence curve	Palar Delta
			Transverse	Longitudinal		
350	{ 300—400'		{ 300—350'	{ 300—350'	340'	
300					300'	
250	{ 150—250'		{ 200—250'	{ 200—250'	230'	250'
200					195'	200'
150			{ 150—200'	Not well marked.		175'
						150—160'
100			{ 100—125'	Not well marked.		125'
50						100'—110'
			{ —75'	Not well marked.		70'—80'
			{ 40—50'	{ 40'—50'		50'

SOME ASPECTS OF THE GEOMORPHOLOGY OF INDIA AND PAKISTAN

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In a previous communication* the author recorded chief landforms of the Indian sub-continent associated with horizontal, homoclinal, folded and faulted structures. In the present paper geomorphic features characteristic of certain rocks like the granite, gneiss, sandstone, limestone etc. are described, and a brief account of the landforms resulting from aeolian, glacial, and marine processes is given. The information presented here has been gathered from the publications of the Geological Survey of India especially from the writings of Medicott, Heron, Pascoe, Wadia, West and several others. Their contributions and several others of the same type may lack something when measured by the geographic yardstick, but they show a breadth that geomorphers in this field are still short of attaining.

GEOMORPHIC FEATURES CHARACTERISTIC OF CERTAIN ROCKS

GRANITE TOPOGRAPHY :

In India vast areas are covered by this rock and their landforms are very characteristic. Typical granite landforms can be seen in various parts of Chota Nagpur plateau, Madhya Pradesh, Madhya Bharat, Hyderabad and Mysore. Rounded hills, bare stretches of rock pavements strewn over with boulders, some of which are rectangular, broken up along joint planes, others partly rounded and still others completely rounded are the salient features of landscape over the granitic terrains of India. Some of the rock boulders, rounded or incompletely rounded by subsurface weathering, project out over the sandy soils of the granite country and at other places the blocks are seen scattered forming a veritable maze of stones.

In the vicinity of Jabulpore, Madhya Pradesh, typical granite landforms are seen in Madan Mahal area and in the hills which project in an east-north-east direction.¹ The rocks are coarse-grained and highly jointed. As a result of these joints the rock weathers into large blocks. The blocks of granite show spheroidal weathering. Huge blocks or tors rounded by exfoliation or spheroidal weathering form balanced rocks. They are seen perched upon other blocks in Madan Mahal.

Granite gneiss and hornblende gneiss crop out at many places in the south Gangetic Plain in Bihar and form huge rounded domes due to spheroidal weathering. Near Bela, in Gaya district, Bihar, there is a perched block locally called 'Kaua Dol'. In Manbhum district, Bihar, typical granite domes are noticed.² They owe their origin to exfoliation and are very similar to

* Structure and Surface of India and Pakistan, *Geographical Review of India*, Vol. XVI, No. 1, 1954 (Calcutta).

¹ Chhibber, H. L.—"The Development of Landforms in the neighbourhood of Jabulpore and Bheraghat, Madhya Pradesh." *Bull. Nat. Geog. Soc. India*, 1950, No. 14, Benares.

² Chatterjee, S. C.—"The Physical Basis of Geography", 1951, p. 294.

the granite domes near Yosemite valley in California. The comparatively soft granite in Singhbhum, (Ref. Photo) Saraikella, Mayurbhanj and Keonjhar has been eroded into a flat or gently-undulating plain traversed by the Kharkai and Baitarni rivers. Tors are uncommon in this granite country but monotony is relieved by hillocks or ridges of dolerite.



Granite has weathered into the usual country of tors in north-eastern Nagpur, north-western Bhandara and Gangpur. In eastern Bellary and Anantpur districts, the granitoid rocks produce a wild rocky scenery, with castle-like masses and fantastic tors. At Hosdurga, south-west of Chitaldrug the granite shows a slightly schistose structure when weathered, and stands out in a typically bold steep hill-range, covered with huge boulders rudely piled one on the other.³ In the Warrangal district of Hyderabad and in the Chingleput district of Madras the granitoid rocks, usually very coarse-grained, weather into tors.

In the north-western half of Bundelkhand, Jhansi and Hamirpur districts, and Gwalior, the granite is of very massive structure and often weathers into large concentric spheroidal masses. The uniformity of the granite landforms of the Bundelkhand-Gwalior tracts is diversified by the long narrow serrated ridges of the quartz reefs which form a striking feature of the landscape; they run in straight lines, generally in a north-east—south-west direction, and are exclusively confined to the granite, sometimes attaining an elevation of 600 feet over the surrounding country. Their breadth varies from a few feet upto 100 yards and some of them are traceable in a direct line for more than 60 miles. The narrowness of the gaps by which the minor streams in many places cross the reefs affords peculiar facility for the formation of lakes, a very short dam being often sufficient to pond back large surface water; many of the numerous lakes in Bundelkhand have been formed in this way.⁴

³ Pascoe, E. H.—'A Manual of the Geology of India and Burma', Vol. I, 1950, p. 138.

⁴ Pascoe, E. H.—'A Manual of the Geology of India and Burma', Vol. I, 1950, p. 284-85.

To the west of the Aravalli range, granite (*Eripura granite*) bosses and laccolites are very common over a large area. In some parts the granites are very much jointed and appear like fort walls with huge cuboidal blocks arranged one on top of the other.⁵ From Palanpur and Idar up through Mewar, Godwar and Sirohi the granite forms all sizes of bosses and sills from the great batholith of Mount Abu downwards. The massif of Mount Abu is almost entirely composed of granite. In Godwar district of Marwar, the exceedingly coarse granite easily weathers and forms rounded hummocky knolls. The Mount Abu batholith, about 12 miles in length and two to three miles broad contains the civil and military station of that name and the lake of Nakki Tal which is nearly 3,800 feet above sea-level. The slopes of the Mount Abu plateau are extremely precipitous, especially those on the west and north; the highest peak, Guru Sikkar is some 5,650 feet above sea-level. The granite here weathers to fantastic and prominent land-marks, and exhibits many caverns and large holes.⁶ East of Sirohi town, a more easily weathered biotite granite is noticed. The large feldspars being more resistant to weathering, very frequently stand out on the weathered surfaces.

The granite landforms in the extreme south of the Sirohi State, differ from the granite topography of Mount Abu area, because of the more acid composition of the rock, strong foliation and a definite vertical jointing. At places it is so perfectly foliated that it breaks readily into small rectangular blocks and weathers with sharp edges, some what different from those of the more normal granite topography with typical rounded tors.⁷

Smooth, bare, sparsely jointed tors and flat domes of granite rising from the plains comprise the chief features of the granite landscape in central and western Mewar. In Idar State, granites rise straight out of the alluvium in the form of small groups of rugged, pinnacled hills, often temple crowned, and rising 500-600 feet above the plain, or of isolated bosses and tors of smaller size.⁸

Coarse-textured, porphyritic and slightly foliated granite of the Closepet district in Mysore, forms a range of bold precipitous hills, often over 4,000 feet in height and from ten to twenty miles across, with rugged disconnected peaks. The rock weathers in the form of clusters of isolated rounded bosses or domes often steep-sided and more or less bare of vegetation.⁹

HYPABYSSAL ROCKS :

Dykes cutting through sedimentary beds are rare in India and there is an absence of the characteristic dyke landforms. Differential erosion is, however, seen sometimes in igneous areas. If the dykes are more resistant than the invaded rocks, they stand out like great walls or prominent ridges. On a small scale such dolerite dykes are noticed in many parts of India.

The dolerite dykes form long, straight, narrow, serrated ridges (*dungris*), usually low but at times rising 400 or even 800 feet above the granite plain of Singhbhum. These ridges are sometimes discontinuous, but others extend for many miles and attain a width ranging upto half-a-mile

⁵ La Touche, T. D.—Geology of Western Rajputana, *Memoirs: Geol. Surv. Ind.*, Vol. 35, Plate 8.

⁶ Pascoe, E. H.—A Manual of the Geology of India and Burma, Vol. I, 1950, p. 418.

⁷ The Geology of the Sirohi State, Rajputana, 1933, *Memoir: Geol. Surv. Ind.*, Vol. 63.

⁸ Middlemiss, C. S.—The Geology of Idar State, *Memoir: Geol. Surv., India*, Vol. 44, Part I, 1921, p. 116, Plate 6, Fig. 1.

⁹ Pascoe, E. H.—A Manual of the Geology of India and Burma, Vol. I, 1950, p. 137.

across. Columnar structure is not infrequent, and the weathering is typically spheroidal, the slopes and the edges of the ridges being covered with rounded boulders.¹⁰

The basic dykes are a remarkable feature of the landscape of Bundelkhand. They persist for long distances and often weather into large rounded blocks with no tendency to exfoliation.¹¹ In north Trichinopoly, Salem and South Arcot the dykes are numerous. Dykes of dolerite are common in Mysore, especially in the central and southern portions of the State. In the Kistna and Guntur districts the gneiss is traversed by a few small dykes, standing out in the form of strongly-marked ridges. In Hyderabad, especially in Warrangal and Nalgonda districts, dykes are plentiful. In Bellary nearly 300 dykes traverse the gneissic plain and the Dharwar schists. Their average length is 3 miles, but the great Kailasakonda dyke, if correctly traced, is some 33 miles long. In nearly all cases, the dykes rise as conspicuous walls above the Archaean 'country'. In the gneiss of the Kaladgi area several dykes are remarkable for their great length and size, rising 200 or 300 feet above the plains in rocky ridges conspicuous by their black colour.¹²

If the dyke rocks are comparatively softer than the country rocks, the latter have withstood denudation better, and the dykes are seen to be scooped out into trenches or hollows. A narrow valley formed in this manner is seen near French Rocks, Mysore State.¹³

VOLCANIC LANDFORMS :

As there are no active volcanoes in the Indian sub-continent at present, the distinctive cones and crater landforms are lacking. Recent lava cones can, however, be noticed on the borders of Pakistan and in eastern Iran. Here the largest lava cone, nearly 25 miles in diameter, is Koh-i-Tafdan.¹⁴ A mere truncated remnant of a once much larger cone or caldera is seen in Barren Island in the Bay of Bengal.¹⁵ In Wajrakarur, Madras, volcanic necks consisting of agglomeratic materials have been noticed.¹⁶ As they are softer than the surrounding granites and gneisses, they have been worn down into basin shaped depressions.

In Buldana district, Madhya Pradesh, the Lonar lake is supposed to be a crater like hollow.¹⁷ It is about a mile in diameter and nearly 300 feet deep below the level of the surrounding country. The lake is ringed by blocks of basalts. The origin of the lake has been ascribed to a volcanic explosion unaccompanied by any lava eruption. The lake hollow, according to this view, represents an explosion crater or a caldera. Another view regards the lake as a depression formed by the collapse of lava along circular fractures.

Ash deposits from volcanoes have often the appearance of typically bedded sedimentary rocks; and cliffs of such material are seen in eastern Iran.¹⁸

¹⁰ Op. cit., p. 233.

¹¹ Op. cit., p. 285.

¹² Op. cit., pp. 473-78.

¹³ Rama Rao, B.—'Popular Studies,' No. 1, Mysore Geol. Dept., 1939, Plate 29, Fig. 58.

¹⁴ Vredenburg, E.—A Geological Sketch of the Baluchistan Desert and part of Eastern Persia, *Memoir: Geol. Surv. India*, Vol. 31, 1901, Plate 4.

¹⁵ Wadia, D. N., *Geology of India*, 1949, p. 26.

¹⁶ *Records Geological Survey, India*, Vol. 22, Part I; and Vol. 23, Part II.

¹⁷ La Touche, T. H. D.—The Geology of the Lonar Lake, *Recs. Geol. Survey, India*, Vol. 41, Part 4, pp. 266-75, Plates 27 and 28.

¹⁸ Vredenburg, E.—A Geological Sketch of the Baluchistan Desert and part of Eastern Persia, *ibid.*, Plate 14.

A distinctive landscape has been built up in India, by the successive lava flows over a wide area in the Deccan, including parts of Bombay, Saurashtra, Cutch, Madhya Pradesh and Hyderabad. Enormous quantities of lavas erupted in successive flows, have resulted in horizontally bedded sheets of basalts. After erosion a hill formed of such horizontally bedded rocks has a typical flat-topped plateau-like feature. The weathered flat-topped hills of basalts have a stair-like appearance and are a common feature in the scenery of Deccan.

The volcanic flows in Bihar, form the Dalma range and the Rajmahal hills.

GNEISSIC TOPOGRAPHY :

The gneisses are much older than the granites and the passage of time has caused them to be much more weathered. Generally in India, the gneiss has thus been ground down to a peneplain, with monadnocks sticking out here and there above the general level.

The gneisses of Peninsular India have been eroded more easily than the surrounding rocks; in this way they form the lower and flatter parts of the Mysore plateau. In the Western Ghats area the gneiss is highly schisted and foliated, and enormous slices of it have been wedged off by denudation along planes of schistosity and cross-joints. In this way several beautiful waterfalls have been formed in the courses of some of the westerly-flowing rivers. The best known and most magnificent of these is the Gersoppa Falls where the whole volume of the Sharavati river leaps a fall of nearly 830 feet.

The scenery of the plateau of Nilgiri, which is built entirely of the rocks of the charnockite suite (medium to coarse-grained, dark-coloured, basic holo crystalline granitoid gneisses), is typical of the charnockite country, being characterised by rounded hill tops and undulating 'downs' similar to the chalk country of Kent and Sussex.¹⁹ In Madura and Tinnevely similar hills are noticed. A broad extensive area of plateau and hills of gneissic rocks is found in southern Travancore. Similar low gneissic hills of the Bezwada region show indications of being part of an ancient plateau.²⁰ Numerous small hills of gneiss lie like islands in the schist complex of the Jeypore plateau.

Gneisses form the denuded and dissected plateau—3,000-4,000 feet in altitude in the Kalahandi State,²¹ where it is a continuation of the large Vizagapatam massif, extending from the Mahanadi to Godavari, and constituting the high plateaux of the Eastern Ghats in the Northern Circars. In Madhya Pradesh as a result of denudation; the archaean gneiss forms the Bilaspur plain.²² Here the east-west strike of the gneiss has produced a remarkable system of long, narrow, deeply carved ridges and valleys. A greater part of the Sambalpur district, Orissa, is a broad plain of gneiss with scattered low denuded hills of the same rock.²³ In Surguja a uniform plain of gneiss is seen.

Numerous hills of gneiss protrude through the alluvium along both sides of the Brahmaputra valley to the north of the Shillong plateau.²⁴ In

¹⁹ Pascoe, E. H.—A Manual of the Geology of India and Burma, Vol. I, 1950, p. 125.

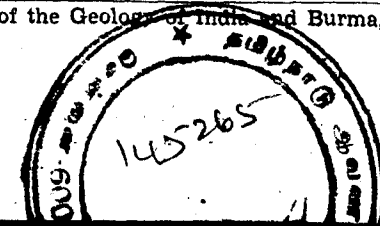
²⁰ *Ibid.*, p. 147.

²¹ *Ibid.*, p. 156.

²² *Ibid.*, p. 168.

²³ *Ibid.*, p. 171.

²⁴ *Ibid.*, p. 241.



Darjeeling district and Sikkim, the river Tista and its feeders have cut deeply into the gneiss²⁵ and have laid bare an underlying series of slates, phyllites and mica schists, which, being more easily denuded than the gneiss have enabled the rivers to cut still deeper. In this way, instead of a narrow gorge, a large river basin has been cut.

In Rajputana, except in the country south of Udaipur city, the gneissic terrain is a level plain broken only by low hummocks. A narrow elongated plateau, built up of calc-gneisses with bands of calcite and dolomite, commences to the east of Beawar and extends south-eastwards throughout Merwara. As a result of the greater solubility of the carbonates, differential weathering etches the surface of these rocks in boldly-ribbed relief.²⁶

SCHIST :

By far the greater part of this ancient rock formations have been removed by denudation, since they are invariably composed of minerals like hornblende, mica, or chlorite, which easily weather. The schistose rocks, therefore, do not generally form elevated regions.

The schist outcrops of Mysore weather to smoother outlines. But the resistant outcrop of banded quartz-iron-ore schists stand up as conspicuous hillocks or ridges over the general peneplain surface of southern Drwg. In Hungunda and Shimoga districts chlorite schist is plentiful. It is softer than the overlying Deccan Traps, and for that reason numerous small caves and waterfalls characterise the junction of the two rocks.²⁷

A conspicuous difference in the topography of the gneisses and schists is seen in Jeypore. The former, specially the coarser gneisses, form bold rocky hills; the schists, on the other hand, weather into smooth slopes.²⁸

A belt of schists on the northern fringe of Chota Nagpur plateau, forms an irregular scarp leading down from the gneissic plateau to the south Gangetic plain of Bihar. Here the rivers flowing from the high and uniform mass of the gneissic plateau have cut deep chasms into the heterogeneous and irregular formations of soft schist and hard granite.

SANDSTONE TOPOGRAPHY :

Landforms in sandstone regions are distinctive because of the particular composition and texture of the rock. Generally the sandstones are more resistant to weathering and erosion than shales and usually form massive hills and ranges in various parts of India. The development of landforms in sandstone depends upon the nature of the cementing material, grain size and the presence of joints. If the cementing material is easily weathered, then the sandstone quickly crumples away. Pot holes are frequently developed in the sandstone strata, and the rock is easily eroded into steep gorges. These features are well developed in the Gondwana Sandstones²⁹ of Peninsular India.

²⁵ Ibid., p. 317.

²⁶ Ibid., p. 402.

²⁷ Ibid., p. 81.

²⁸ Ibid., p. 150.

²⁹ Griesbach, C. L.—“Geology of the Ramkola and Tatapani Coalfield”, *Mem., Geol. Surv., India*, 1880, Vol. 15, Part II, Fig. 3, Plate II, Fig. 1.

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When the strata are not folded, sandstones give rise to plateaux with regular crest lines such as those of the Vindhya Mountains. Prominent scarps occur in the sandstones of the Mahadeva hills³⁰, and in the sandstones of Rajputana³¹. In the Kohat district of N.W.F.P., Pakistan, the tertiary sandstones form steep cliffs near Hassanshah so that the rocks have been designated as ‘perpendicular sandstones’.³² Residual pillars of sandstone formed by sandblasting along vertical joints are seen in semi-arid Rajputana.

QUARTZITE TOPOGRAPHY :

Metamorphosed sandstones or quartzites, because of the interlocking arrangement of the individual grains of quartz with one another become highly resistant to weathering and develop different types of landforms. Quartzite outcrops in parts of Rajasthan, Mysore, Chota Nagpur etc. build conspicuous features of the landscape.

They outcrop almost like massive igneous rocks in Rajputana³³ and Udaipur³⁴, and after erosion form steep precipitous cliffs and escarpments. The scarp of the Gwalior quartzite³⁵ in Rajputana and the quartzite cliffs in the Aravalli mountains near Ranthambor in Jaipur³⁶ are typical examples of the quartzite landforms. The greater part of Western Rajputana, Marwar and Bikaner is covered by desert sand in which there is no running water. Exposures of rock are limited to isolated knolls and group of hills which are the highest points of continuous ranges now buried in sand. Several of these “islands” in the sand, within a distance of forty miles from the limit of the main Aravalli range, consist of thick beds of quartzite.³⁷ A striking contrast in topography is seen in Rajputana where quartzites and the gneissic rocks occur. The quartzites, on the one side are characterised by high steep ridges and intervening narrow valleys, while the Aravalli and pre-Aravalli gneissic areas on the other side, are level plains with only low hummocks breaking the monotony.³⁸ There is little intercalation of soft argillaceous bands between the beds of quartzite in the Alwar hills of Rajputana. The parallel ridges and valleys locally called *mala* and *chhind* respectively which are so largely developed in the Alwar hills are due to these variations. To the south of Alwar, in eastern Jaipur, we find the vast alluvial and sandy plain, with occasionally a narrow strike ridge of quartzite. One of these, the Lalsot-Toda Bhim ridge stretches for over forty miles in length and forms a bold castellated ridge, with slopes buried in large fallen blocks.³⁹

³⁰ Medlicott, J. G.—“On the Geological Structure of the Central Portion of the Nerbadda District”, *Ibid.*, 1860, Vol. 2, Part II, Figs. 7 and 22.

³¹ Heron, A. M.—“The Geology of South-Eastern Mewar, Rajputana”, *Ibid.*, 1936, Vol. 58, Plate 16, Fig. 2.

³² Wynne, A. B.—“The Trans-Indus Salt Region in the Kohat District”, *Ibid.*, 1875, Vol. 11, p. 187.

³³ Heron, A. M.—“Geology of South-Eastern Mewar”, *Mem., Geol. Surv., India*, 1936, Vol. 58, Plate 7, Fig. 1; “The Geology of North-Eastern Rajputana and Adjacent Districts”, *Ibid.*, 1917, Vol. 45, Plate 2, Fig. 1. “The Gwalior and Vindhyan systems in south Rajputana”, *Ibid.*, 1922, Vol. 45, Part II.

³⁴ Hobson, G. V.—“The Metamorphic Rocks and Intrusive Granite of Udaipur State”, *Rec., Geol. Surv., India*, 1926, Vol. 59, Plate 21, Fig. 1.

³⁵ Heron, A. M.—“The Gwalior and Vindhyan Systems in South-Eastern Rajputana”, *Mem., Geol. Sur., India*, 1922, Vol. 45, Part II, Plate 28.

³⁶ Heron, A. M.—“The Geology of South Eastern Mewar, Rajputana”, *Ibid.*, 1936, Vol. 58, Part I, Plate 11, Fig. 1.

³⁷ Pascoe, E. H.—A Manual of the Geology of India and Burma, 1950, p. 273.

³⁸ *Ibid.*, page 384.

³⁹ *Ibid.*, page 396.

The general slope of the plains of the districts of Delhi and Gurgaon is eastwards towards the Jamuna, but the drainage of nearly all streams is either absorbed by the sand, or floods the low country in Gurgaon and Bharatpur and very little reaches the river. Features of relief in this region are due to the exposure of hard (Alwar) quartzites, and to a lesser extent of the comparatively soft (Ajabgarh) shales repeated again and again in closely-pressed folds. The valleys among the outcrops are of two kinds: (i) the narrow *chhind*, formed by the removal of easily eroded strata inter-bedded between more resistant beds, and (ii) the broader and larger synclinal valley excavated in the weaker supra-Alwar rocks contained in the fold-basin of the Alwars. In the latter the coincidence of the valleys with the syncline is abnormal in a folded region of mature topography and is a result of the more resistant character of the Alwar quartzites. The comparatively definite bedding of the quartzites lead to the formation of bare smooth precipices, the faces of which coincide with the dip slope of the highly inclined strata and display the abundant and more or less rectangular jointing in the form of lines or clefts; these precipices are breached by V-shaped gorges at right angles to the strike, giving rise to conspicuous and highly characteristic feature of the Alwar hills.⁴⁰

North-South running belts of pre-cambrian Alwar quartzites form the flat-topped Delhi ridge (800 to 840 feet). The symmetrically folded quartzites were subjected to peneplanation by Tertiary times and uplifted to form the present-day flat-topped ridge.⁴¹ North-South valleys were initiated along lines of structural weakness i.e., along the anti-clinal axis, so that we now get a parallel system of flat-topped synclinal ridges intervened by anti-clinal valleys, which latter are covered by *Bhangar* alluvium. The historic Delhi Ridge is flanked by two types of sediments—the eastern *Khadar* (clay and coarse sand) on lower grounds (700 feet) and the western *Bhangar* (silty sand) on slightly higher grounds (700 to 800 feet). The quartzites are characterised by blocky weathering. The *Bhangar* is now subjected to degradation as indicated by the young system of ravines in the area.⁴²

The quartzite bands in Gujarat, give rise to innumerable ridges often steep and characteristically serrated, which, though highly sinuous, show a remarkable parallelism. Although seldom more than 300 feet above the ground level, they form striking features of the local landscape, stretching sometimes for fifteen or twenty miles. Between these ridges, which are well developed in Bariya, Sunth, Sanjeli, Lunawada and Kadana States are well-watered valleys occupied by the softer phyllites and the schists.⁴³

The steep inclined hills of quartzite near Sheikhpura, Gaya and Rajgir resemble 'hogbacks' across the south Bihar plains.⁴⁴ They weather into rectangular blocks which form masses of talus below the vertical cliffs. The slope of the quartzite hills tend to be convex. The banded haematite quartzites form steep ridges, rising to nearly 3,000 feet in Keonjhar and Bonai, and in the adjoining district of Singhbhum. In Mysore also the banded ferruginous quartzites form some of the highest hills in the State. The indi-

⁴⁰ Ibid., page 387.

⁴¹ Heron, A. M.—'The Gwalior & Vindhyan System in South-Eastern Rajputana', *Mem., Geol. Surv., India*, Vol. 45, p. 8.

⁴² Sen, N.—'Geomorphological Evolution of Delhi Area', *Current Science*, Vol. 21, No. 6, pp. 157-159.

⁴³ Pascoe, E. H.—*A Manual of the Geology of India and Burma*, 1950, p. 276.

⁴⁴ Chatterjee, S. C.—'Physiographic Evolution of the Chota Nagpur Plateau, Calcutta Geographical Review, No. 3-4, 1948.

vidual bands of quartzites, as in the Bababudan hills, often form steep scarps. Again in Bastar and Kanker the haematite quartzite rock forms straight, bare, deeply notched, sharp crested, precipitous cliffs.⁴⁵

The beds of the quartzites form the conspicuous hill "Naggery Nose" near Madras.⁴⁶ At the well-known Gokak Falls, north-east of Belgaum, the Ghutprabha river pours from a quartzite cliff nearly 180 feet high.⁴⁷

LIMESTONE AND MARBLE TOPOGRAPHY:

Limestone landscape is characteristically developed in the region of limestone and marble rocks near Jabulpore in Madhya Pradesh. Other regions where limestone topography is developed to different degrees are the Central Himalayas in Kashmir, the Kirthar range in West Pakistan, the Rohtas plateau in Bihar and the Kurnool district of Madras. In spite of the variations in the climatic conditions between these widely scattered parts of the Indian sub-continent, there is a certain measure of similarity in the landforms, which shows that the control exercised by the rock is more important than process in the development of limestone landforms.

Outcrops of cherty limestones occur in the central portion of the Narbada valley in Jabulpore district, Madhya Pradesh. They are known as the Lamheta limestone from the Lamheta Ghat near Jabulpore where they were first noticed. The Lamheta limestone is well jointed and pebbles of jasper and siliceous material are present in the rock. The surface of the limestone shows widening of joints, fret work and fluted appearance with sharp edges. The limestone at places has pitted surface due to the removal of pebbles.

In the immediate vicinity of the City of Jabulpore limestone topography is displayed on a very small-scale in the adjoining hills.⁴⁸ Here the Lamheta limestone is usually capped by the Deccan Trap formation. Limestone in the Pat Baba ridge is well bedded, practically horizontal and is traversed by joints. Large widening of joints is seen here. Along some joints small swallow holes or sink holes have developed. The weathered surface of the limestone has a rough and pitted look.

About 13 miles to the north and east of Jabulpore there is a large outcrop of marble rocks at Bheraghat where a distinctive landscape can be observed.⁴⁹ The marble is well bedded, highly jointed, and dips at steep angles. The Narbada flows through the region of marble rocks and together with its tributaries has played an important part in the development of landforms in the area. The Narbada has carved a narrow gorge in the marble rocks below Dhuan Dhar Falls with almost vertical cliffs rising to 120 to 150 feet on both banks which are in places not more than 40 feet apart. The marble rocks are highly jointed in two directions; these directions are almost at right angles to the bedding planes, along which huge blocks are sliced off by the action of the river. The joints have been widened by solution and the rock has weathered into sharp and fine edged blocks along the joint planes. The fluting and fret work is to a certain extent deve-

⁴⁵ Pascoe, E. H.—*A Manual of the Geology of India and Burma*, 1950, p. 173.

⁴⁶ Ibid., p. 359.

⁴⁷ Ibid., p. 367.

⁴⁸ Chhibber, H. L.—'Development of Landforms in the Neighbourhood of Jabulpore and Bheraghat, Madhya Pradesh. Bulletin No. 14, 1950. National Geographical Society of India.

⁴⁹ Ibid.

loped in this region. The surface of the country has pitted appearance with widened joints, steep-sided 'sinks' and swallow holes formed by the enlargement of the joints. Large cavities have been formed on the sides of the Narbada gorge due to the solution of the marble. Near Bheraghat the Narbada drops over the Dhuan Dhar Waterfall about 50 feet in height. At the waterfall, the Narbada flows almost along the strike of the marble rocks.

The thickly bedded limestones in Kashmir Himalayas compose a very picturesque feature of the landscape.⁵⁰ The limestone here, forms cliffs and prominences from which numerous fresh water springs issue. Massive limestone builds the range of high hills and precipices in the Vihi and Islamabad districts.⁵¹ At Gurais the Kishenganga river has excavated through this limestone a broad U-shaped valley bounded on both sides by an imposing line of precipices, towering 4,000 to 6,000 feet above the flat scree-strewn bottom.⁵² The group of Amarnath peaks with the sacred cave on their southern flank is composed of limestone and dolomite.⁵³ Limestone is conspicuously displayed in the isoclinal folds of the Kala Chitta hills of the Attock district.

In Simla region, the limestone found along the Naldera ridge weathers into irregular crests and hollows.⁵⁴

GEOMORPHIC FEATURES RESULTING FROM AEOLIAN, GLACIAL, AND MARINE PROCESSES

AEOLIAN PROCESSES :

The landforms built by wind action are seen in Rajputana-Sind Desert, East and West Punjabs, and in Baluchistan.

The wind agency is very powerful in Sind-Rajputana Desert and the velocity attained during the monsoon season is nearly 40 miles per hour. Due to extreme aridity, the denuding action of the wind is also very great and it is generally marked on the few outcrops of rocks in the desert, e.g., the Jodhpur sandstone and the Malani rhyolite. The polishing action by wind-borne sand is very common in the Thar, and in the case of Malani rhyolites the cutting of the sand-blast sometimes differentially erodes their flow structure, producing a grooving like slickenside. At Idar, Jalor, Jaisalmer, and other areas the rocks show a characteristic erosional topography of the desert regions, resulting in rounded bosses and tors with wind polished surfaces. Undercutting of the granitic blocks into mushroom forms (resembling *gour* or *gara*) has been recorded by La Touche.⁵⁵ Another feature developed near Abu-Idar region are the peculiar caves and rounded hollows reminiscent of potholes, which possibly owe their origin to the abrasive action of aeolian sand grains. A particular erosional feature noticed along the whole submontane zone is the gullyng of alluvial screes, talus, fans and terraces.

Wind is responsible for building certain landforms by deposition. The prevailing winds have a tendency to heap up the sands in a well-marked series of ridges, dunes and hillocks. The Rajputana desert contains some big

⁵⁰ Wadia, D. N.—*Geology of India*, 1949, p. 422.

⁵¹ *Ibid.*, p. 423.

⁵² *Ibid.*, p. 423.

⁵³ *Ibid.*, p. 424.

⁵⁴ *Ibid.*, p. 435.

⁵⁵ La Touche, T. D.—*Geology of Western Rajputana*, *Mem., Geol. Surv., India*, 1902, Vol. 35, Plate 1, Fig. 2.

sand dunes which are sometimes 500 feet high. The sand hills present the aspect of a series of magnified wind-ripples. Heron has described the dunes of Marwar⁵⁶ and those near Jaipur⁵⁷. Dunes in Rajputana are of 3 types: longitudinal dunes, barchans and transverse dunes. The first type running NNE-SSW, i.e., parallel to prevailing winds occurs to the south and west; barchans with the concave sides facing the wind in the interior, and the transverse dunes aligned across the wind direction to the east and north. The general explanation given for their origin is that while all are due to the wind, the longitudinal dunes occur near the sea-coast in the south-western part of the Thar where the force of the wind is great. The transverse dunes are common in the distant north-east where the wind is not strong. The windward slopes of the dunes are long and gentle while the opposite sides are abrupt and steep. All the dunes are advancing slowly inland and some are noticed near the south-west border of Uttar Pradesh and Punjab. Crescent shaped dunes or barchans are also seen in Baluchistan and have been described by Vredenburg.⁵⁸

Dunes built up by the action of winds are also a common feature of sea-coasts of India and Pakistan. Oldham has described the dunes occurring near Karachi.⁵⁹ Sand dunes are met with on the Mekran coast in Pakistan, and in Cutch. Large dunes occur especially on the Malabar coast. The lagoons and backwaters of the Malabar coast have been formed by these coastal dunes.⁶⁰ Sand dunes formed by the sands blown by the strong winds from the sea are also seen in the broad valleys of the Kistna and Godavari rivers. On the coastal plain from Balasore to Puri southwards in Orissa, several parallel ridges of sand dunes are noticed. These coastal dunes are also gradually progressing inland in the direction of the prevailing winds. Grasses and vegetation check the further advance of the sand dunes inland.

In Baluchistan, North-West Panjab, and the Salt Range wind-blown loose unstratified earthy or sandy deposits of the nature of loess are found. The general aridity and the long dry season of this part of the subcontinent are responsible for the development of loess. Violent dust-storms occur in the long hot-weather season before the break of the monsoons. These dust-storms transport vast clouds of dust, silt and sands from the sun-baked plains and dried river basins and deposit them in the country to the west of the Indus, in North-West Panjab and on the Salt Range. As the loess are not very resistant, they have been carved into an irregular network of gullies and ravines giving rise to 'bad lands'.⁶¹

Hollows lying among wind-blown sand-heaps and dunes form small aeolian basins of temporary duration. Some of the Salt Range lakes in Pakistan are aeolian basins⁶²; the saline or alkaline lakes (*Dhand*) of Sind and West Rajasthan are other illustrations of such aeolian basins.⁶³

⁵⁶ Heron, A. M.—*The Geology of North-Eastern Rajputana and Adjacent Districts*, *Ibid.*, 1917, Vol. 45, p. 102.

⁵⁷ Heron, A. M.—*The Geology of Western Jaipur*, *Records Geol. Surv., India*, 1923, Vol. 54, Plates 24 and 25.

⁵⁸ Vredenburg, 'A Geological Sketch of the Baluchistan Desert and part of Eastern Eastern Persia', *Mem., Geol. Surv., India*, 1901, Vol. 31, p. 216.

⁵⁹ Oldham, R. D.—*A Note on the Sandhills of Clifton near Karachi*, *Mem., Geol. Surv., India*, 1903, Vol. 34, Part 3, Plate 1.

⁶⁰ Wadia D. N.—*Geology of India*, 1949, p. 302.

⁶¹ Wadia, D. N.—*The Geology of Poonch State (Kashmir) and Adjacent portions of the Punjab*, *Mem., Geol. Surv., India*, 1928, Vol. 51, Plate 4, Fig. 2.

⁶² La Touche, T. D.—*Lakes of the Salt Range in the Punjab*, *Records Geol. Surv., India*, 1910, Vol. 40, Plates 10 and 11.

⁶³ Wadia, D. N.—*Geology of India*, 1949, p. 324.

GLACIAL GEOMORPHOLOGY :

The landforms of the Himalayan region bear clear evidence of ice action. The Great Himalayas reaching beyond 20,000 feet are the gathering grounds of snow which feed the multitude of glaciers. The mountains of the Lesser Himalayas, whose general elevation is within 15,000 feet are below the snow line and do not support the glaciers at the present day. But the ranges of the Lesser Himalayas like the Pir Panjal, exhibit the characteristic glaciated scenery, in the thick masses of moraines covering their summits and upper slopes, in their striated and polished rock-surfaces, in the presence of numerous erratics, and other features of ice-sculptured mountains such as U-shaped valleys, cirques and lake-basins. Terminal moraines, often covered by grass, are to be noticed in the Pir Panjal Range at an elevation of above 6,500 feet. Hanging valleys, a characteristic of the landscape of glaciated mountain regions, are found in Sikkim and Kashmir Himalayas.⁶⁴ A well-known example is afforded by a former tributary of the Tista river in Sikkim, discharging its waters by precipitous cascades into the Rathung Chu, which is flowing nearly 2,000 feet below its bed. Ice erosion is responsible for the excavation of some of the lakes of the Tibetan Himalayas, which are true erosion-hollows scooped out by glaciers. At Pokaran, in Rajputana, there occurs a typical roches moutonnee formed during the upper Carboniferous glaciation.⁶⁵ Groved and polished rock-surfaces have been found at Pangri, in the upper Chenab Valley, and at numerous localities that have been explored from Sikkim to Kashmir. The upper slopes and peaks of the Panjal range have a typically glaciated aspect—pyramidal peaks, corries, arete and truncated spurs, while the valleys are filled with moraines and glaciofluvial drifts—eskers and kames.⁶⁶

On the Potwar plateau, lying between the northern slopes of the Salt Range and the Rawalpindi district, the distinctive landscape due to glacial deposits is seen. Scattered moraine and erratic blocks are found between Attock and Campbellpur on the surface of the Potwar plateau. The material of the blocks suggests their derivation from the high central ranges of the Himalayas, while their size suggests the action of ice, the only agency which could transport to such distances immense rock masses. Large transported blocks are also met with in Kashmir at various localities.⁶⁷

In Kashmir, the Jhelum Valley between Uri and Baramulla contains a number of large boulders of granitoid gneiss brought from the summit of the Kaj Nag range to the north-west, some of which are as large as cottages. These are common features in all other valleys of Kashmir. On the cliff-faces of Lidar, Sind and their tributaries rock polishing and grooving are well seen. Typical roches moutonnees are not rare on the hard resistant rock-surfaces in the Lidar and Sind Valleys. In the Sind Valley, near the village of Hari on the road to Sona Marg, Drew has noticed a well-grooved roches moutonnee.⁶⁸

Small lakes and tarns in the Himalayas owe their origin, in some cases to glacial erosion, in other cases due to the moraine barrier across glacial streams. Tarns on the north-east slopes of the Pir Panjal range and in Kumaon are of this kind. Former glacial basins bounded by terminal moraines and now covered with meadows are noticed in front of some of the Himalayan glaciers which are now retreating. The margs (basins) of Kashmir are examples of such moraine bound basins.

⁶⁴ Grinlinton, J. L.—Notes on some glaciers of the Dhaul and Lissar Valleys, Kumaon Himalayas, *Records Geol. Surv., India*, 1914, Vol. 44, pp. 295-96.

⁶⁵ Wadia, D. N.—Geology of India, 1949, p. 155.

⁶⁶ *Ibid.*, p. 279.

⁶⁷ *Ibid.*, p. 390.

⁶⁸ *Ibid.*, p. 390.

COASTAL LANDSCAPE

Rarity of creeks, inlets and promontories of large magnitude, and comparative regular disposition are the main features of the coastline of the sub-continent. Shallow lagoons and backwaters are met only on the Malabar coast. The sea coast is everywhere bordered by the plain of marine denudation—the shallow submarine platform being wider on the Malabar coast than on the Coromandel. In front of the deltas of the great rivers of the sub-continent like the Ganga and the Indus the coastline very frequently changes according to the intensity of the growth of the delta and erosion by the waves. Some geologists suggest that the Malabar coast is faulted, while the Mekran coast of West Pakistan is considered by Blandford, as making an east-west fault.

The coastlines illustrate some features due to emergence as well as subsidence. A slight emergence is noticed both on the east and west coasts which has brought the denuded marine shelf or platform with marine deposits above the level of the high tides. Raised beaches at an elevation of 100 to 150 feet, composed of gravel, sand with marine shells and coral fragments, are noticed at several places along the coast. The low level and flat nature of the south-east coast backed by the gneissic highlands of the Eastern Ghats suggest emergence from the sea. Evidence of prominent upheaval of the coast during recent times is found in East Bengal near Dacca where the tract of land known as Madhupur has risen nearly 100 feet above sea level. Slow upheaval has also been noticed in the Rann of Cutch with dry saline desert and shallow swamp which was lately occupied by a gulf. Slight rise of the sea coast is also suggested by the occurrence of oystershells, barnacles and serpulæ much above the level of the high tides in Sind and Kathiawar.

Clear evidences of recent coastal subsidence are supplied by the submerged forest, about 12 feet below the low-water mark, on the eastern coast of the Bombay island, similar submerged forest land on the Tinnevely coast, and by the existence of thick beds of lignite below ground level at Pondicherry and in Ganga delta. The creeks, inlets and rias in Malabar are essentially features of the submergent coast.

Coastal erosion is more active on the west coast of India than the east coast because of comparatively more powerful waves. A wave-cut cliff has been formed near Varkala, on the Travancore coast, due to the wave action.

Sands drifted up along the coast in Orissa and Madras, by the action of oblique sea-currents across the mouths of small bays or inlets, form bars and spits. The Chilka Lake in Orissa, Pulicat Lake in Madras, and the lagoons of the Travancore coast owe their origin to the deposition of bars and spits.

It is obvious that Indian Geographers have given relatively little attention to the study of geomorphology. A check of M.A. dissertations and articles in the Indian Geographical publications substantiates this conclusion. Why has this subject attracted so few investigators? Doubtless many have felt that they lacked the technical background that studies of geomorphology seemed to involve. There is ample room for Indian Geographers to direct their attention to some of the aspects of geomorphology like the different kinds of processes—fluvial, solution, glacial, and aeolian, the analysis of areal relationships between landforms and the occupation of land by man, and the character of our large river floodplains and the processes that shape them. It is hoped that this article will stimulate geomorphological studies in critical areas of India that have not yet been examined.

POTHOLE EROSION

By

B. M. THIRUNARANAN.

Textbooks have not given much space to the details of pothole development, perhaps because it has been difficult to observe them in humid regions where streamflow will seldom cease entirely. Alexander (1932) has examined eddy development by means of experiments in a tank specially built for the purpose. Eddies have been classified by Rehbock (quoted by Angebz, 1951) into horizontal rollers and vertical eddies on the basis of experimental work at the water-laboratory at Karlsruhe. Angebz (1951) has studied the location and shapes of potholes in certain rivers in Northern Sweden, whose beds are left exposed for the greater part of the year, because their water is now diverted for hydro-electric power development. Opportunities for examining potholes occur annually in monsoonal climates where many of the streams dry up completely during the hot weather months. The high floods resulting from the heavy seasonal downpour also induce in many streams velocities adequate for pothole excavation.

Potholes are common features of ungraded stream courses where stream flow of high velocity impinges on the bare surface of any hard rock. Water jets or eddies of specially high speed direct the abrasive action of suspended fragments or 'grinders' against chosen spots and thus the holes are scooped or gouged out in the rock at these places. The high velocity of the stream may be due either to the steep slope of the ground, or to the high pressure on the water. Such high pressure may be produced by constrictions in the stream bed which reduce the volume of discharge.

At times this may be due to artificial circumstances, as in an instance at Tiruttani, about 50 miles west north-east of Madras. Adjoining the temple-topped hill here on its south is a dolerite dyke ridge, locally called *Pinnakku Mulai* ('Oil-cake mountain') running east to west. South of this ridge is a road running parallel to it, and therefore crossing at intervals, the streamlets draining the south slope of the ridge. A fairly large part of the drainage of the ridge passes under a stone culvert on which the road runs. The course of the streamlet follows at this point a small dyke, about 12" to 15" thick, running nearly north to south. On the downstream side of the culvert the channel cut in the gneiss is filled with sand and pebbles about ten or twelve feet beyond the culvert. The exposed surface of the gneiss, between the culvert and the alluvial cover, is pitted with numerous potholes, while there are none in the stream bed above the culvert.

Potholes are quite common in streams traversing gneissic country, and are noticeable even from the trains, when crossing rivers during the dry season. Railway bridges favour sites which combine narrow crossings with firm foundations. Since this combination of structure and process is just what is needed for pothole formation, potholes are probably more common at the bridge sites than elsewhere.

A pothole examined by the author at Addatigala, in the East Godavari Agency, furnishes a typical example. It occurs just below a small fall in a



Fig. 1. Madugu Mallanna Gudi



Fig. 3. Wave-cut Platforms, Dolphin's Nose, Vizagapatam



Fig. 2. The Sath-Kund Waterfalls, Ajanta

streamlet. The spot is locally known as *Madugu Mallanna Gudi*, and its delightful sylvan setting attracts a considerable crowd each year during the Sivaratri festival. The development of the pothole in relation to the joints in the gneiss is shown in Figure 1. The pothole has evidently been scooped out by the water flowing along a vertical joint plane. The block originally enclosing it has fallen into the stream, and thus the pothole is now revealed as though cut in half by the vertical joint plane which gave birth to it.

The little knob in the centre of the base of the pothole should be noted. It has been formed where the velocity of rotation of water will be least. Alexander (1932) has noted that sand particles tended to form a conical heap at the bottom, in the centre of the eddy set up in his experiments. In the corresponding position, in a naturally developing pothole, the surface will suffer least abrasion from the action of the 'grinders', and thus a knob of this sort will be formed. Similar features are shown by Angebz (1951) in his cross-sections of the potholes examined by him.

This knob in the Addatigala pot is regarded as a 'swayambhu linga', i.e., a naturally manifested image of Iswara, and is called *Madugu Malleswara*, i.e., 'the Lord of the streamlet'. The pothole is his 'gudi' or temple.

We may consider next the remarkable set of potholes called the Sath Kund (Seven Pots) Falls, on the Waghara River, at the head of the Ajanta valley, nearly two miles above the celebrated Buddhist caves. They are clearly shown in Figure 2, which brings out also the polycyclic character of this valley. The mature, broad and shallow valley into which the Waghara has cut backwards appears very clearly above the falls. The water-fall has receded upstream along the meanders of the river, incising them into the floor of the old valley. There is a marked correspondence in height between the old valley floor, which is still intact above the falls, and the crests of the well-sharpened spurs enclosed by the meanders. They are all a little more than 1,600 feet high, and about 250 feet higher than the incised river bed. (The special Guide Map of the Ajanta Caves is the best map for examining these details of the topography.)

The Ajanta ridge is composed of Dekkan trap, and hence the 'pots' have been scooped out in the successive lava flows as the stream flows over them. The top and the base of each lava flow, having cooled more rapidly, will be somewhat more compact and hence more resistant to erosion than its inner core. Consequently, wherever the stream cuts into the harder crust at the top of a lava flow, it will also tend to scoop out the inner core more rapidly than it is able to erode the crust or the base. The vertical pounding by water falling from a height will be all the more conducive to the formation of such cavities. The Sat-Kund falls are a series of plunge-pools, each one being formed where the stream descended from a lava flow to the one below it. The structure of the Dekkan trap, and the variations within each lava flow, account for their development here.

Potholes are also formed by wave action, on the wave-cut ledges of rocky shores. Along the sea-face of the Dolphin's Nose promontory, just south of Vizagapatam harbour, several ledges of this type are found at different levels. Two of these ledges are shown in Figure 3. A shelf just above the water level may be seen adjoining the hill in the background, and a higher shelf, which is actually about 18 to 20 feet above the water level occupies the foreground. These ledges at different levels above the present sea-surface must have been cut when the level of the sea was formerly at those heights, and are therefore indicative of several changes of sea-level.

The lowest of these ledges corresponds to the present level of the sea, and is therefore exposed at low tide. Potholes can then be readily noticed, often filled with water. Fragments which doubtless serve as grinders are also common. But in one pothole, a broad and thick slab of rock was found, almost filling it. This slab fitted the cavity very exactly, and must have acquired its shape by constant rotation in that position, and mutual wearing of both slab and hole. The mode of work of this 'grinder' was essentially similar to that of a drill-bit. Usually the fragments acting as grinders are quite small compared to the cavity they scoop out, and the abrasion is similar to the process of sand-blasting in industry.

The force of moving water is also exerted in a different way in wave action. The weight of the water, as well as the velocity of movement are brought to bear on the cavities and the fragments in them. The great force thus exerted by breaking waves are quite adequate even to dislodge and turn tightly jammed rock masses. Potholes will therefore be much smaller and more short-lived along the seashore than along river courses.

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THE WATERFALLS OF THE CHOTANAGPUR PLATEAU : A Study in Geographic Geomorphology

By

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The Chotanagpur Plateau located in the North-east corner of the Deccan Tableland is dotted with a number of Waterfalls. They are of great interest to the sightseers but they hold equal fascination for the students of Geomorphology.

That the Chotanagpur Plateau is a rejuvenated peneplain is an admitted fact.¹ The meandering courses of the rivers, the rolling appearance of the interfluvies, the monadnocks and the absence of natural lakes point to the peneplanation of the plateau. There is also evidence to testify its rejuvenation. The active degradation of their beds, the headward erosion of the streams during the rainy season, the incised meanders, the potholes and the development of terraces on the valley sides seem to uphold the above-mentioned view.

The uplift causing rejuvenation has developed scarp-faults which mark the sites of the prominent falls of the region. Thus the earth movements to which the plateau has been subjected need attention.

EARTH MOVEMENTS :

1. An early tertiary peneplain uplifted² by about 1,000' is represented to-day by the isolated plateaus of Pakhar, Rudnipath, Bugru, Garhpat, Neterhat etc., called the "Pat" region running in a North-east—South-west direction and separating Ranchi and Palamau districts. On the North-east it merges into the Rajmahal Hills and in South-west in the plateau of Jaspur and Surguja.
2. The later tertiary uplift of 1,000' appears to have been caused by block movement with a sharp upwarping along a North-south line, now representing the eastern edge of the Chotanagpur Plateau, and a trough faulting of the Damodar Valley which separates the Hazaribagh Plateau from the Ranchi Plateau.
3. A further rise of the whole plateau seems to have taken place to the extent of about 700'-1,000' causing a sharp upwarp in the Subarnarekha region and a tilt to the east from the edge of the Chotanagpur Plateau to the coastal alluvium and to the north-east towards the Rajmahal Hills. The tendency west of the Rajmahal Hills has been towards steepening of the tilt culminating in sharp warp represented by the scarp face from Koderma to the plain of Gaya.

According to the mode of origin the falls of the Chotanagpur Plateau may be grouped as follows :

1. Fault Scarp Falls.
2. Differential Erosion Falls :—
 - (a) At the junction of the main and tributary streams.
 - (b) At the junction of different types of rocks.
3. Vertical Barrier Falls.

¹ Chatterjee, S. C.: *Some Aspects of the Geomorphology of the Ranchi Plateau*, Cal. Geog. Review, Vol. VII, June and September, 1945, p. 32.

² Dunn, J. A.: *Post-Mesozoic movement in the Northern parts of the Peninsula*, Mem. Geo. Survey of India, Vol. 73, 1938, p. 141.

(1) FAULT SCARP FALLS :

Uplift has caused the formation of cliffs at the fault plane. Such cliffs or fault scarps have become the sites of waterfalls. They are the most spectacular and the most common types of falls of the Chotanagpur Plateau e.g. Hundru, Jonha, Dossom, Hirni etc. Every-one of the three earth-movements to which the plateau was subjected gave birth to waterfalls of this type.

(a) Early tertiary earth-movement created most of the falls of the "Pat" region. It attains a height of 3,000' and presents steep faces to the main Ranchi plateau in the east and the North Koel Valley in the west. The Sankh, the North Koel and their tributaries while emerging from the "Pat" region create falls at the fault scarps. Sadnigagh (200') on the Sankh River, Chhenriatanga (150') on the Kunda, a tributary of the Sankh, Nidnigagh (150') on the Ghaghra, Jalimgagh (125') on the Jori, Ghaghri Falls (140') and Burhagarh (465') on the Burha Nadi are a few important ones which deserve mention. Apart from these there are many other falls. As a matter of fact no other part of the Chotanagpur plateau can claim to have such a great number of falls.

(b) *Late Tertiary Movement.*—The upwarping formed the eastern edge of the plateau overlooking the Subernarekha Valley. The rivers which descend from the plateau into the valley have falls at the scarp face. The notable are Hundru, Jonha, Dossom, and Hirni. They are aligned along a line which points to their origin by faulting. This is also supported by the presence of the same rocks above and below the falls, their abrupt front and the increase in the gradient of the streams as the falls are approached. Granite-gneiss is the rock of Hundru, Jonha and Dossom while that of Hirni is calc-schist³. The plunge pool at the foot of the falls bears testimony to the abrupt front; whereas the steepness in gradient is supported by the fact that above Hundru falls within a short distance of nearly two miles, the Subernarekha river descends down more than 150'. The step-like feature of the Jonha falls must not wrongly be taken as step faults. It has been carved by the breaking of the blocks of the granite-gneiss along joint planes.

(c) The third movement culminated in sharp upwarp west of the Rajmahal Hills and the formation of the scarp face from Koderma to the plain of Gaya. This scarp face is the site of a number of falls on the rivers which plunge into the Gaya plain from the Chotanagpur plateau. Mohana Nadi, Tilya and its tributaries have falls at the edge of the plateau. The falls are on an average 100' high, while one on a tributary of Tilya is 200' high.

(2) DIFFERENTIAL EROSION FALLS :

(a) *At the junction of main and tributary streams.*—

Rajruppa Falls is the best example of this type. It occurs at the junction of the Behra Nadi and the Damodar river. The main stream, Damodar, has carved its bed deeper than the tributary. So the Behra hangs over Damodar and the fall has come into being. The differential erosion is due to the following causes :

(i) Damodar being the main stream has greater volume of water and load than the Behra, thus the former performs greater erosion than the later.

³Chatterjee, S. C.: *Some Aspects of the Geomorphology of the Ranchi Plateau*, Cal. Geog. Review, Vol. VII, June and September, 1945, p. 34.

(ii) Damodar has a steeper gradient caused by the uplift of its headwaters located in a highland connecting Ranchi and Hazaribagh plateaus in early tertiary and the fault trapping of its basin in the late tertiary.

(iii) Damodar is a perennial stream. Bahra is intermittent. It becomes a turbulent stream only in the rainy season. So Damodar is continually deepening its bed, whereas Behra becomes inactive during the dry season.

(b) *At the junction of different types of rocks.*—

The south-eastern edge of the Chotanagpur plateau is highly dissected. Turbulent streams role down upon the steep slopes forming a number of falls which are not a very prominent feature of the topography. They are mostly due to the presence of rocks easily susceptible to erosion. Sandstone, conglomerate, shale and limestone are the common rocks. This group of sedimentary rocks is known as the Kolhan Series.

(3) VERTICAL BARRIER FALLS :

Such falls occur wherever a block of hard rock lies across a river bed beyond which the rocks are comparatively less hard. It is most common in a region where igneous intrusion has taken place. The Chotanagpur plateau is not devoid of igneous activity. The isolated plateau of the "Pat" region is mostly capped by laterite or bauxite beneath which lies the basaltic lava. In this region many hard rocks have been intruded and lie across the river channels forming falls. Such falls are low and insignificant. They do not have any attraction to the tourist and go unheeded by the people of the region. Its geomorphic importance, however, cannot be ignored. Rajderagarh on the North Koel may be taken as an example. It is only 12' high.

The waterfalls of the Chotanagpur plateau may thus be classified into different types. The fault-scarp falls are the most prominent and the most common. They are associated with three earth-movements to which the plateau was subjected in the Tertiary period. The falls of the "pat" region, those lying along a line at the eastern edge of the plateau and those overlooking the Gaya plain represent the three earth-movements. Differential erosion falls are the next in importance. Rajruppa Falls is the best known example of this type. Vertical barrier falls are difficult to find but are not absent.

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REVIEWS

BIHAR IN MAPS by Dr. P. Dayal, M.A., Ph.D. 9 $\frac{1}{4}$ " $\times$ 7 $\frac{1}{2}$ ". Pp. 83. Kusum Prakashan, Kusumpuri, Patna-3, 1953. Unbound: Rs. 5/-. Bound: Rs. 5/12.

An Atlas is just a collection of maps bound together. Dr. Dayal's 'Bihar in Maps' is not an atlas of this conventional type. It consists of 39 maps, in black and white, using chiefly dot and shade methods: 1 key map; 9 maps portraying the distribution of different physical components; 19 maps relating to land-use, crops and livestock; 2 maps on population; 4 maps on industries and minerals; 2 on transport; 1 on Damodar Valley Project and 1 on Community Projects. Each map is accompanied by a brief descriptive and explanatory note. It should be said that the map of industrial zones (No. 34, p. 73) is a special and welcome feature. Basic inter-regional contrasts, both physical and economic, are well brought out by the atlas, and this variation in life-circumstances in one administrative region may be considered as a healthy feature of Bihar though, of course, the economy of the province is far from 'balanced'.

While the Atlas is certainly a praiseworthy publication bringing credit to Dr. Dayal, it has given scope for a few criticisms. Instead of giving only the district boundaries in the key map (1st map, p. 7) thus leaving it blank, taluk boundaries with taluk headquarters could have been shown. By showing the administrative details in the first map and by including some of the important tributaries of the plateau rivers in the relief and drainage map, the second map (p. 9), which, as it is, gives a confused picture, could have been omitted.

The author could have included the aspects of floods and rainfall variability in his study. The significance of these two hazards to the life of our people needs no special mention. The highly simplified pattern of the distribution of agricultural resources as revealed by the crop maps and the map of agricultural regions poses the question: Is the pattern really so simple? or Are the interregional variations concealed because district has been taken as the unit of mapping? The author has not dealt with the Sugar-cane industry in a more detailed way emphasising the recent trends in the locational shift probably because the atlas is intended to meet popular demand.

Inset graphs showing population and land-use trends in the respective maps and a few cartograms bringing out the relative position of Bihar in India and comparing with other provinces would certainly enhance the value of the atlas. Statistical appendices and that too, data marshalled on the basis of natural or economic regions, however generalised the regions may be, would further add to the reference value of the atlas.

In summing up, Dr. Dayal is to be congratulated for his work, and 'Bihar in Maps' should be in every Geography Department and also in the shelf of every teacher and student of Indian Geography, as nowhere in a single publication, and that at such a low price, one gets so much relevant and up-to-date geographical material on Bihar.

V. L. S. P.

TRANSACTIONS AND PAPERS 1953. Pp. 143. The Institute of British Geographers. Publication No. 19. 21 sh. net. London: George Philip & Son, Ltd., 1954.

The publication No. 19 of the Institute of British Geographers—Transactions and Papers 1953, includes the following papers:—

1. On the relations of Geography and History—by Prof. H. C. Darby.
2. The Relationship between Wave Incidence, Wind Direction and Beach changes at Marsden Bay, County Durham—by Cuchlaine A. M. King.
3. The Denudation Chronology of the Middle Trent Basin—by K. M. Clayton.
4. The Development of Roads in the Surrey-Sussex Weald and Coastlands between 1,700 and 1,800—by G. Joan Fuller.
5. Some Medieval Rural Settlements in North Wales—by G. R. J. Jones.
6. Horticultural Developments in East Yorkshire—by June A. Sheppard.
7. A Study in the Economic Geography of the pre-war Coastwise Coal Trade—by H. C. Brookfield.
8. Towns and Rural Service Centres—An Index of Centrality with special reference to Somerset—by H. C. Bracey.
9. The Urban Regions of St. Albans—by H. S. Thurston.
10. Hydro-Electric Power Development in Norway—by Alice F. A. Mutton.
11. The Cologne Brown-Coal Field—A study of the Law and Landscape—by T. H. Elkins.

The general position of Historical Geography has been discussed more frequently these years. The definition that Historical Geography studies the influence of geographic factors upon historical events is not accepted now,

the modern version of the definition being the reconstruction of past geographies. Prof. Darby, who is with little question, one of the productive scholars in modern Historical Geography stresses on the value of the method of cross-sections in the study of the historical geography of an area, as it provides both depth and genetic approach. Prof. Darby points out that the characteristics of different landscapes are the result not merely of environmental factors, but of their utilisation by man, and emphasises the need for a fourth dimension in geographical study. He claims that geomorphology and historical geography should form the foundation for the study of geography.

King on the basis of his surveys and observations made at Marsden Bay comes to the conclusion that in the area under study, sand generally moves normal to the coast, off-shore winds being associated with constructive wave action and on-shore winds having a destructive effect. The analysis of the observations with reference to model experiments is really the most instructive part of the paper.

Clayton, utilising various techniques such as hypsometric curves, superimposed and projected profiles, recognised a sequence of four main erosion surfaces and a number of minor surfaces. He suggests that the highest surface which occurs at a height of about 1,000' probably belongs to the Pliocene period rather than pre-Triassic as suggested by earlier writers. He finds that projected and superimposed profiles are effective in bringing out only the surfaces developed above 500' and not the lower levels where the vertical interval between the surfaces is less.

Fuller's paper is a study of road development in the Surrey-Sussex Weald between 1,700 and 1,900 and its effect on the economic development of the region.

Jones adopts the historical approach for the study of rural settlements in North Wales. On the basis of the 16th century surveys he tried to reconstruct the medieval settlement pattern (i.e., at the end of the 13th century) and with reference to particular examples he traces the evolution of the settlements. Like Professor Darby, Jones stresses the importance of the historical approach.

Sheppard analyses the geographical factors responsible for the remarkable concentration of market-gardening in East-Yorkshire especially in the area near Hull, and gives an account of the Dutch gardening practised there.

Brookfield analyses the 'coal import' with the south-eastern countries of Cornwall, Devon, Dorset and Somerset in the 12 month period from mid-1937 to mid-1938, with reference to quantity and origin of the coal. His study is interesting as it brings out certain facts which at first sight appear to be anomalous, i.e., the greater importance of the north-east coal fields as compared to the South Wales Coalfield.

Bracey suggests an Index of Centrality which is used by him to 'identify and arrange in order of the importance of rural service, the main service centres of Somerset.' The method of scoring adopted by him leads him to the identification of three zones surrounding the urban centres. Thurston outlines a method whereby the different regions in an urban centre may be distinguished. He uses the Fractional Code Method: The numerator with functional character of the Industry and the denominator with the details of Structure (i.e.) the materials used in the building and the age-group to which it belongs. This method is really of interest and value to the students of Urban Geography. Thurston traces the growth of St. Albans and gives an account of the Urban regions in 1918 and 1950.

Alice Mutton gives an account of the hydro-electric developments in Norway in recent years to meet the industrial demand for electrical energy as in the production of aluminium and chemical fertilisers.

Elkins draws attention to a factor that is generally ignored in mining areas (i.e.) the effect of legislation upon the landscape in an area of open-pit mining. He points out the contrast between the landscape of the Cologne Coalfield, where, as elsewhere in Germany, mining has precedence over all other types of activities, so that 'legislation permits sweeping away of roads, railways and even complete villages' if they stand in the way of complete extraction of the coal, to that in Britain where a mining concern cannot even remove a foot-path.

A. S.

NEWS

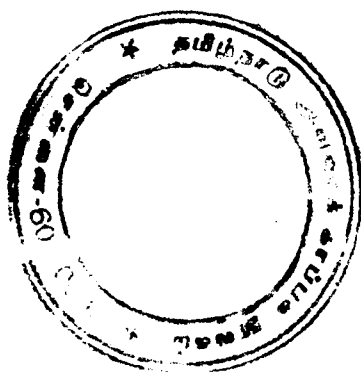
THE EIGHTEENTH INTERNATIONAL GEOGRAPHICAL CONGRESS, 1956

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Professor Sternberg should also be notified of any changes of address as set down in the Directory."

Dr. George Kuriyan, Professor of Geography, Madras University and the President of the Indian Geographical Society, was in U.S.A. for five months from June to October, 1954 as Consultant to the American Geographical Society on a forthcoming Geographical Compendium on India.



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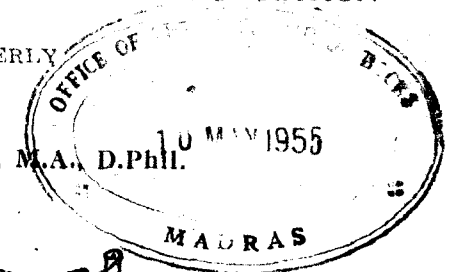
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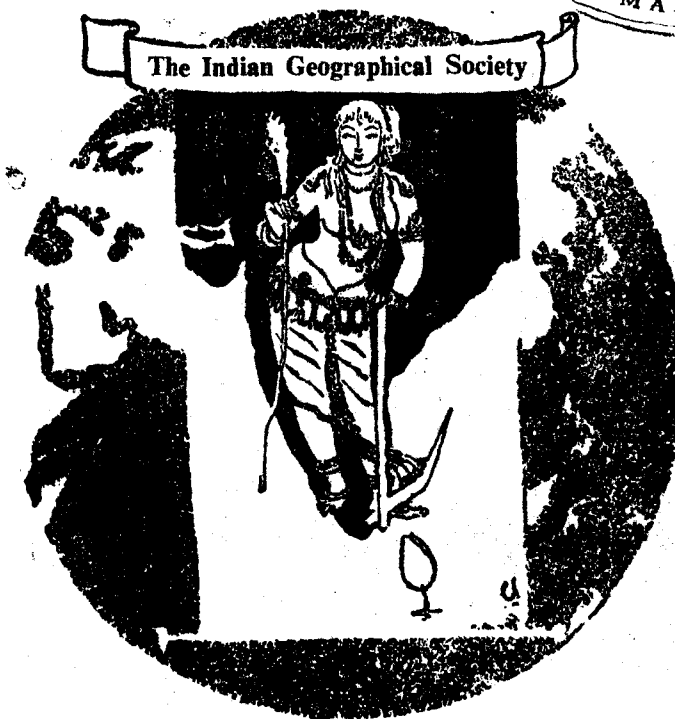
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FLOODS AND THE REGIONAL ECONOMY OF WEST BENGAL

P. K. SIRCAR

INTRODUCTION

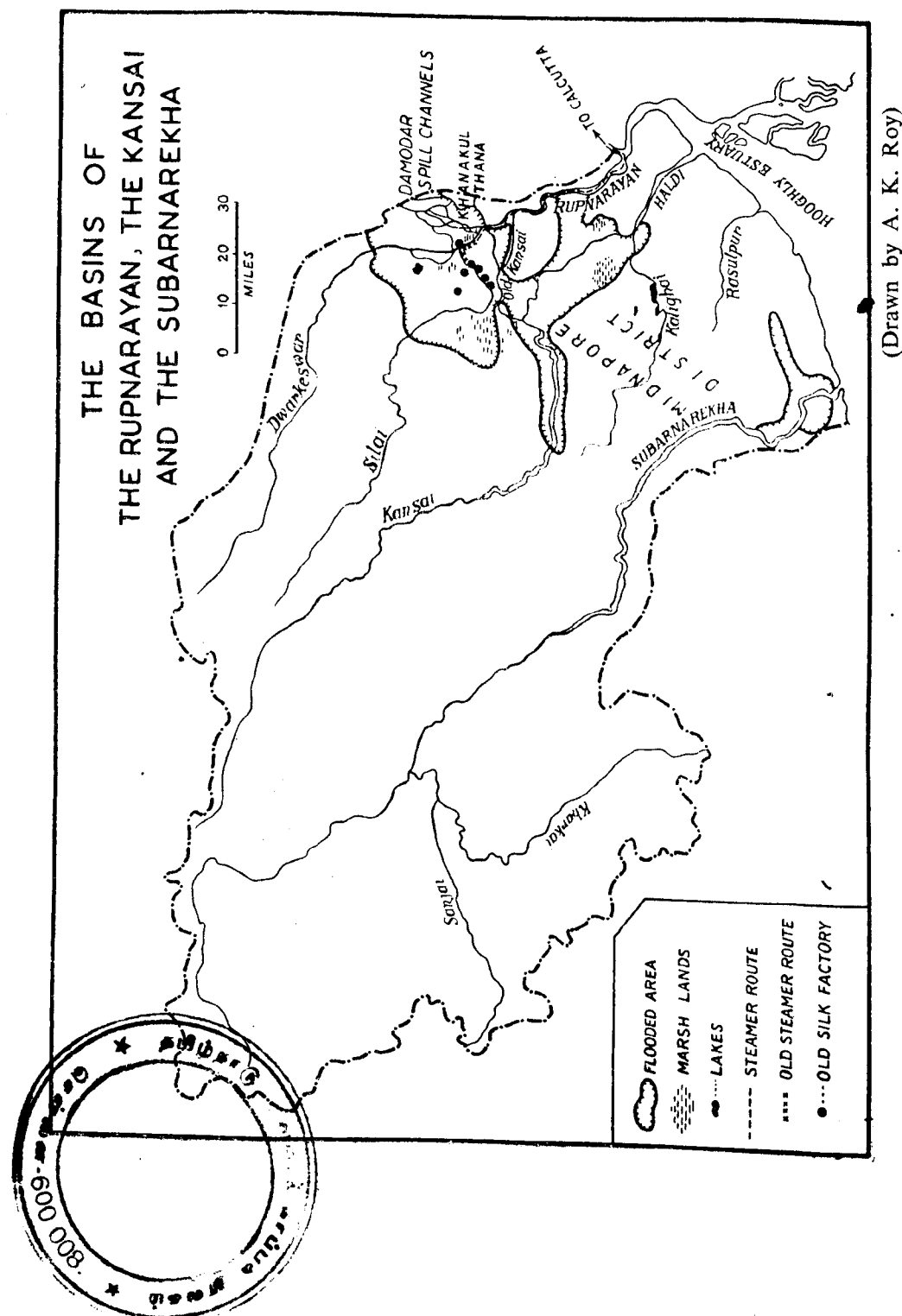
It is almost a truism to say that Bengal is the gift of her rivers. Yet, paradoxically enough, it is the rivers in West Bengal to-day that are proving themselves an increasing liability. It is in the area lying to the west of the Hooghly that the problem has presented itself most acutely in the shape of recurring floods, which have become a very potent factor in the land and life of a considerable part of the lower basins of the Rupnaryan, the Kansai and the Subarnarekha. (Ref. Map.)

Apart from the direct loss of life involved in catastrophic floods and much destruction of, and damage to, the property and standing crops entailed in floods less severe, these floods leave an impress on the area in several other ways. This paper seeks to discuss the effects of the succession of floods on the geography of the region, both physical and economic.

PHYSICAL EFFECTS OF FLOODS

Formation of Marshlands :

Alluvion and diluvion are the two most obvious processes observed in times of floods, whereby new land formation and destruction of old land go side by side. West of the main Damodar spill-channel, and at a distance of about 1 mile from it, is a band of land, of between $\frac{1}{2}$ to $1\frac{1}{2}$ miles width, which, owing to frequent flooding, has become uncultivable and is now covered with grass, 2 to 6 feet high, growing on a very sticky, muddy soil. Further south similar features occur, where complications occur as a result of the incursions of high spring tides.



Waterlogging :

The soil structure is also adversely affected by frequent flooding, especially if there is delayed or defective drainage,¹ and this tells on the productivity of crops even in years which are themselves free from floods. Sowing of winter crops may be delayed by the waterlogged condition of the soil, and this sometimes has a considerable effect on the yield of potatoes in the flooded area of the Khanakul thana.

Changes in the Soil Texture :

But perhaps the most important physical effect of floods is on the soil texture. Floods which have flowed on land and have had a comparatively quick egress may be either beneficial or harmful to crop lands according to the character of the deposits that they leave behind. Flood waters carry both silt and sand, but whereas silt can improve the soil texture and fertility, sand is liable to convert paddy fields into wastes, unless they are reclaimed at a heavy cost. It is difficult to foretell which places will receive silt and which sand, and even the same place may get sand in one year and silt in another. Kingsford in his Settlement Report made the following observations with regard to the area immediately north of the mouth of the Subarnarekha : "Great damage occurs in *parganas* Kismat Katisahi, Katisahi and Sahabandar through flood, erosion and occasionally by sand deposit. In Sahabandar, particularly in the area enclosed by the old and new channels of the river, the surface of the soil is in a continual change owing to the action of the water. The course of the river is erratic, and its action deposits in some places sand, in others, silt, so that the cultivation varies from year to year. In Daradachaur and Nangaleswar less damage is caused, and throughout these and other *parganas*, excepting those directly upon the bank, silt is deposited in large quantities, and when the flood occurs early in the year, as in 1898, the results are entirely beneficial."²

According to the Embankment Committee, the "rivers of Bengal do not always bring sand, but every second or third year a deposit of silt is laid down on the sand and these form the richest cultivated land."³ It may be remarked in general that, while a gradual inundation is beneficial inasmuch as the heavier sand is deposited in a narrow band along the bank, whilst silt may be spread far and wide, a sudden rise of the river which breaches embankments is much more dangerous, since the faster moving water disperses sand over larger areas. It is believed that this is precisely why in old times when embankments were weaker and less continuous than to-day, inundations, although probably frequent, had effects which, on the whole, were as beneficial as they still are in the major part of East Bengal.

Sand Invasion :

The problem of sand invasion is thus very real in riverine tracts open to the hazard of heavy floods. To take but one example, south of Bandar there occurred in 1946 a big breach in the embankment resulting in sand invasion over a large area. Before this area could be sown under potatoes it had to be cleared at a heavy cost—an important fact since the potato is a cash crop. In 1 bigha (approx. 1/3 acre) plot of sand invaded land at Kagnan the cost of cultivation was Rs. 544, as compared to Rs. 414 in a sand-free plot at neighbouring Dhanyagori. Actually the cost of sand clearance in this instance amounted to Rs. 150.

¹ Allan, R. G. Soil Drainage, Agr. Res. Inst., Pusa, Bull. No. 85 (1918), 1-21. Ref. pp. 1-2.

² Quoted in O'Malley, L. S. S., Balasore District Gazetteer (Calcutta, 1907), p. 115.

³ Govt. Bengal, Report on the Embankments of the Rivers of Bengal, (Calcutta, 1846), p. 2.

Some lands may get too deeply buried in sand to be worth reclaiming. In such cases, where possible, *Daincha* is planted, which is a leguminous crop and a green manure. But when the percentage of sand in the soil sample exceeds 80, the land is mostly left uncultivated.

ECONOMIC EFFECTS OF FLOODS

Effects on Cultivation :

There are several ways in which floods affect agricultural operations. Thus, if sowing is delayed because of an early flooding, optimum conditions as regards the reception of the monsoon rainfall may not be effectively fulfilled, and this tells on the yield of paddy. Experiments at Pusa have confirmed this.⁴

In the cultivation of *aman* rice by far the most important factor is the depth of water on the field. A depth not exceeding 9 to 10 inches⁵ during transplantation and for 2 to 3 weeks afterwards is beneficial for the growth of tillers in rice, but after that, all that is required is moist soil, and water standing on the field certainly suppresses tillering.⁶ Still later, at flowering time, excessive rainfall is again harmful, and standing water seriously affects the yield.

The most critical period is thus from the middle of August to the end of October, and this is the very season when the floods are most frequent. Thus even when the standing crops are not actually washed away or totally submerged by high floods, too much water standing on the fields in the critical period diminishes the quantity of the harvest.

Crop Changes :

A further effect of flooding, less evident to the immediate observer, is a change in the type of crops grown. Thus at Mayal and Bandipur, in the flood-stricken Khanakul *thana*, it has been noted that whereas mulberry and sugar-cane were profitable cash crops not so long ago, they have now been practically replaced by jute and potato. Jute favours a limited degree of inundation, but the potato, with its short growing season, can be sown after the floods have subsided and harvested before the time of next flood. A study of crop acreages during 1930-37 and 1944-45 shows that there has been an increase in the acreages of *boro* paddy, jute and potato, but the acreages under *aman* and *aus* paddy and sugar-cane have considerably declined. It would be idle to pretend that all these changes can be attributed solely to the increased incidence of floods, for in reality many causes combine together to produce diverse effects. Nevertheless, it should be noted that *aman* is normally the first choice of the farmer because of its better quality, and a reduction of output by 33 per cent is unlikely except under the compulsion of circumstances. Similar conclusions seem warranted for the flooded area of the Midnapore district from a study of the pattern of crop changes there between 1911-17 and 1944-45. Particularly noticeable here are the decrease of *aman* paddy and the increase of *boro* paddy.

⁴ Sherrard, G. C. A summary of the Experiments on Rice in Bihar and Orissa from 1912 to 1919, Agr. Res. Inst., Pusa. Bull. No. 96, (1921), 1-64. Ref. p. 14.

⁵ Saha, K. B. Economics of Rural Bengal, (Calcutta, 1930), p. 23.

⁶ Sen, P. K. Studies in the Water Relations of Rice. I. Effect of watering on the rate of growth and yield of four varieties of rice. Ind. Jour. Agr. Res. 7, 1 (1937), 89-117. Ref. pp. 89 and 105.

It is interesting to read in this connexion the recommendations of the Orissa Flood Committee, specifically advising a change of the crop grown in the flood zone of the Subarnarekha from the autumn to winter paddy and other winter crops.⁷ The Orissa Government Agricultural Department, after the floods of 1926 and 1927, made special efforts to introduce flood-resisting strains of paddy and to encourage the growing of winter crops.⁸ In the absence of relevant statistics it is difficult to say how far this has resulted in a significant change of crops grown there.

Decline of Mulberry and Sugar-cane :

Another crop which has shown a marked decline, though statistics are not available, is the mulberry. Very little mulberry is grown now in this area, but even at the turn of the century it was an important crop grown between the Old Kansai and the Rupnarayan, and farther across, in the Khanakul *thana*. The crop used to be grown on river banks and on *Kele* or *Udbastu* land, which is lower than *Bastu* (Homestead) land, but higher than the rice fields. This facilitated the irrigation of the young plants, but at the same time prevented their inundation in floods, which is particularly injurious. These lands all had a high rate of valuation.

Depending on the mulberry cultivation a number of silk factories grew up along the Rupnarayan and the Silai. A portion of the raw material in the form of yarn was exported to England, France and elsewhere via Calcutta. The rest was fabricated locally into various fine cloths. The silk industry passed through many vicissitudes during the 18th century, but in the 19th there set in a gradual decline in the production of both raw material and finished goods. A factor of some importance in this decline was apparently the increased injury to the mulberry from floods. The decline of the industry in the Khanakul *thana* has been ascribed to "the fluctuating nature of the demand, the restriction in the mulberry-growing area caused by the Damodar floods, the degeneracy of the silk-worms and their dying off from disease."⁹ In contrast, silk weaving is still prosperous in the flood-free Bankura district. The riverine mulberry cultivation was the first to be destroyed, and the floods later destroyed the inland crops. The high floods of 1885 and 1898 are said to have been particularly destructive. These mulberry fields now remain in many places uncultivated, although the land revenue is still high. Some farmers have converted a few of these plots into kitchen gardens and flower beds.

After the destruction of the mulberry, sugar-cane was tried on these fields, but that also suffered in the same way from floods. This has been a reason for the decline of the indigenous sugar industry of the Midnapore district.

Change in the Waterways :

The foregoing are some of the direct effects of floods on the regional economy. We now proceed to discuss the indirect effect of floods as shown in the change in the waterways. The reason of this change is to be sought in the deterioration of channels consequent upon the construction of embankments, which were erected to cope with the floods. The embankments prevent the fertilising silt from enriching the fields. Instead, the river, perforce,

⁷ Dalziel, W. W. Final Report on the Revision Settlement of Orissa, 1922-1932 A.D. (Patna, 1934), p. 13.

⁸ Ibid. p. 10.

⁹ O'Malley, L. S. S. Mooghly District Gazetteer, (Calcutta, 1912), p. 183.

deposits a portion of the silt on its bed, thus raising its level. Due to increased soil erosion in the upper catchment, the river loads have been increasing, and river channels that were formerly deep and narrow tend in this way to become wide and shallow. People living near the Rupnarayan at Ghatal and Bandar can remember the days when the river was deep and how large steamers laden with merchandise could ply between Calcutta and Ghatal and even beyond. Even a decade or so ago steamers could come up to Ghatal. But now the river traffic has become restricted, and the service has to be maintained in two sections—one from Calcutta to Kolaghat via Tamluk, and the other from Kolaghat to Ranichak. Even then it so frequently happens that steamers from Calcutta can reach only up to Banka and not even Tamluk. Similarly, on the other route from Kolaghat, steamers now have to await tides, and the writer was caught aground on both occasions that he used this route.

The restriction in river traffic is reflected in the relative decline and growth of different trade centres. In 1795 Ghatal was the port of Khirpai, Chandrakona and Dewanganj and between January and May 800 bullocks passed daily between Radhanagar and Ghatal.¹⁰ It was the most important inland port until it lost its place to Ranichak, 8 miles downstream, which is the present steamer terminal.

In the hinterland of Ghatal the brass and bell-metal industry was important. The finished articles were sent to Calcutta, and the raw material and the scrap were imported, through Ghatal. But now it is easier to distribute the raw material and export the finished goods through Ranichak, near which new small factories have grown up along the Rupnarayan. This growth of new industries here is going on at the expense of the old centres inland. Kharar was a well-established centre of the industry, but it has declined and in the memory of man the total number of artisans has dwindled from 20,000 to 2,000. Rasikganj on the Silai has now no brass industry worth the name. The migration of this cottage industry is thus unquestionably related to the change in the waterways.

The sailing up of the Old Kansai has had its repercussions also. Ajure on its bank was once an important trading centre for rice when this river was navigable. But this has now declined.

CONCLUSION

Such then are some of the geographical implications of the recurrence of floods in parts of West Bengal. In these areas floods have become a significant factor in the landscape, and Geography, as a chorographical study, cannot ignore this. More than that, in order to understand fully the geography of these parts of West Bengal, one must know more about these floods, their history and distribution, the factors which are their contributory causes and their general effects on the regional economy. The present paper is an attempt, in a preliminary way, to deal only with this last aspect.

TEA INDUSTRY IN CEYLON *

Miss NALLAMMA SUBRAMANYAM, M.A., B.Sc. (HONS.)

Tea is the most important non-alcoholic beverage widely consumed in the world. Nearly two-thirds of the world's population drink tea as a beverage. United Kingdom ranks first¹ among the consuming countries of the world with an annual per capita consumption of 10 lbs. More than 500 million pounds of tea are consumed in that country. Australia, Irish Free State and New Zealand come second, third and fourth with a per capita consumption of more than 7 lbs. U.S.A. and U.S.S.R. are becoming increasingly important tea consuming countries.

Tea is obtained from the leaf of a plant called '*Thea Sinensis*'. The use of the infusion of the dried tea leaf as a beverage has its origin in antiquity and according to the existing records, dates back to 350 A.D. when tea was first obtained from bushes grown wild in China. From China it spread to other parts of the world and to-day it has become a universal beverage. Tea has been hailed as the 'Machine age tranquilizer' in the West. The popularity of tea as a beverage is due to the chief stimulant, 'tannin', it contains. It not only facilitates all kinds of physical work but also produces a condition of wakefulness and increased mental activity.

History of the Industry: Though tea was cultivated in China and Japan as early as 350 A.D. the introduction of it into India, Ceylon and Netherlands East Indies awaited European initiative and capital.² The first attempt to grow China tea in Ceylon by the Dutch in 1782, proved a failure. For a period of 50 years from 1816-1869 coffee formed the chief industry in Ceylon and the height of Ceylon's prosperity resulting from this industry was reached in 1867. Ten years later when the coffee blight struck Ceylon, tea was introduced in an experimental way but the financial outlook for the new industry was not satisfactory. The few coffee trees that escaped the attack showed little chance of raising money to promote tea cultivation. Lukers writing about this period says 'To these men who faced seemingly insurmountable obstacles at the blackest period of Ceylon's history, the tea trade of the world is indebted for the raising of a magnificent industry from the ashes of the coffee estates, an industry conceived in penury and nurtured in economy, yet producing to-day the finest quality teas that reach the world's markets.'³ In 1839, the first tea seeds from the newly discovered Assam indigenous plants were received from Calcutta and grown in Peradeniya Botanical Gardens. In 1840, 205 plants were planted near Queens Cottage. When these proved successful there was a rush to plant tea. In 1938, the area under tea in Ceylon reached, 552,103 acres when the production of tea in the world well exceeded the demand. Since then there has been no expansion of tea cultivation into new areas. International agreement made in 1933 placed a restriction and the area of tea in Ceylon has become standardised at around 550,000 acres.

Important tea producing areas of the world lie in the tropical and sub-tropical regions chiefly in Southeastern Asia. China leads the world in tea

* Adapted from a Dissertation submitted by the author in part fulfilment of the B.Sc. (Hons.) degree of the Madras University.

¹ No accurate figures are available for China, but the consumption is very high; even perhaps higher than that of U.K.

² All about Tea by Ukers, Vol. I.

³ Agricultural Journal of the Royal Botanical Gardens.

¹⁰ Toynbee, G. A Sketch of the Administration of the Hooghly District, (Calcutta, 1888), p. 92.

production followed by India, Ceylon, Netherlands East Indies, Japan and Formosa. Tea is cultivated for local consumption in Georgia in U.S.S.R., Brazil, Iran, Malaya, Belgian Congo, Mauritius, Tanganyika, Uganda and The Union of South Africa.

Ceylon is second only to India in its contribution to world market. Nearly $\frac{1}{2}$ million acres, 20 per cent of the total cultivated area of Ceylon is under tea and tea⁴ now practically controls the commercial economy of the island. More than 65 per cent of the value of exports from Ceylon is tea. Ceylon's tea is one of the finest that reach the world market to-day. Little more than a fourth of the total amount of tea in the world market comes from Ceylon alone. Among the tea producing countries of the world, Ceylon gets labour and capital from abroad. In spite of the high cost of maintaining the imported labour force, Ceylon is able to compete successfully with other tea producing countries which use cheap native labour, mainly because of the climatic and edaphic conditions that are ideally suitable for the growth of tea and the high efficiency of the organisation of the industry.

Tea Areas of Ceylon: A triangular area occupying the south-central portion of the island is under tea. Matale forms the apex of the triangle and the line joining Ratnapura and Baudulla forms the base line of the triangle. The line running from Matale via Peradeniya Gampola and Hatton forms the western limit of this area while the line from Matale via Gaulla, Teldeniya and Lungala forms the eastern limit. Outside this triangle there are small native holdings in the southern and Subaragamuwa Province (vide maps 1 & 2).

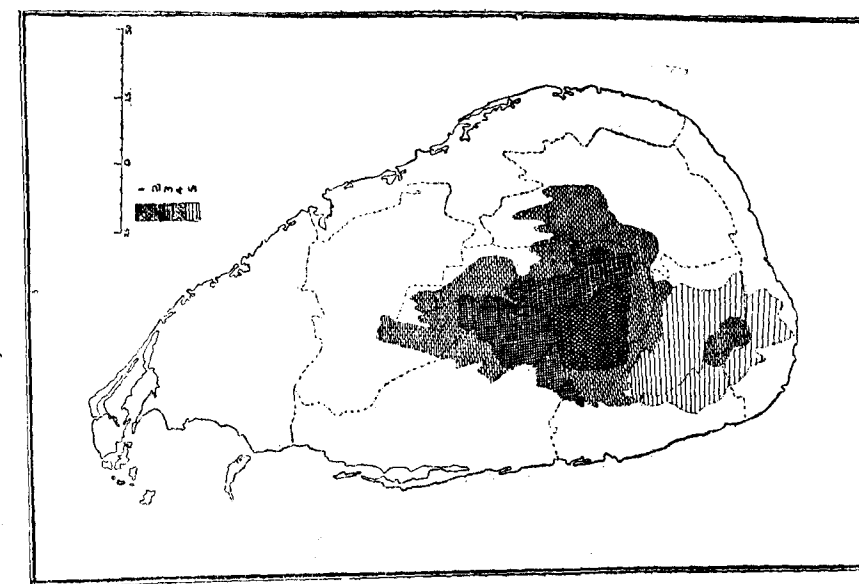
⁵ Tea is undoubtedly the most valuable crop in the hilly country. Estates are situated at elevations ranging from 2,000 feet to 7,000 feet. There are 2,308 plantations in Ceylon each with an average area of 200 acres and covering 487,801 acres in all. Four-fifths of the plantations are owned by the British. In addition, 61,824 acres produce tea for local consumption.

Province	Acreage under tea.	Percentage of the area to the total cultivated area.	Percentage of the area under tea.
Central	309,669	60	54
Uva	92,236	51	18
Subragamuwa	83,432	16.6	16
Southern	36,339	6.6	8
Western	11,531	2.1	3.7
North-western	623	.25	3

More than 50 per cent of the tea grown in Ceylon is grown in the Central Province. The principal tea estates are situated in the mountainous area, on the slopes of the Hatton, Hewahata plateaux and the central hill mass. Tea occupies more than 60 per cent of the total cultivated area in this province and almost all the teas grown at higher elevations are found in this province. Kotmale, Uda Bulatgama districts have the largest acreage with more than 90 per cent of the land under Tea. Udapalata comes next with 87 per cent of the land under tea. It is not uncommon to find a variety of crops along with tea in these hilly areas.

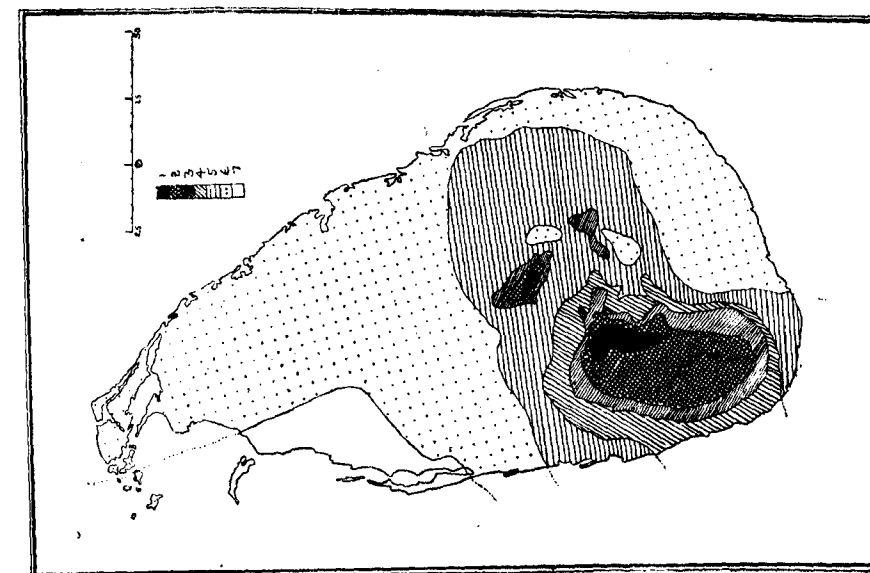
⁴ Year Book of Ceylon, 1949.

⁵ According to the Census of Agriculture, 1946, page 134, Statistical abstracts of Ceylon.



Map 2. Percentage of the area under Tea to the total cultivated area.

1. 80—100 ; 2. 60—80 ; 3. 40—60 ; 4. 20—40 ; 5. <20.



Map 1. Mean Annual Rainfall

1. > 200'' ; 2. 150—200'' ; 3. 125—150'' ; 4. 100—125'' ; 5. 75—100'' ; 6. 50—75'' ; 7. < 50''.

Uva and Subragamua provinces contain 35 per cent of the area under tea. Badulla is the important district where most of the medium grown teas are found. Estates are situated at elevations of 2,000—4,000 feet in the slopes of Wellimeda Plateau and the eastern hills of Namunakula Kanda. In the Subragamua Province tea is grown in the Kelani valley at an elevation of 2,000 feet. Most of the low grown teas of Ceylon are found in this area.

Southern, Western and North-western Provinces account for 12 per cent of the tea cultivated in Ceylon. They are recently opened under tea, and most of them are small native holdings. Estates are found on the slopes of small hillocks in this area. Most of the tea in this area is medium grown.

Tea is an institutional perennial crop and is grown in plantations. ⁶ Plantation agriculture may be defined as the cultivation of one or more types of crop plants in large compact communities in order to economise in the production and harvesting of the crops concerned. This type of agriculture involves the establishment of large areas under one main crop and the application of labour and capital to it in such a way that the production is rendered most profitable over the whole crop-period.

With a perennial crop like tea the period of lag between the application of capital to the crop and the sale of the finished product is often considerably longer than is the case with other crops, and one of the primary necessities is to prolong the life of the crop so that the capital expended on it is spread over an economic period of profitable returns. There are two basic requirements of all perennial crops without which their life cannot be economically prolonged. They are a good soil and a suitable climate. The conservation and maintenance of the former is even more important for the success of the crop.

Climatic and Edaphic Conditions: Tea is one of the hardest of all sub-tropical plants and can be grown in almost any climate so long as no severe drought or cold is felt. It is said that tea can be grown in the humid south of England and it grows in Ranchi in India where the temperature in the month of May reaches 115 F. and humidity falls at times to 17 per cent. The tea areas of the world lie within a wide range of latitude. The most northerly tea area is in Georgia situated in the Trans Caucasian Province of the U.S.S.R. The tea districts are near the Black Sea about 42 N. where the winter is long and severe and 10° of frost is sometimes registered and snow is common.

A vivid description of the climatic conditions under which tea can be successfully cultivated is given in the Tea Encyclopaedia.⁷

'To describe the best tea climate in two words we point confidently to Eastern Bengal. A hot moist climate where the thermometer in the shade never exceeds 95°F. never falls below 55°F. where the rainfall yearly aggregates 100"—130", where there is never any long drought, where rain falls at reasonable intervals all the year round, where heavy dews are frequent, where morning fogs are not uncommon, where the sun shines hot in an atmosphere perfectly free from dust, where at no season can a breath of hot wind be felt, where light penetrating rain is more common than furious down-pours, where the effect of the entire climate is essentially enervating to man and takes much out of him, these in our opinion are the conditions that make a good tea climate.'

⁶ Tea Quarterly of Ceylon, Vol. 20, Part I, 1949.

Yield in relation to bush growth by T. Eden, D.Sc., F.R.I.C.

⁷ Tea Encyclopaedia, Calcutta (1881), page 91.

⁸ Tea areas of Ceylon lie between 6° 12' and 7° 48' N. latitudes. The mean monthly temperature in these areas ranges from 60°—80°F. and there is no month in the year in which the temperature shoots up to more than 95°F. or falls down to less than 55°F. The lowest temperature recorded in this region is 56.13°F. in Newara Eliya, and the highest temperature is 76.8°F. in Badulla. There is very little variation in temperature from year to year. The following table shows the mean monthly temperature and mean monthly range for a few selected stations in the tea area:

Stations	Mean Annual Temperature in degrees F.	Range of temperature in degrees F.	Height above Sea level.
Nuwara Eliya	59.2	4.5	6000
Badulla	73.7	6.0	2225
Kandy	74.3	4.3	1600

This shows that the temperatures in the tea growing areas of Ceylon are ideally suited to the cultivation of tea. Temperature does not impose any limitations on the growth of tea. Altitude and rainfall factors are more important than the actual temperature.

Altitude: Tea is grown under varying altitudes. In North-East India it is grown in the Brahmaputra Valley in Lakshmipur District to an altitude of 340' and in Nuwara Eliya it is grown at an elevation of 7,000 feet. But elevation ranging from 2,000—7,000 feet are considered to be the optimum. The nature of the soil and the climate varies with altitude and consequently the quality of the tea also varies. It has been deduced that the flavours of Ceylon teas are influenced by the elevations at which they are grown. Tea from estates in low country are strong and have practically no flavour, while good flavour is produced by estates of medium elevation and very fine flavour is characteristic of tea grown in certain estates above 6,000 feet sea-level. Low country teas compensate for their lack of quality by their greatly increased yield. The following table brings out the acreage under low, medium and high grown teas in Ceylon.

	Feet	Acres
⁹ High grown-above	6000	121,000
Medium-grown	2000—4000	221,000
Low-grown	1000—2000	138,000
Unclassified		63,000

This table shows that high and medium teas constitute more than two thirds the total acreage under tea. With the introduction of rubber in Ceylon, a larger portion of the area under low-grown tea has been devoted to rubber. More than altitude, the nature of the hill slopes is important for the successful growth of tea. The slopes must have a good gradient and should be well drained, for stagnation of water in the subsoil is highly injurious to the roots of the tea plant. Steep slopes are avoided for they offer great difficulties in the construction of roads and drainage systems.

Rainfall: Tea is an ever-green plant and requires plenty of rain for its successful growth. Though 100—130 inches of rain is said to be ideal for

⁸ Dr. F. J. Martin, Agricultural Chemist, Climate, Crops and soils in British Tropical colonies.

⁹ Report of the Tea Control Department, 1949.

tea cultivation, it can be profitably grown in areas receiving more than 75 inches annually. But more important than the total amount of rainfall is the periodicity of rain. It has been mentioned already that the rain should fall in well distributed light penetrating showers; for this is very important to keep the subsoil moist. More than 30 days of continuous drought and occasional heavy down-pours kill the plant.

In Ceylon tea is grown under widely varying amount of rain from 75 to 130 inches. There is no month in which rain does not fall in this area. The areas under tea have less than 20 days of drought in any year. It has been said that generally the period of drought is 10 days or less and this is followed by light-penetrating showers. This kind of periodicity in rainfall is very good for heavy flushing of tea leaves.

Months	Hatton	Kandy	Nawalapitiya	Nuwara Eliya	Badulla
January	4.6	6.7	8.2	6.7	10.6
February	2.2	1.8	3.65	1.7	2.5
March	6.7	5.8	5.11	4.3	5.6
April	9.4	6.2	7.90	4.7	6.4
May	12.2	6.0	13.84	6.9	4.7
June	22.0	9.6	15.81	10.9	1.8
July	21.4	7.6	38.54	11.8	2.4
August	15.9	5.5	39.64	7.7	2.7
September	14.1	6.6	40.67	8.9	4.5
October	14.0	10.9	24.57	10.6	9.7
November	11.0	11.2	16.43	9.5	10.0
December	6.0	9.1	6.62	8.0	11.4

There is very little variation from year to year in the rain received. A study of the 60 years' rainfall records of the Colombo observatory shows that the rainfall in this area is highly reliable and for the past 33 years there has been no month in the year in which rain did not fall in this area.

Two groups of tea areas can be recognised according to the rainfall regimes. The year can be divided into two monsoonal, during which there are continuous winds from South-West and North-east and two inter-monsoonal periods of less regular winds, but considerable rainfall. The heaviest rain occurs during the South-West Monsoon on the wind-ward side of the hill country and is associated with the shielding effect on the lee side. The rainfall is heaviest in June, July, and Hatton and Nawalapitiya receive their heavy showers in these months.

In the Uva and North-Western and Eastern parts of the Central Province, rain is received from North-Eastern Monsoon, but the amount received is less than that received in the South-Western areas from the South-West Monsoon. Badulla in Uva Province receives its heaviest showers in November and December. The rainfall in this area has the same regime as that in North-East India and hence the cultivation practices mostly resemble those in North-East India. But the flushing period is not confined to 6 months as in the case of North-East India.

The former region mainly South-Western part of Ceylon has strikingly the same cultural practices as that of South India and the rainfall regime is also the same in these two areas.

March, April and May are the heaviest flushing months in both North-East and South-West monsoon areas. Many of the estates obtain 60 per cent of their crop during the first 6 months of the year. In June, July and August the South-West Monsoon brings lots of rain with poor flushing. After August the crop increases to a second maximum in November and December. January and February again are poor months in the South-Western Districts.

The effect of rainfall on the flavour of tea is well marked, the colder less tropical conditions in the hill country tending to check the acute rate of growth while promoting the fuller development of the essential flavouring constituents. During the months in which growth is more acute namely from March to May and again to a less extent in October and November, the quality of tea decreases even in the highest estates and return again when the growth is rapid. Dry winds are said to impart pungency and flavour to the leaves. Thus in June, July the teas grown in Uva Province have better flavour than those grown in the South-West Monsoon areas. In the North-East Monsoon areas the teas obtained in November and December are poor in quality while the tea obtained from South-West Monsoon areas are good.

Humidity and Cloudiness: Humidity is an important factor both in the cultivation and manufacture of tea. Humidity coupled with high temperature of about 85°F. make the bush flush heavily and increase the yield to a great extent. Uniform humidity is highly desirable in the manufacturing process. The mean cloudiness of tea growing areas is 0.6 to 0.65 and this retards the rapid evaporation of rain water and keeps the subsoil moist for a longer period than in South India or North-East India. Again this is the reason why shading the tea bush is not required to the extent as is required in South India where the climatic conditions are identically the same. Summarising the climatic conditions that enable tea cultivation a success, we may note the following facts:

- (1) a high and uniform temperature and humidity;
- (2) the former not falling below 55°F. or rising above 80°F.; and
- (3) a rainfall of 80—150 inches well distributed throughout the year and absence of drought for a period of more than 20 days.

Soils: We find that tea is grown in the world in widely different types of soils. In North-East India most of the tea soils are quaternary and recent alluviums, and the rest are mainly soils formed in situ from gneisses and tertiary sandstone.¹⁰ In South India and Ceylon much of the tea is on soils resulting from the weathering of archaean rocks. The soils of Java consist of the products of eruptive rocks, and most of the tea soils are derived from the weathering of volcanic ash, sand and lava of the tertiary period. This does not indicate that tea can be grown on any soils.

Among the plantation crops there is none which demands more precisely than does tea, a special soil if a paying yield is to be obtained. The tea plant requires a depth of at least 5 feet of well drained, easily penetrable soil, though not so well drained that the surface dries out. It is important that the roots should be able to distribute themselves freely through the first 4 to 5 feet of soil and the presence within this depth of hard pan or other impenetrable layer of equally dry sand in which roots cannot grow, results

¹⁰ C. R. Harler—Tea in Ceylon—India Tea Association Quarterly Journal, Part 4, 1982.

in a very short life to the crop.¹¹ The peaty 'bheel' soils of North-East India on which huge yields of tea are obtained after draining, deteriorate rapidly as the peat is oxidised and the roots cannot penetrate into the clay subsoil. Tea is a calcifuge and will only thrive in acid soils such as normally develop in humid tropical climates.

The presence in the natural vegetation of various species of 'albizzia' a leguminous tree, frequently indicates the suitability of land. The tea plant makes great demands on the soil and for this reason, virgin wooded or grass land soils rich in organic matter are most frequently selected by the tea planters. A chemically poor soil may, however, produce better quality tea than a rich one in a stimulating climate. The first chemical requirement is nitrogen and organic matter and given sufficient nitrogen, a good supply of phosphate tends to raise the quality. Potash, either in the soil, or applied as fertilizer, has little effect on quality and lime is injurious if present in sufficient amount to affect the soil reaction adversely.

M. K. Bamber¹² who has done extensive survey of the tea soil of India and Ceylon says that the soils in almost the whole area in which tea has been planted in Ceylon consists of decomposing crystalline schists and gneisses, belonging to Paleozoic and Pre-cambrian system which have disintegrated *in situ*, and in conjunction with the decaying animal and vegetable matter form a soil well suited to the growth of tea plant. Analysis of Ceylon tea soils shows that they are generally deficient in lime and phosphoric acid when compared to those found in more temperate climates. The deficiency of lime is accounted for by the comparatively high temperature and rainfall that prevail in the planting districts which owing to the solubility of water, leach it rapidly out of the soil. The shortage of phosphoric acid is due to the fact that the rocks from which the soils of Ceylon are largely derived are naturally poor in that constituent. The content of nitrogen and potash vary considerably, the former depending on the presence of felspar or mica, and the latter on organic matter. The characteristic feature of Ceylon tea soils is the very great deficiency of organic matter in the subsoil. Owing to the tremendous amount of soil erosion wash on the hill slopes, the soil now remaining on many estates is not representative of the true type on which tea was originally planted.¹³ Eden points out that in Ceylon most of the tea soils can resist erosion much more effectively than the soils in Java or South India. But to-day soil erosion is a serious problem in the estates in Ceylon. Many acres of tea land have been abandoned and planted under paddy with terracing because of the soil erosion. On a visit to the Kandy District where some of the old tea estates are situated it was found that the soil cover has been washed out completely in many estates and the tea roots are clearly exposed. In most slopes the tea plants are hanging on to the bare rock. Extensive investigation has been done by the scientists in the Tea Research Institute of Ceylon and various methods have been devised to control soil erosion.

Methods of Cultivation and Cultural Practices: The cultivation methods and cultural practices that are found in Ceylon resemble those found in South India. In both these countries, the hilly terrain and the climate necessitate adopting methods that are quite different from those in North-East India or the Netherlands East Indies.

¹¹ Imperial Bureau of Soil Science Technical Communication, No. 34.

¹² M. K. Bamber, Report on Tea Soils and their effects on the quality of Tea, 1900. Address read in the proceedings of the Planters Association.

¹³ The Manuring of Tea Emp. J. Exp. Agri. 1, 1933, pp. 237-308.

As has been mentioned already, a variety of crops are grown along with tea in the hill country of Ceylon. It is not very uncommon to find rubber in the lower elevations of the slopes of the hills, tea in the high elevations, paddy in the narrow valleys of the streams. Plantations of kitul palm from which a kind of sugar fibre is taken, jack fruit and breadfruit are found near the paddy fields. Cinchona, cardamom, tobacco, and cocoa are other crops which compete with tea for land. All these crops are cultivated in the hilly country and it is very interesting to note how every inch of the fertile soil in this area is under crop all the year round. Like the Japanese farmer the Sinhalese farmer also takes great pains to cultivate every bit of the land that can be cultivated.

Clearing land for tea: If a forested hilly area is to be brought under tea the first step is to burn off the forest thoroughly, so that it reduces the amount of clearing to be done and also the quality of seeds that would lie dormant under the jungle merely awaiting the necessary light and air to germinate. The next step is to reserve sites for coolie lines and other estate buildings including the factories and nurseries for plants.

Propagation tea seed, etc.: All the tea grown in Ceylon is raised from seeds. Formerly seeds were imported from Assam but this was stopped after the attack of blister blight in Assam. Seeds are sown in nurseries a year and a half or two years in advance in order to provide a supply of tea plants or stumps when required. A well sheltered hollow, where there is good soil and an unfailing supply of water, is a good site for the location of nurseries. Before germination the seeds are tested and spread closely over the sand and provided with shades to protect them from the sun and they are watered daily.

Seeds of light and dark leaved Assam indigenous, China and China hybrid varieties are commonly grown in Ceylon. The medium hybrid variety is the best from the stand-point of price and quality. The most popular seed now is dark hybrid Manipuri. Besides these, a number of hybridised varieties evolved by the Tea Research Institute are also used. The germinated seeds are planted in nurseries and protected by shades. In about 18 months the shrubs are ready for planting. The young plants are cut to a height of 4 to 8 inches, the soil is loosened and the plant is pulled up. A few estates had been planted with cuttings from tea prunings on older gardens, but now this practice is not in vogue.

After the preparation of nurseries attention should be devoted to laying out roads and drains. Soil erosion can effectively be prevented if roads and drains are planned carefully. The excellence and number of roads in the planting districts of Ceylon has always been a subject for remarks by visitors to this island. The roads should provide inter-communication between estates and factories. All roads slope their surfaces towards the drains so that in a way that protection is afforded for the roads against wash outs. Drains are laid out as soon as the roads are built and the former are planned in such a way that protection is afforded for the roads against wash outs. Drains are started from the top of each hill, and carry off the surplus water into the leading drains, care being taken to see that the roads are protected from any possible overflow. Natural ravines can be used to the best advantage as drains, and where the drains are far apart, it is necessary to cut artificial leaders.

Planting: The planting season varies from district to district. June, July and August are the months for planting in the South-West Monsoon area and October, November and December in the North-East Monsoon area. The

most common planting distance for tea in Ceylon is $3' \times 3\frac{1}{2}'$, considerably closer than in Assam. The tea plants are set out in parallel rows running horizontally across the hill sides as in Java.

¹⁴ *Shades, wind belts and soil covers:* A well distributed and light shade is necessary to protect the plant from the tropical sun. Leguminous plants are given preference as they not only shade plants but provide the necessary wind break. A wind break is formed by planting several rows at right angles to the direction of the wind. A number of varieties of plants are used, e.g., *Grevilla Robusta*, *Altrizzia Moluccana*, *Altrizzia stupulata*, etc. Every 7 to 8 years these trees have to be removed to prevent the growth of root disease in tea.

Selective weeding has been much in vogue in recent years. In this method, one sort of weed is allowed to grow while all the others are removed, with the result the ground between the tea rows is soon carpeted with this cover, protecting it against wash. The main disadvantage in this method is that these weeds may absorb much moisture needed by a tea plant during a dry period. The plants often used are *Oxalis Corni* and Shamrock.

Manuring: As tea replaced coffee in Ceylon, for a considerable period, tea was grown in these areas without the application of manure. In a newly opened estate tea can be grown for a few years without the application of manure. The practices of manuring vary from district to district, according to the nature of the soil and the time of application. Considerable amount of experimental work has been done by the Tea Research Institute on this subject and various kinds of mixtures have been advocated. Application of some of these manures in the field met with wonderful success. In 1946, when the blister blight attacked the Ceylon tea plantations it was feared that the amount of tea exported would decrease in quality and quantity to a great extent. But the careful application of manures enabled Ceylon to keep up the amount of tea exported in a comparatively high level. As has been mentioned before, Ceylon soils are rich in iron and other constituents and they have to be supplemented by natural or artificial fertilisers rich in lime, potash, phosphorous and Nitrogen.

Organic manures such as blood meal, groundnut-cake and fish-offals are widely used as manures. ¹⁵ Potash promotes wood growth and phosphoric acid promotes quality. Therefore these two together with sulphate of ammonia are widely used. The time of application is as important as the constituents of the manure itself. Immediately after pruning a manurial application is given in order to give the bush a fillip on the road to recovery and thereafter annual application of manure is usual. The pruning mixture as it is called contains the various nutrients in the following proportion:

Nitrogen 3/7; Phosphoric Acid 2/7; Potash 2/7.

Green manuring is not practiced in Ceylon on the scale usual to North-East India. Cowpeas and sun-hemp which can be grown and hoed in 6 weeks are not used on most estates owing to their steepness. Instead some of the leguminous shade trees and wind breaks are cut off periodically and their toppings are buried. *Dadap*, *Erythrina Lithos Perma*, *Gliricidia Maculata*, the Ceylon san, *Albizzia Moluccana* are some of the trees used for this purpose.

¹⁴ Petch Cover Plants. The Tropical Agriculturist, Vol. 23, Paradeniya, 1924, page 76-78.

¹⁵ Chemistry and Agriculture of Tea by Dr. Mann, Journal of Indian Assn.

¹⁶ *Tea Diseases and Pests:* Most of the tea diseases and pests common in North-East India are also to be found in the Ceylon estates. Leaf diseases common to Ceylon's tea estates are grey brown and copper brown blights whose names are due to the characteristics of discolourations they cause to the leaf. 'Witches Broom' called so because it forms tufts and a disease as yet unnamed in which branching occurs abnormally are also common. The stem diseases found in Ceylon are mainly 'red rust' and 'black rot'. Stem diseases include various forms of 'branch canker', 'stump rot' and 'die back'. A disease known as 'thorny stem blight' and found only in Ceylon has the strange characteristics of producing black thorns on the plants. Root diseases are not very serious in Ceylon.

In lowland and mid-country districts insect pests do their share of damage. The tea 'tortix', 'shot hols borer' and 'nettle grub' are the ones that cause the greatest damage. The red spider is the pest in the higher areas and it is worse during dry periods. The Kalutra Snail is common in the low country, white ants are plentiful in the Central Province and the tea bushes attacked by them are dug out or treated with solignum. The 'tea mosquito' is sometimes met with in the low country. The Tea Research Institute has done extensive study of these diseases and has devised various methods of combating them.

The sudden appearance of Blister Blight disease of tea in October, 1946 caused widespread alarm; for the memories of the fate which overtook the coffee industry were still fresh. In contradiction to the coffee leaf disease, the 'Blister Blight' does not attack mature leaf. The fungus attacks young leaves and shoots and is therefore of particular importance in relating to tea recovering from pruning. Attacks are almost severe in the wet periods of the year and in areas where mist is prevalent. The fungus is unable to stand hot weather and attacks are therefore at a minimum in the dry season. High temperatures are inimical to the fungus and disease has in consequence been of minor importance only in low country at an elevation below 2,000 feet. Review of the effects of Blister Blight shows that it is undoubtedly the most serious disease which has ever threatened the tea industry in Ceylon. But Ceylon was fortunate in that the disease did not appear until late in the year when climatic conditions prevailing in the dry season could take effect and check attacks.

For mid-country zone the intensity of attacks varies very greatly according to the situation of the fields, but there is a general feeling that crop losses in these areas have now become serious amounting to between 5—10 per cent. For the up country zones, the losses appear to be even greater, estimated between 5—20 per cent according to the situation of the fields. Nearly a loss of 5 per cent of the total tea production was incurred due to this blight.

Pruning: Pruning is regarded as the most important operation in the tea calendar. For a period of 5 years after planting tea bushes are pruned periodically. In most tea districts in Ceylon, where rainfall is continuous, this operation is done all the year round. In the south-western part of the island, two periods are considered to be more suitable for this operation; they are from February to March and June to Mid-September. In the dry districts of the Uva Province, pruning is done mostly from June to September. This operation should be done with the greatest care, not to cause wounds in the plants.

¹⁶ Tea Production in Ceylon, Monograph, No. 2, 1950.

Plucking: Plucking requires a large labour force, as no machines have been invented to do this so far. Gathering of the leaves requires practice and careful supervision. Plucking is done every 7 to 14 days throughout the year according to the elevation. Usually women and older children are employed for plucking.

Tipping is the term given to the first and several subsequent plucks after pruning, and are done by a gang of expert pluckers under the supervision of the well trained Kangany. ¹⁷ The tipping period ranges from a few months in the low country to a year at high elevations. The plucking is graded into three groups (1) fine pluck, (2) medium pluck and (3) coarse pluck.

The leaves are gathered in cane or bamboo baskets. The baskets are filled loosely to prevent bruising of leaf and after weighing, they are taken to the factories by pluckers if they are in the field. If the factories are far away they are sent by lorries or by rail.

Yield: Yield varies with climate, soil and varieties. Mention has already been made that teas grown in low elevations give a better yield than in high elevations. ¹⁸ A dry spell of not more than 10 days followed by light penetrating showers increases the yield. High yields are got when organic matter and nitrogen are present in sufficient quantity in the reactive part of the soil. Addition of nitrogen not only stimulates the growth of the plant but also increases the flushing of leaves. The yield of tea in Ceylon compares favourably with those in other countries. The following table shows the average yield per acre in the important tea producing countries of the world:

¹⁹ Ceylon	..	600—650
India	..	600—625
China	..	400—425
Japan	..	500—550
Pakistan	..	400—450
Indonesia	..	400—425

The yield of tea in Ceylon is one of the highest in the world. The high yield is mainly due to the admirable cultural practices and efficient organisation of the industry. Though the average yield is 600—650, actual yields vary from 300 to 1,200 pounds. The yield in the same estate varies from year to year, for example in one of the high grown estates the following yields are reported:

In the first year after pruning	..	500 lbs.
2nd -do-	..	900 lbs.
3rd -do-	..	950 lbs.
4th -do-	..	850 lbs.

The yields are generally higher in the low countries in recent years, for infection is rather less in these areas, especially in the Uva District. During the past 5 years the export has been kept up in the same level in spite of the attack of Blister Blight. This is because of the increased manuring on low country estates following the greater availability of fertilisers after the war, the high yields from those estates that escaped the Blister Blight and a higher

¹⁷ Elliot E. C. and Whitehead F. J. Tea Planting in Ceylon, page 126-128

¹⁸ Tea Quarterly of Ceylon, Vol. 20, Part I, 1949.

¹⁹ All about Tea, Ukers, Vol. II, page 126-128.

intensity of plucking on estates that have recently changed hands. Increase in yield is great in Uva Province where weather conditions have been conducive to good flushes and where application of manure has also been increased. It is said that the yield of small holdings has also increased to a great extent.

Manufacturing Process: Efficient manufacturing process is as important as efficient cultivation for the production of good quality tea. The plucked leaves sent to the factory are spread on lofts and heated air at a temperature of about 95°F. is circulated for about 18 to 24 hours to wither the leaves. Humidity is more important than the actual temperature of the air, the optimum being 60 per cent. Natural wither produces a better effect than artificial wither and from this point of view location of factories plays an important part in withering. Many of the earlier Ceylon factories are converted coffee factories and are located in more or less shut in-valleys to get water power. In modern factories, electricity is used for power and their situations at higher elevations ensures good natural wither.

The withered leaves are passed through the rolling machines 5 to 8 times and rolled. This process twists and breaks the leaf cells releasing the properties that give colour, flavour and strength to the tea in the cup. The rolled leaves are allowed to ferment by spreading them in shade for about 2½ to 4 hours. Where flavour and pungency are sought, light ferment is given and where strength and body are sought, fermentation is allowed to continue for a longer period. The fermented leaves are dried to stop further fermentation by passing through drying machines where hot air is circulated at a temperature of 170°F. The dried leaves are sifted by machines and sorted into grades.

Broken Orange	50 per cent
Broken Pekoe	20 per cent
Orange Pekoe	20 per cent

Pekoe Souchong, Dust and fannings .. 10 per cent

The sorted teas are packed in tea chests lined with sheet lead or aluminium lines, each containing 90—130 lbs and are despatched to the nearest railway station. In most of the estate, factories are situated near the railway station.

Labour: A large labour force is essential for the successful cultivation and manufacture of tea. There are a number of operations in tea culture that have to be done by hand. No machines have been invented to do these, especially plucking. One plucker can pluck 30 lbs, of fresh leaf, equivalent to about 8 lbs. of finished tea per day. This indicates the amount of cheap labour required in the estates. It is said that an estate requires an average of about 1.5 labourers per acre. The labour on most of the Ceylon tea estates is provided by Tamils from South India.²⁰ There are about 385,000 Indian labourers and 70,000 Ceylonese labourers on these estates.

Conditions of estate life and the wages earned offer considerable inducement to South Indian peasants to leave their village, where in most cases they are dependent on a normal season for their crops, which are often their sole means of existence. The South Indian labour force consists of skilled and semi-skilled and field labourers. The first includes tea-makers, clerks and factory workers, the second, kanganies and sub-kanganies and the third

²⁰ Postwar Development Proposals, 1946, Government Record Office, Colombo.

pluckers. The time of work and wages earned are controlled by the International Labour Organisation. The dexterity of female fingers for plucking is superior to that of the male, and therefore, there is a preponderance of female element in the labour of the estates.

The cost of housing of the labour, building hospitals, schools and creches for infants is very great. The cost of labour forms 60 per cent of the cost of tea production. The labour cost is sub-divided as follows :

²¹ Labour for cultivation	..	25 per cent
Plucking	..	10 per cent
Native supervision	..	15 per cent
European supervision	..	10 per cent
Distribution, packing, freight and profit	..	40 per cent

During the second world war, the cost of maintaining the labour force increased to a tremendous extent, for Ceylon had to import food from abroad for the labourers. This is one of the major handicaps of the industry.

Production and Trade : The economy of Ceylon is dominated by its plantations. Their prosperity, however, reflects the conditions that prevail in the other parts of the world where there is competitive production or where these markets are located. Tea is the leading plantation crop and it contributes more than 65 per cent of the total value of the export.

Tea forms 1.2 per cent by value of the total merchandise entering world trade. Out of the total world production of 1,100 million pounds of tea, more than 900 million pounds enters the world market. Ceylon contributes 25 per cent of the total world export, nearly 290 million pounds a year. The export has increased to 296.7 million pounds in recent years. As an exporter, Ceylon is second only to India which exports 38 per cent of the total amount of tea that reaches the world market. But Ceylon teas are the finest and fetch the highest price in the world market. The average wholesale price of Ceylon tea in the London market is 20.8 pence per pound and Darjeeling tea from India is 19 pence per pound.

Out of the 316 million pounds of tea produced in Ceylon, 18 million pounds are consumed locally. The local consumption of tea has increased by 80 per cent from 10 million pounds in 1942 to 18 million pounds in 1946. The Commonwealth countries buy more than 63 per cent of the exports of tea :

²² United Kingdom	..	47 per cent
United States of America	..	10 per cent
Canada	..	5.4 per cent
Egypt	..	8.9 per cent
South Africa	..	6.1 per cent
Australia	..	12.2 per cent
New Zealand	..	3.6 per cent
Iraq	..	2.9 per cent
Holland	..	2.6 per cent
Argentina	..	1.3 per cent

During the second world war all the exportable surplus was bought by Britain for distribution to other consuming countries. From 1947, the

²¹ Annual Report of the Tea Planters Association of Ceylon, 1948.

²² Tea Marketing Report of Ceylon.

contract prices of tea for each estate are fixed and tea is exported directly to the consuming countries under the supervision of representatives from these countries. Though tea is cultivated in South Eastern Asian countries, the world market for it is London. This is because more than 50 per cent of the export of the world is consumed in the United Kingdom and more than 20 per cent is consumed in the British Commonwealth countries. Over 70 per cent of the tea exported is produced in countries which were formerly parts of the British Empire.

Mention has been already made of the three slumps suffered by this industry. During the early part of this century, after the tea industry had become stabilised, it was quite prosperous, the increasing demands were not over-run by increasing production. During the first world war, war time controls were exercised by the British Government. When they were lifted there was a boom that quickly led to over-production. Therefore, in 1920 and 1921, a voluntary restriction plan was put into effect by the British. This coupled with a falling off of production due to adverse natural conditions brought about a drop in the stocks of tea held in London, so that the crisis was weathered. During the middle of the 1920, good profits were being made and planters and traders were very optimistic about the future of tea. The world wide depression of 1929-32 led to further valorization schemes. In 1933, the International Tea Agreement including India, Dutch Indies and Ceylon was made. These areas controlled 80 per cent of the world exports of tea. According to this agreement the export of tea from Ceylon is standardised at 270 million pounds. But this restriction was removed in 1947. Now there is a free trade in tea.

Future of the Industry : Any attempt to gauge the future of the Ceylon industry should take into account its present status in the world. The production of tea exceeded the demand of the world a few years ago, and to-day every tea producing country is making attempts to intensify the cultivation and to improve the quality. The International Agreement made in 1933 included the major tea producing countries of the world namely, India, Ceylon and Netherlands East Indies. Acreage under tea has been increasing during the restriction period in countries that were outside the agreement. In East Africa the production had increased from 8 millions to 13.6 millions and in Iran from 2 millions to 12 millions. The tea production in the Caucasus in the U.S.S.R. is also increasing steadily. Ceylon tea will have to face with a greater number of competitors in the world market than it has done hitherto. But the world demand is also increasing steadily especially after the second world war. But fear of another tea slump has been expressed by many an agricultural economist of the island. The Colombo six year plan aims at self-sufficiency in essential food commodities. Plantation products form 93 per cent of the value of export from the island. ²³ It is highly undesirable that Ceylon has to depend so heavily upon her plantations, the prices of products of which are subjected to violent fluctuations. Changes in the world conditions affect all plantation industries simultaneously. This fact was increasingly realised in 1929-30, when the prices of all plantation products fell heavily. Therefore, it is imperative that Ceylon should diversify its cultivation. Cocoa, Cardamom, Cinchona and other plantation crops can also be introduced in areas favourable for their cultivation. There is an attempt to cultivate a variety of paddy called 'elir' which is a favourite of the aristocrats in Colombo in the abandoned tea estates of Ceylon. But tea is undoubtedly a more profitable crop than any other plantation crop and Ceylon has to continue the cultivation of it. ²⁴ The

²³ The Economy of Ceylon by Ivor Jennings, page 120.

²⁴ A Short Economic Survey of Ceylon by Prof. B. B. Das Gupta, page 18-20.

area under paddy in the low lands of Ceylon can produce enough to support the 6 millions and self-sufficiency in essential food commodities is not apparently a distant goal. But the fear of a tea slump is unfounded for many reasons, some of which are furnished below.

The Ceylon tea industry has a bright future. It has been mentioned that Ceylon produces one of the finest teas in the world. Though the acreage under tea in the new lands has been increasing steadily it will be long before they are able to produce tea of a very high quality to compete with Ceylon tea. The latter by its inherent quality and character, may command a premium in the world market for years to come. Importance of the Ceylon tea in the world market is great, for it is used to blend teas from every producing country.

Secondly, Ceylon can be sure of a market in the United Kingdom for the latter has been the most important customer for Ceylon tea all these years and the British choose the Ceylon tea for its taste. An agreement was made 5 years ago that a certain percentage of the tea produced in the island would be brought by Britain every year. Moreover, the trade relationships between the United Kingdom and Ceylon are very cordial, more than between the United Kingdom and any other tea producing country.

The production of the new countries is very small about 13.6 millions pounds in East Africa, 12 millions in Iran. Production in the Netherlands East Indies is steadily going down. U.S.S.R. cannot expand her industry because there is a hard pan within five feet of the surface in the Caucasian region. The only strong competitor is India. The Assam industry which suffered from the effects of the earthquake will take a long time to restore its high yields. The production in South India is only about 80 million pounds and the quality is not as good. Therefore, the immediate future of the Ceylon tea industry seems to be very bright.

Thirdly, the port of Colombo is popularly known as the Clapham junction of the East. Its situation in the middle of the Indian Ocean enables it to command the sea routes to the Far East and Australia. Ships plying between these countries and the United Kingdom can transport tea at a very low freight charge and this is a notable advantage which Ceylon has. Again 65 per cent of the Ceylon tea is consumed by countries under the British Commonwealth and Ceylon is becoming more and more a centre of these countries. Formerly, Ceylon tea was exported to London from where it was re-shipped to the other consuming countries. But to-day, tea is directly shipped from Colombo to the consuming countries though it is still under the control of the organisation in London.

Fourthly, Ceylon's position near the world's greatest source of cheap labour has proved a favourable factor throughout the growth of the industry. To-day its nearness to the world's greatest potential market namely South-East Asian countries is another advantageous factor. When the standard of life in these countries increases, they will prove a very great market for tea. This is further confirmed by the fact, that tea consumption in these countries is steadily increasing.

All these considerations show that Ceylon's tea industry has a great future. Improved methods have already been adopted to combat diseases, soil erosion and to evolve new varieties. The chief problem of the industry to-day is the high cost of labour. This can be minimised to an extent in the following way.

The old tea estates where the effect of soil erosion has been great and where the yields are low can be abandoned and the cultivation intensified in the better lands. Mention has already been made about the relationship between climate and cultural practices, the months of planting, plucking and pruning in the South-West Monsoon areas are different from those in the North-East Monsoon areas. The distance between these areas is less than 125 miles and there are good systems of railways and roads. To meet local requirements, there can be an organised migration of labour from one area to the other. The success of this method depends to a great extent on the labourers themselves. In most cases, the labourers do not work for more than 15 days in a month. It is very difficult to make the labourers work regularly. The reason for this is, it is understood, that most of them are fond of idling.

General Survey : A general survey of the tea industry in Ceylon brings out some interesting features. Ceylon's tea industry is an example showing that geographical factors alone do not control the industry at all stages. They vary at different stages. At a certain stage they cease to influence the industry, and economical and political factors become important.

It has been noted that in the early stage of the industry in Ceylon, apart from the European initiative and capital, geographical factors such as climate and soil had been the main considerations in determining the growth of the industry. Later, world conditions, chiefly the set back, suffered by the Chinese industry led to the rapid opening of land under tea. In the early 20s of this century when the world production exceeded the demand, tea slumps were frequent and Ceylon had to restrict the area under tea. At this stage geographical factors such as climate and soil ceased to influence the industry and economical and political factors were more important. To-day the increasing demand for tea has lifted the restriction but Ceylon does not want to increase the acreage under tea for it has realised the danger of depending heavily on plantation products. But the present and the future of the industry is influenced by geographical factors, not factors of soil and climate, but distances and locations. Ceylon's position at the junction of sea routes and the fact that it is becoming more and more an important centre of the Commonwealth of Nations, and its nearness to the potential markets of the world holds out a bright future for the industry. The only geographical factor that has been always influencing the industry is its nearness to the world's greatest source of cheap labour namely, India, the great neighbour of Ceylon.

IRRIGATION IN THE MAHANADI DELTA

BICHITRANANDA SINHA, M.A. (Cal.)

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In a country like India, where more than 70 per cent of the teeming millions are intimately connected with agriculture, and where agriculture is a gamble with the monsoons, irrigation is a necessity for productive agriculture. The uncertainty of the bursting of the monsoon, its maldistribution, and, often, great variation in the total amount of annual precipitation have forced the people and the Government, to provide artificial irrigation to prevent frequent crop failures.

The Mahanadi Delta receives a total annual (average) rainfall of 60". It is not the total, as its uneven distribution that limits successful agriculture in the delta. More than 78 per cent of the total annual rainfall is confined to only four months of the year with little or no rain in the winter months.

Rainfall Distribution in Inches.

No. of Stations	Winter Dec.-Feb.	Summer Mar.-May	Monsoon June-Sept.	Autumn Oct.-Nov.	Total
12	1.80	6.30	43.98	8.37	60.45

Even during the effective rainy season, which itself is short, rainfall is so erratic that sometimes the standing crops do not get water at a time when they require it most, and the harvest falls far short of expectation, disappointing the rural community. Thus, to be free from the vagaries of rainfall, canal irrigation scheme was first undertaken in the area under discussion, during the years 1863-74 by a private company* under the guidance of Sir Arthur Cotton, and canal water was first supplied in 1869. But with the increase in population and the decrease in land productivity, the need for developing and stabilising irrigational facilities became even much greater, and now it can be said that irrigation holds the key to agricultural prosperity in the delta.

Irrigation Types and Practices :

(a) Major Irrigation.

- (i) Canal irrigation ;
- (ii) Inundation canal irrigation.

(b) Minor Irrigation :

- (i) Tank irrigation ;
- (ii) Well irrigation ;
- (iii) Irrigation by other native methods.

* Sir Arthur Cotton visited Orissa in 1858 to give some advice regarding the flood control in Orissa and just after two years, in the year 1860, the work of canal construction was started by the East India Irrigation and Canal Company.

(a) Major Irrigation :

(i) *Canal Irrigation* : The canals are all contour canals and are fed by the Mahanadi, and the entire system is called "The Mahanadi Division". To supply water to the canals of this system, three anicuts have been constructed. The anicut at Naraj (3,833 ft. long), at the head of the Kathajuri serves as a feeder anicut by diverting the water to the Mahanadi. The anicut at Jobra (6,349 ft. long) and on Birupa (1,980 ft. long) help in making an artificial lake at the head of the confluence of the Mahanadi.

The canals may be grouped into three sub-divisions :

(a) Canals of the Devi-Mahanadi sector :

- (i) Machagan Canal ;
- (ii) Taldanda Canal.

(b) Canals of the Mahanadi-Birupa sector :

- (i) Kendrapara Canal ;
- (ii) Kendrapara Extension Canal ;
- (iii) Pattamundai Canal ;
- (iv) Gobari Canal ;
- (v) Gobari Extension Canal.

(c) Canals outside the delta limit :

- (i) High-level Canal Range I ;
- (ii) High-level Canal Range II ;
- (iii) High-level Canal Range III.

For administrative purposes the area under the command of the existing canals is divided into four sub-divisions.

Sub-division	Long Lease	Season Lease	Area under command
Jagatsingh Pur ..	88,199	504	200,632
Kendrapara ..	43,749	2,495	95,475
Kendu Patna ..	58,343	1,793	73,637
Jobra ..	24,893	90	44,637
Total ..	215,184	4,882	414,381

The total irrigation area increased from 193,000 acres in 1946-47 to 197,500 acres in 1950-51. Of all the individual canals, the Kendrapara canal irrigates the largest acreage whereas the smallest acreage is irrigated by the Gobari canal.

Canal	Length of the canals in miles	Length of the distributories in miles	Area under gross command in acres	Area irrigated in acres
1. Kendrapara (navigable) ...	39	370	116,099	67,000
2. Kendrapara Extension (navigable) ...	16	—		—
3. Gobari (navigable) ...	15.5	25	13,534	6,000
4. Gobari Extension (navigable) ...	6	17		3,000
5. Taladanda (navigable) ...	52	110	65,179	24,000
6. Patamundai (navigable) ..	47	116	57,997	25,000
7. Machha Goan (not navigable) ...	39	241	127,696	43,000

(ii) *Inundation Canals*: These canals are locally known as 'Kaja' and were designed mainly for two purposes, namely,

(i) the purpose of functioning as 'escapes' for extra flood water and thus to protect the embankments from breaches; and

(ii) to supply water to the paddy fields with deficit water supply.

(b) *Minor Irrigation*:

In the non-canalised areas of the Mahanadi Delta, the minor irrigation is of greater importance. In the year 1950-51 the total acreage irrigated by the minor irrigation works was 4,746 acres which resulted in an extra yield of 40,267 maunds and in the year 1951-52 the total area irrigated by the minor irrigation shot up to 7,110 acres.

The increase in the irrigated area under minor irrigation in the delta is made evident by the following table.

Year	Area irrigated by minor irrigation (in acres)	Extra yield in maunds	Estimated cost (in Rupees)
1949-50	1,190	9,956	66,102
1950-51	4,746	40,267	69,070
1951-52*	7,110	23,000	60,423

* Figures for Puri District are not available.

Thus the minor irrigation is gaining more ground in the agriculture of the area. Besides these main types of minor irrigation there are many other native types which are scattered throughout the Delta. The 'Janta', 'Sena', 'Sodua' and 'Tenda' are widely used in the remote corners of the rural areas.

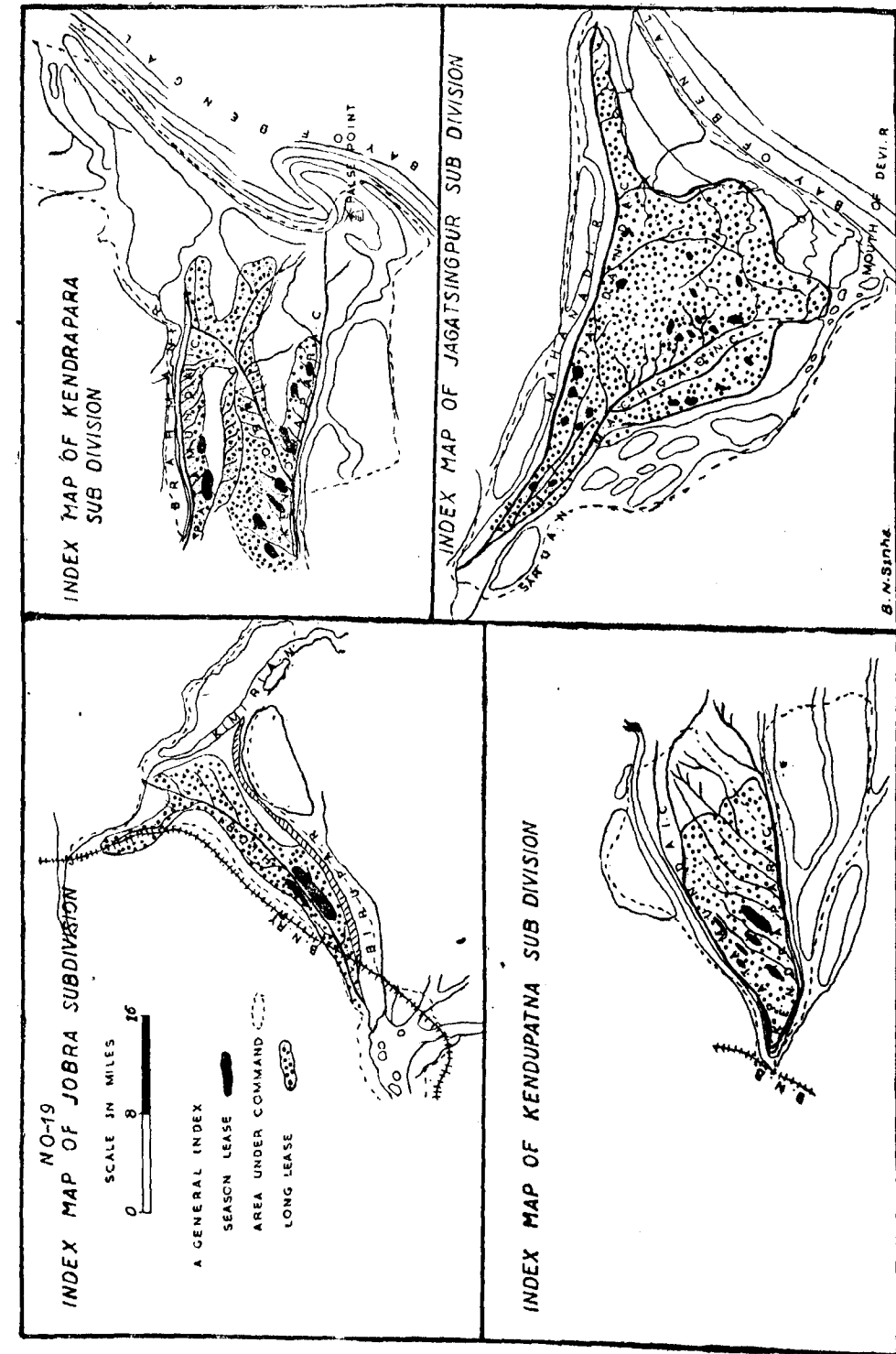
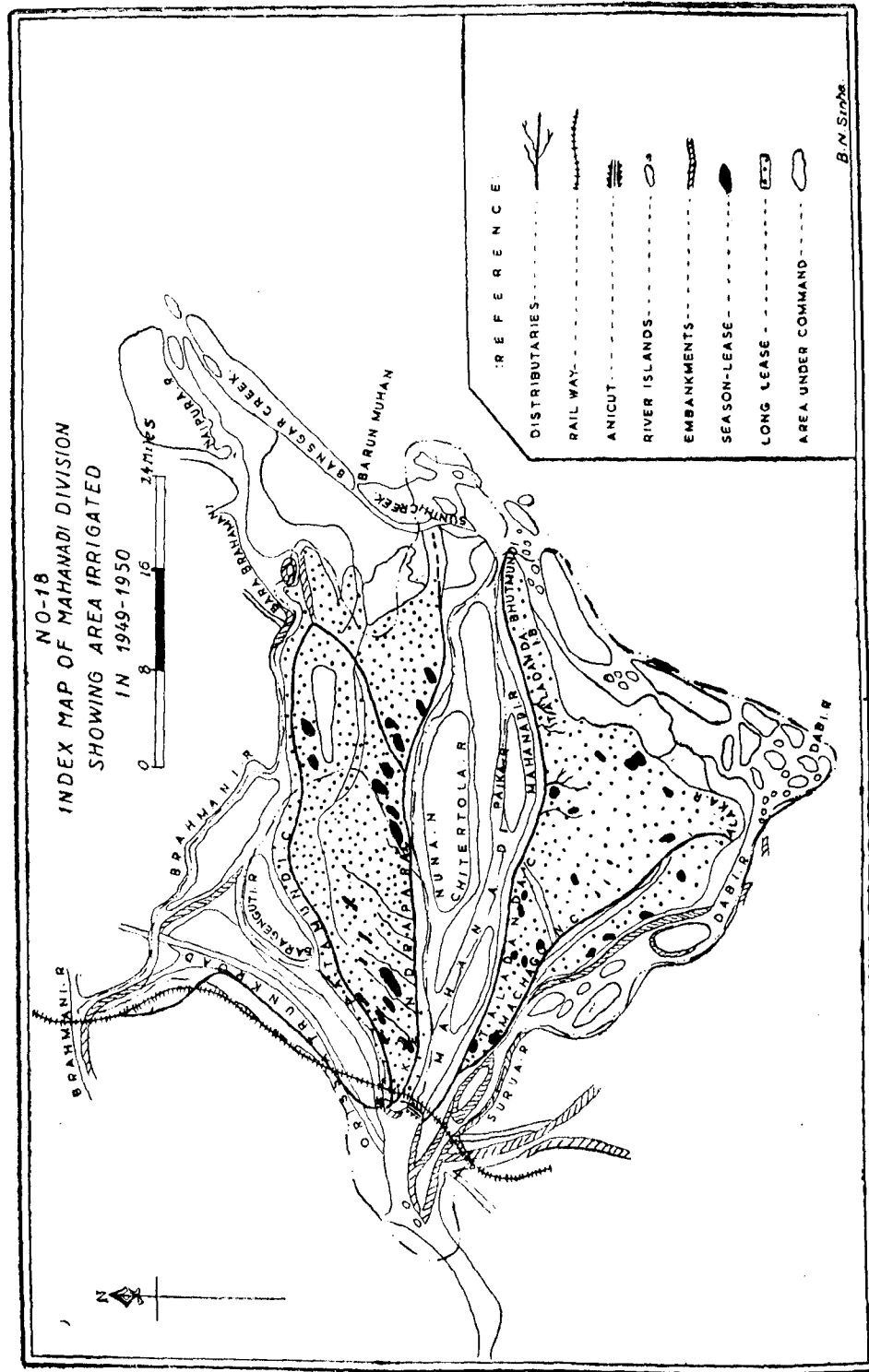
Of all these, the Janta is more popularly used in the lower reaches of the delta where the sources of water are not far below the general level of the ground. There exists a strange relation between the underground water level and the utility of these means of lifting water to the paddy fields. The use of the Janta for lifting water and draining the marshy lands near the lagoon areas of the Puri Sadar Sub-division is a popular sight. But as the water-table falls in the upper reaches of the Delta, the use of Janta becomes rare, and it is gradually replaced by the 'Sena' and 'Tenda' only because by the help of these indigenous tools, water can successfully be lifted without much cost from lower levels.

Cultivation and Irrigation:

The response of the cultivation to irrigation is unique in the Mahanadi Delta. Irrigation provides security, often leads to bumper harvests, and brings economic stability for the agriculturist. In the Mahanadi Delta, not only the outturn per acre and crop rotation are influenced but also the *per capita* income of the agrarian population is largely determined by irrigation. Irrigation also influences the pressure of population, intensity of paddy cultivation, percentage of double cropping, *per capita* distribution of cultivated land and, above all, the average size of the cultivated plots. (Refer to the table given below):

Revenue Thana	Irrigated or not	Density of population (per sq. mile)	Intensity of paddy cultivation %	Percentage of double cropped to the total area cultivated	Per capita cultivated land (in acres)	Average size of the cultivated plots (in acres)
Cuttack ..	Irrigated	839.9	80.4	19.55	0.333	0.26
Salepur ..	do	847.2	64.7	27.52	0.484	0.16
Jagatsinghpur ..	do	898.7	73.4	26.27	0.513	0.18
Tirtol ..	do	517.6	87.9	9.59	0.657	—
Kendrapara	do	847.7	69.5	20.33	0.559	0.23
Pattamundai	Irrigated partly	429.2	86.1	8.03	0.956	0.27
Puri ..	Not irrigated	339.7	73.7	8.63	0.643	0.47
Gop ..	do	549.5	87.4	7.45	0.633	0.82
Pipli ..	do	719.9	89.1	32.55	0.652	0.34

The greater yield of paddy per acre (13 mds., to 15 mds.) in the canalised areas (compared with 10 to 13 mds., in the flooded tracts) roughly coincides with that in the areas of tripple cropping (jute, rice and pulses) in the irrigated areas. Peculiarly enough, the area of jute cultivation is confined to the irrigated areas of Kendrapara and Cuttack Sub-divisions, and is completely absent in the flooded tracts of Puri Sub-division. To regain the lost fertility through intensive cultivation, by the process of nitrogen-fixation, the cultivation of leguminous crops is in wide practice in the canalised areas of the Mahanadi Delta. The intensity of paddy cultivation is slightly low in these regions, compared with that of the flooded tracts of Puri Sub-division. The areas of greater percentage of double cropping roughly coincide with the areas receiving irrigated water.



IRRIGATION AND DOUBLE-CROPPING

(Areas in acres)

Revenue Thana	Irrigated or Unirrigated	Total cropped area acres	Total area under double cropping acres	Percentage of the double-cropped area to the total area cultivated	Rabi
Cuttack ..	Irrigated	88,377	17,278	19.55	23,268
Salepur ..	do	124,140	34,170	27.52	36,755
Jagatsinghpur ..	do	171,303	45,009	26.27	48,111
Tirtol ..	do	136,650	13,112	9.59	14,048
Kendrapara	do	148,504	30,202	20.33	33,638
Pattamundai	Irrigated partly	104,925	8,523	8.12	15,869
Puri ..	Not irrigated	188,162	16,440	8.63	30,940
Gop ..	do	97,599	7,282	7.45	10,413
Pipli ..	do	183,420	59,715	32.55	62,858

All these summed up together have resulted in a greater density of population and hence lower *per capita* cropped land and smaller average size of the cultivated plots in the irrigated than the non-irrigated tracts.

Are the Irrigation Facilities Adequate ?

Our ever growing population is facing the ever decreasing production of crops. The area under irrigation on the other hand has remained more or less static. Only 10.4 per cent of the total cultivated land in the Mahanadi delta is irrigated while nine-tenths of the entire area is deprived of such facilities.

Region	Per cent of the total area under cultivation	Per cent of the total area under paddy cultivation	Per cent of the total area under irrigation
Mahanadi Delta	79.9	60.3	10.4

The need for irrigation is great in the region bounded by the Kathjuri-Devi in the East and Kuakhai-Daya in the West. In the delta, as a whole, it is clear how 90 per cent of the cultivated area depends on the most undependable rains. Herein lies the need for increasing the area under irrigation.

The Problems :

One of the most fundamental drawbacks of the existing Canal system is that the original plan was executed "rather too hurriedly", without a detailed consideration of its future effects on the agrarian economy of the delta. As a result of the construction of the Anicut at Naraj, the average annual discharge in the Kathjuri decreased and consequently the river's carrying capa-

city diminished considerably. This resulted in the rise of the level of the Kuakhai bed at the point of bifurcation from Kathjuri. Thus floods are becoming rarer in low and medium flood levels in the Daya-Kusabhadra sector than before. This has led to the development of moribund conditions and consequently due to water logging malaria has become a common disease in these areas. Thus the agriculturists are becoming increasingly inefficient to discharge the farm operations successfully as most of them are confined to bed for a greater part of the rainy season, and hence, per acre yield is gradually falling.

The other problem of canal irrigation, to-day, is the lack of supply of irrigation water. Due to considerable fall in the discharge of water in the Mahanadi during the winter and early summer the canals fail to supply water for agricultural purposes from April to June. But this is the season of low rainfall, when water is greatly needed for early jute crop or early sowing of the paddy.

As regards a solution for the development of the moribund condition, it may be said that there is no complete escape from it, though it could have been compensated by providing these regions with canal facilities. This could have been done if the present Naraj Dam was constructed a little below the present position, and as a result of which there would have been another reservoir from which canals could have been extended to the Devi-Kusabhadra sector. The present moribund condition of the rivers like Daya, Bhargabi and Kusabhadra can be averted if the Kuakhai head could be brought to its former level by dredging away deposits. The other problem of scarcity of water supply can be solved after the construction of the proposed Dam at Naraj under the Mahanadi Valley development scheme.

The problem associated with minor irrigation to-day is the proper utilisation of money allotted for it. Instead of simply criticising the official agencies in regard to the utilisation of money, this problem could to a great extent be solved by co-operative methods. In future, more money should be allotted to the non-irrigated and flooded tracts (of the region Devi in the East and Daya in the West) instead of equal allotment between the irrigated and unirrigated tracts.

The Future Possibilities :

The possibilities of harnessing the distributaries of Kuakhai and Kathjuri independently are very little due to lack of flow of water during the dry season. That is why it has already been suggested to lay more emphasis on minor irrigation. Further development of the existing canal system seems promising. Now only 47.7 per cent of the total area under the command of canals is irrigated, which means, there is scope for significant increase in the area under canal irrigation.

REVIEWS

THE SKIN OF THE EARTH: By A. Austin Miller, D.Sc., 198 pp., 67 figs., Methuen & Co., Ltd., London, 1953. 21sh.

This is primarily written as a manual of practical Physical Geography, and in about 100 exercises dealing with the examination, analysis and correlation of geological, relief, meteorological, climatic and hydrological maps, it leads the student to modern methods of research in physical geography. The author has taken great pains to collect from various research publications up-to-date techniques and assemble them together. It is consequently a book which must appeal to a much wider audience than what the title would seem to warrant. Each individual element of the physical environment like structure, relief, climate is first studied in isolation and then there is an appraisal of their interaction. Thus, it shows how physical geography is not merely an agglomeration of bits of geology, meteorology, etc., but is a subject, complete in itself, with a philosophy of its own.

Methods have been devised to define and describe the anatomy and the physiology of the landscape. This should certainly help one to understand how the cultural features which add personality to the landscape have tended to grow up. It is well known that geography concerns itself with the link between man and place; the fullest analysis of the physical background would therefore, be necessary before the bond between man and his environment can be clearly understood. Since the map is the most valuable tool giving a synoptic view of distributions, both physical and human, a study and interpretation of maps would not only give a complete analysis of the physical landscape but also, lead on to a comprehension of the cultural landscape. It could, therefore, be said with a great deal of truth that this book summarises the essential nature of the science of geography in a remarkably stimulating way.

G.K.

CLIMATOLOGY: By A. Austin Miller, D.Sc., 318 pp., 82 figs., 8th edition, 1953. Methuen & Co., Ltd., London, 21sh.

This is a very well known text book, which was first published in 1931 and its popularity is to some extent indicated by the number of editions it has gone through since then. The latest edition, although it preserves the main features of the original, has been completely revised and has many interesting features and refinements, for example, the attempt to bring the suggested classification of climates in conformity with the distribution of natural vegetation. By concentrating much more on the distributional aspects of climate, even when dealing with fairly complicated problems, the book retains its essential characteristics of being a text book of geographic meteorology and not of physical meteorology. It must, however, be pointed out that the ideas in the chapter on Air Masses, are not put to much use in the subsequent chapters, although all modern interpretations of climatic phenomena are tending to be nothing more than studies and analyses of air masses. This may be because the author believes that this book is nothing more than a text book which deals with the geography of the atmosphere, with no claims to an interpretation of the associated physical phenomena.

Special mention must, however, be made of the last chapter of the book dealing with Evolution of Climates. This is an able presentation of a really vast subject in a very concise manner. The climatic statistics and the numerous illustrations considerably add to the value of the book, but besides all these, specific mention must be made of the excellent diction and the extremely readable language of the author, which makes it one of the classics in the subject. It must find a place in the shelves of every University student of geography.

G.K.

WORLD CARTOGRAPHY, VOL. 2, 1952: (United Nations, Department of Social Affairs, New York), pp. 112. \$ 1.25.

'World Cartography' is published annually by the Cartographic Office of the Department of Social Affairs, United Nations. "It reports upon activities, plans and progress in the various branches of cartography taking into account the present needs in all countries as well as the results already achieved." The present volume has four sections: I. General Questions; II. Technical Notes and Studies; III. Reports on Activities; and IV. Bibliography.

Prof. Tardi, Director of the Central Bureau of the International Association of Geodesy, stresses the need for International Collaboration with special reference to Geodesy. He explains in detail, the advantages of a World Geodetic System which will provide a uniform basis for the conversion of Geoidal co-ordinates into Ellipsoidal co-ordinates and *vice versa*. It will then be possible, the author contends, "to base the preparation of maps on scales upto 1:100,000 on a network of astronomical observations." This will be very useful for mapping underdeveloped regions of the world, such as, Central Africa, South America, Australia and parts of Asia. For a definition of the World Geodetic System, it is necessary to know the vertical metric distance between the ellipsoid and the geoid at as many points as possible, and this in turn, involves the calculation of the gravimetric anomaly at several stations on the surface and their combination into homogeneous network. We fully agree with the author that a solution of this problem is possible only with "extensive international collaboration" in establishing a large number of gravimetric stations, both on the land and on the sea floor. In conclusion, Prof. Tardi gives a short account of the growth of the International Geodetic Association and the work done by it, in collecting and standardising gravimetric data from a number of stations, and in initiating additional measurements in unexplored continents and oceans.

Maj. Gen. R. Llewellyn Brown, Director-General of the Ordnance Survey of Great Britain discusses the "problem of keeping large scale plans of Great Britain up-to-date." He explains in detail the system of continuous revision now used by the Ordnance Survey. The country is divided into areas, each under a small section of surveyors, whose duty is "(a) to ascertain the exact locality where alterations had taken place; (b) to survey such alterations in the field; and (c) to incorporate them on the map." "Normally a fresh edition is put out automatically either when the stock of the former edition runs out, or when the changes on the ground warrant." The continuous revision of large scale plans will also make it possible to keep the small scale maps up-to-date. This article is of special significance to cartographers in India where there is need for revising the large scale maps, with the change that are taking place in the landscape of the country.

The article on "Cartography in the service of regional planning" is of special interest to geographers, though the contribution as such, comes from a group of Belgian architects. In fact a number of geographers from the University of Liege contributed to different sections—zoning, land-relief, mapping of population and industries, etc., of course, in addition to a host of other scientists: geologic engineers, botanists, phyto-sociologists, sociologists and meteorologists. A preliminary survey of the Liege region was made for the purpose of formulating a development plan. The results of the survey were presented in a series of 60 panels (frames 2 metres X 1.60 metres in size), each with maps, suitable tables and diagrams and a brief text. A short account of the details represented on each panel is given along with the reproduction of some of the maps. It should be said about the seven black and white maps reproduced in the article, that the cartographic work is somewhat crude, and the selection of the different shade grades, particularly in the Land use map (Fig. 1) is open to criticism. For example, the industrial areas, port installations, etc., are shown as white (blank) spaces, and to make the shadings suggestive the undeveloped land should have been left blank. Of course, the research value and the utility of these maps to the planners have to be accepted, and full credit goes to "Equerre" and other scientists, who participated in the survey of the Liege region.

In the second section, Mr. W. S. Dix, describes the latest technical developments in "Map Reproduction in the United States". The article includes details of Map Reproduction facilities available in Federal Agencies, such as the Departments of Agriculture, Commerce, Defence, etc. At the end of the article, there is a selected bibliography.

In the third section, there are articles on the development of Cartography in Argentina, Burma, France and Thailand. These articles are based on the latest official information and indicate the progress made in several fields such as Geodetic Network, Triangulation, Levelling, Air Survey, Topographical Maps, Map reproduction, etc. There are maps illustrating the progress made in each country. It is surprising to learn that large areas of Argentina are not mapped even on a scale of 1:100,000. Maps of Argentina seem to be over-reduced, as details cannot be made out. The article on France includes details of progress made in surveying the French territories in Africa and other parts of the world.

A report on "The history and recent progress of primary and secondary triangulation in Great Britain" gives a short account of the growth of the Ordnance Survey, since its inception in 1791, and the progress made in Re-triangulation. Two maps showing the network of Re-triangulation and the progress made have been included. There is a short summary of the proceedings of the International meetings held in 1951-52. In the last section, there is a selected Bibliography of Photogrammetry prepared by the International Society of Photogrammetry.

A special feature of this Journal is the inclusion of official reports describing the status of different branches of cartography in the different countries of the world. The general articles are devoted to various aspects of cartography, both theoretical and applied. This bulletin will be specially useful to geographers specialising in Cartography, and should be in the library of every Geography Department.

SILVER JUBILEE SOUVENIR: 1928—1953, pp. 384. Andhra Chamber of Commerce, Madras and Kurnool.

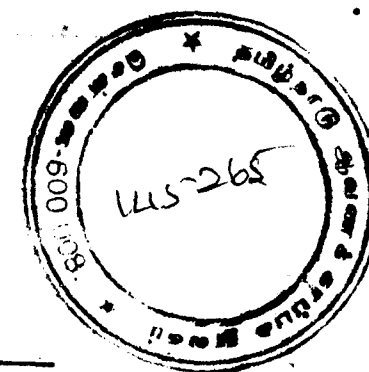
After completing twenty-five years of useful service, the Andhra Chamber of Commerce celebrated its Silver Jubilee in January, 1954, and this synchronised with the inauguration of the Andhra State. The Chamber should be congratulated for publishing a souvenir which gives a good insight into the different aspects of the Andhra State.

The volume is divided into ten parts: Introductory, Agriculture, Irrigation and Power, Minerals, Industries, Commerce, etc., Transport, Communications, Finance and Miscellaneous. The section on Industries is the bulkiest of all, and Agriculture ranks next. Any reader feels that the cultural aspects should have been dealt with comprehensively in the first section. In a volume of this type, with a host of contributors, drawn from different sectors, the articles cannot be made to conform to set standards, and sometimes, the treatment, tends to be superficial, as in the case of the agricultural commodities (section ii). Of course, some of the articles like those on Irrigation, Power, Minerals and Soils, having been contributed by the official experts, are highly informative and authoritative, and certainly add to the reference value of the volume.

There are 17 maps in the text, and most of them are coloured. The schoolish-colouring, crude cartographic work and over-reduction have defeated the purpose of these maps. The mineral map (map. 14, p. 177) and the contour map (map. 11, p. 147) are cases in point, the victims of over-reduction.

It should however be said, that as a reference book on Andhra, the souvenir scores a good mark.

R.N.



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