Presidential Address.

CALCUTTA, 1938.

By PROF. M. N. SAHA, *D.Sc., F.R.S., F.R.A.S.B.*

THE PROBLEM OF INDIAN RIVERS.

CONTENTS.

I. GENERAL.

Meetings of the Institute

Since our last Annual Meeting held at Hyderabad [under Brigadier Sir Harold Couchman] we have, in pursuance of a general plan adopted last year by the Council, held a number of meetings in different cities of India. A meeting was held during the Easter holidays at Allahabad ; this was followed by a symposium on the 'Malaria Problem in India' at Calcutta on the 27th and 28th August, 1937 at the All-India Institute of Hygiene and Public Health. The symposium was attended by a large number of medical and scientific workers from all parts of India. Considering the large number of papers contributed and the high level of the discussions, it may be considered to have been a great success. We also held on the 6th November, 1937, a meeting at Delhi which was attended by Fellows living in Northern India. We hope that in future. meetings will be organized in other parts of India as well and that such meetings will lead to a fruitful exchange of ideas amongst scientists living in different parts of this continent and engaged in different pursuits.

Publications

We have continued the publication of the Proceedings, the Transactions, and the Indian Science Abstracts two parts of which for the year 1935 have already been published. On the occasion of the Silver Jubilee of the Indian Science Congress, a Report on the Progress of Scientific Research during the last twenty-five years has been prepared, and this will be followed by our Annual Reports on the Progress of Science in India. This will complete the series of our publications. We have to thank our general editor, Dr. Baini Prashad, for the meticulous care with which he has edited these publications.

Financial Problems

Financial problems have been a source of anxiety to our Council. Scientific bodies like ours can never be self-supporting. Our proto-type, the Royal Society of London, gets a grant of about £8,000 from the Government of the United Kingdom towards its publications. In the first year of our existence we applied to the Government of India for an annual grant. We are glad to announce to you that the Government of India has sanctioned an annual grant-in-aid of Rs.6,000 commencing from the financial year 1937-38. Our grateful thanks are due to the authorities for this grant. This grant has, for the time being, relieved to some extent our difficulties, but it is not sufficient to meet all our requirements. The excellent get-up of our publications has naturally encouraged our Fellows to send their papers in increasing numbers to the Institute, and this has added to our burdens.

Need for a Permanent Office

Up to this time, we have been helped by the Royal Asiatic Society of Bengal which has very generously placed at our disposal an office room in their premises. Owing to increase in the work of the Institute, this accommodation is proving insufficient, and the Council will soon have to consider the question of finding suitable accommodation elsewhere.

This year, the Institute has suffered severe losses by the death of several distinguished Fellows.

Dewan Bahadur Anantakrishna Iyer

Dewan Bahadur Dr. L. K. Anantakrishna Iyer, one of our Foundation Fellows, who died on the 26th February, 1937, in his native village of Lakshminarayanpuram, Palghat, at the age of 75, was one of a small band of distinguished Indians who did pioneering work in Indian Anthropology. Dr. Iyer made his mark in Anthropology with two volumes on the Cochin Tribes and Castes, which he published in 1909 while Curator of the Museum at Trichur and Superintendent of Ethnography of the Cochin State. His great reputation as an anthropologist led to his being invited by the late Sir Asutosh Mukherjee to organize the Department of Anthropology of the Calcutta University. He has enriched Indian Anthropology by many contributions and by his death India loses a pioneer who made the civilized world familiar with the habits and customs of some primitive tribes of India.

Sir Jagadish Chandra Bose, D.Sc., F.R.S.

Late during the last year we had to mourn the loss of Sir Jagadish Chandra Bose, one of our Foundation Fellows. He was the first Indian to attain international reputation and that by virtue of his scientific work. The present generation of Indian scientists can have very little idea of the struggles of our early pioneers of Science, Sir J. C. Bose and Sir P. C. Ray, for it happens very frequently that those who eat the cake are very apt to forget those who ground the corn and kneaded the dough for them. As my friend Dr. Birbal Sahni has put it :—'An incredibly long period of degradation separated us from a great and proud past. Indians were known only as dreamers and philosophers, their right to be heard as scientists was only laughed at. India will for ever remember Sir J. C. Bose as the pioneer who broke this spell.' Early in the nineties of the last century Bose, while a subordinate professor of physics at the Presidency College, Calcutta, was inspired by the researches of Hertz in Germany, who, following Maxwell's theoretical works, had produced electro-magnetic waves in the laboratory. With crude apparatus of his own design and without guidance from any quarter, and amidst innumerable difficulties, Dr. Jagadish Chandra Bose, then 36 years of age, repeated all the experiments of Hertz, at the laboratory of the Presidency College, Calcutta. Further, with the aid of ingenious apparatus of his own design, he produced extremely short electro-magnetic waves, which closed the gap between light waves and electric waves. He was one of the first to realize and perform experiments proving that Hertzian waves can be used for the propagation of signals, but in this work he was forestalled by the young Italian Marconi. With a little more luck and a better environment, he might have gone down to history as the discoverer of Wireless Telegraphy. Later in life, he turned his attention to the solution of a great problem, namely the Problem of Life ; how inanimate atoms combine to form substances which give rise to the phenomenon of life. This problem, so long the theme of innumerable speculations by magic men, founders of religions and philosophers, was for the first time attacked in an entirely novel way, viz. with the aid of physical instruments. He devised marvellously sensitive physical instruments (e.g. the Magnetic Crescograph) for recording the phenomenon of growth, decay, and death due to natural as well as to artificial causes, and also for solving other associated phenomena, such as for example the ascent of sap in plants. Though his conclusions have not in general been accepted, it will be conceded at all times that he tackled a great problem from an entirely new and probably the only point of view which is likely to lead to success. Probably this problem will be nearing solution after the discovery of Induced Radioactivity, and attacks on the problem of life by physical methods have been started by Profs. Bohr, Krogh, and Von Hevesy at Copenhagen, and the Curie-Joliots at Paris. If the problem is ever solved the scientific world will probably remember that t was an Indian savant who first conceived it.

Lord Rutherford of Nelson, O.M., F.R.S., Nobel Laureate

We have also suffered very heavy losses in our Honorary Fellows. Lord Rutherford of Nelson whose loss we mourn to-day was elected our Foundation Honorary Fellow in 1935. We all expected that he would be present here this week and guide the deliberations of the Silver Jubilee of the Indian Science Congress. But it is an irony of fate that we have to mourn his loss to-day, and the address, which is the last written work of the great scientist, has to be read by Sir James Hopwood Jeans, who agreed to preside in his place. Lord Rutherford was the foremost among the experimental physicists of the present time and probably of all times and his place is in the same company with Faraday and Newton. As the discoverer of the law of spontaneous disintegration of radioactive atoms, of the nuclear theory of atoms and as the pioneer who was the first to realize the mediæval alchemists' dream of transmutation of elements, Rutherford has for all times an assured place in the Hall of Immortals. His influence spread so rapidly that he easily attained leadership amongst British and international men of science, a leadership which he utilized for the benefit of his country and of the world.

In this connection, I may be permitted to add a few personal reminiscences. I visited Cambridge in June, 1936 and had the privilege of interviewing Lord Rutherford at the Cavendish Laboratory. The offer of the Indian Science Congress Association and the British Association to preside over the joint session (Silver Jubilee Session) had just then been communicated to him, but he was still hesitating in his mind whether to accept or reject the offer. His main difficulty was, as he explained to me, that as he had no first-hand knowledge of affairs in India, he did not feel quite comfortable in accepting leadership on such a historic occasion. We had a long discussion—lasting for about an hour—and I conveyed to him as much information as possible, regarding the utility and needs of scientific research in India. We went very thoroughly into the existing state of scientific education and research, the scope of work of the existing research institutions, and the need for further and more efficient organization of research work in India for the service of the nation. He took notes about our conversation and it was a pleasant surprise when I found that almost half of his address which was read to us by Sir James H. Jeans was devoted to these topics. His address is his last written work, and should be regarded as a message not only to Indian scientists but also to Indian administrators, public men and philanthropists. It emphasizes, in the clear and concise language characteristic of Rutherford, the need for greater recognition and encouragement of Science by the State and the leaders of society.

Prof. Albert Heim

Prof. Albert Heim, who was elected Honorary Fellow in 1936, died on August 31, 1937, at the ripe old age of about eighty-nine years. He was a very great man whose name is intimately connected with the structural interpretation of the Alps.

Heim was Professor of Geology at the Polytechnic and at the University in Zürich from 1873–1911. He was the author of a three-volume work on the Geology of Switzerland which is recognized as perhaps the finest national text-book ever written.

Besides tectonics he was interested in many other aspects of Geology, particularly the glaciers.

He was Director of the Swiss Geological Commission from 1894–1925, and was the recipient of honorary doctorates from Bern, Oxford and Zürich, and was elected a Foreign Member of the Royal Society of London.

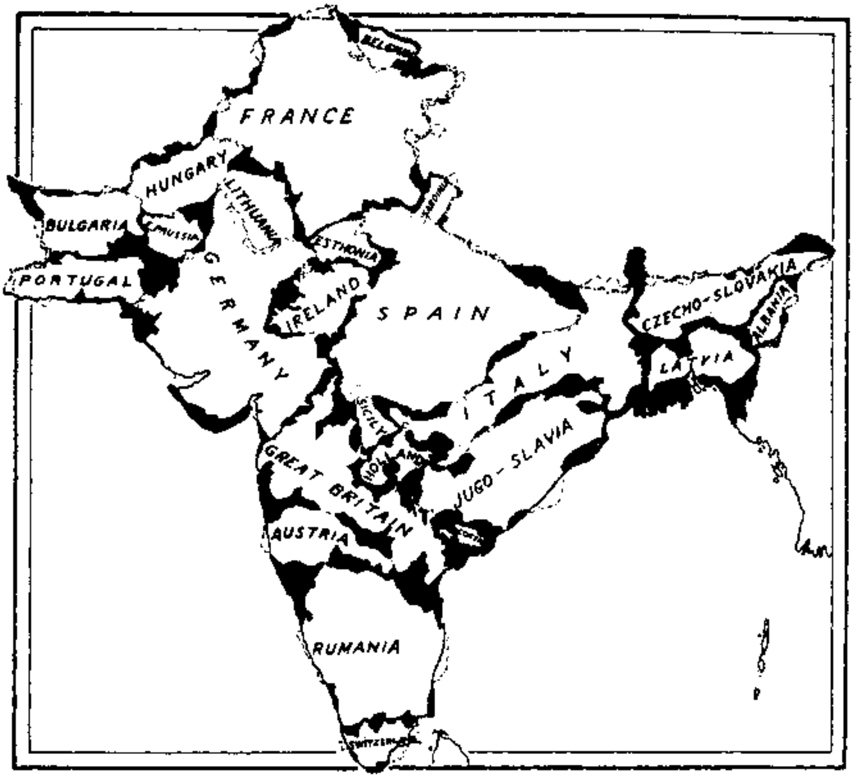
Our first President, Sir Lewis Fermor, laid down the rule that the President of the year should deliver an address dealing with the particular subject in which he has carried out original research in a way which will be quite comprehensible to scientists working in other lines. If I follow this advice, I should deliver an address on Astro-Physics, a subject to which I have made some little contribution. I have purposely refrained from attempting an address on this subject because we have this week two of the world's leading astro-physicists among us, viz. Sir James Hopwood Jeans, the President of the Silver Jubilee Session of the Indian Science Congress, and Sir Arthur Stanley Eddington. It appears to me that I shall be on safer grounds if in the presence of these distinguished astro-physicists, I talk on a subject to which, to the best of my knowledge, they have not contributed anything and are not likely to contribute anything. I would like to invite the attention of the scientists gathered here to a problem of practical scientific importance on which the welfare of millions of our countrymen depends. It is about the problem of Indian rivers. My address would be an introduction to the symposium on River Physics which has been organized under the joint auspices of the National Institute of Sciences, the Indian Science Congress, and the Indian Physical Society. I have to thank the other distinguished scientists, geologists, zoologists, engineers and mathematicians who have generously responded to my invitation.

II. Problem of Indian Rivers.

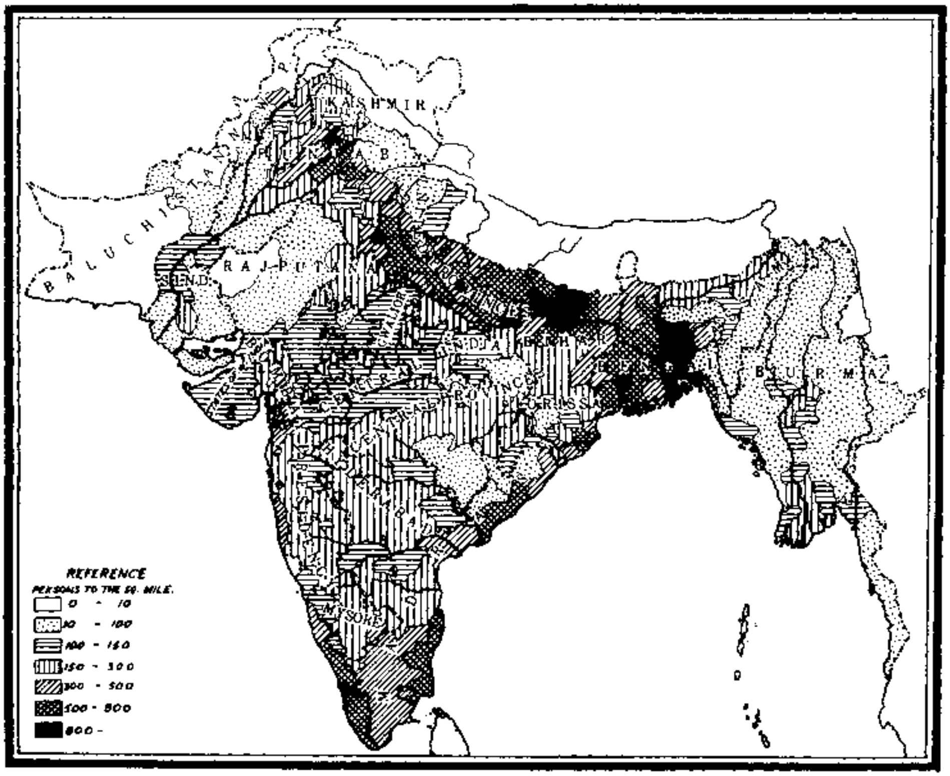
1. *Introduction.*

Indian Civilization mainly a River Valley Civilization

You would probably like to know why I chose this particular subject for my address. I have on the screen two maps of India (Maps 1 and 2); the first, which I have reproduced from Sir L. L. Fermor's presidential address to the Indian Science Congress in 1932, shows that India is vast enough to accommodate all the countries of Europe except Russia. The second is a population map of India. You will observe from this that the Indian population is still mainly concentrated in the valleys of the great rivers which intersect this continent. With a few exceptions, the great cities which are centres of industry, culture and administration are mostly to be found on the banks of the great rivers. If we go back in


FRANCE
HUNGARY
LITHUANIA
BULGARIA
E.PRUSSIA
PORTUGAL
GERMANY
ESTHONIA
IRELAND
SPAIN
CZECHO-SLOVAKIA
ALBANIA
LATVIA
ITALY
SICILY
HOLLAND
JUGO-SLAVIA
GREAT BRITAIN
AUSTRIA
RUMANIA

Map 1.


KASHMIR
RAJPUTANA
SIND
MYSORE
REFERENCE
PERSONS TO THE SQ. MILE.
0 - 10
10 - 100
100 - 150
150 - 300
300 - 500
500 - 800
800 -

Map 2.

time and survey our past history, which can now be traced to 4,000 years before Christ, we shall find the same story; my own studies in the history of our country have confirmed me in the belief that even 200 years ago, there was a very scanty population in the country away from the banks of the great rivers.

Rivers essential for agricultural communities

In fact, this condition is not peculiar to India. Human civilization on this globe of ours has, since time immemorial, chiefly centred about rivers and river basins. Who can conceive of Egypt without the Nile, of ancient Sumer and Babylon without the Tigris and the Euphrates, and of China without the Hoang-ho (the Yellow River) and the Yangtsekiang? The early growth of settled human life in river basins is to be ascribed to the fact that rivers supplied the largest amount of needs of early societies which were mainly agricultural. They supplied them with the all-important water for drinking, bathing and other domestic uses, and for irrigating their fields. Rivers also formed the indispensable highway of communication before the discovery of the steam locomotive. Since rivers were so important to human life in its early stages of cultural development, convenient sites on them used to draw large populations, and such sites gradually grew to be great cities and capitals of mighty empires.

New Pathways of Human Activity

The rise of maritime civilizations like those of Greece (centred round the Aegean Sea) and of Rome (centred round the Mediterranean Sea), which was due to the extension of human activity away from riparian tracts, did not at all diminish the importance of rivers, though development of maritime activities gave rise to new centres of population like sea-ports. But these were generally clearing houses for the country products, which were produced in riparian tracts. In modern times, the growth of large-scale human activities and of the factory system has given birth to new centres of population which are in many cases away from rivers, but as the largest part of humanity has still to depend on agriculture, the rivers have not lost their importance to mankind. Moreover, in recent times, in addition to agriculture, novel use has been found for rivers. In the first place, for convenient and cheap transport of goods it has been found that no other method of communication can beat river transport. Secondly, some of the rivers, if properly harnessed, can supply electrical power which is all important for the development of industry and for other human needs in the present century.

2. *Rivers need attention.*

Irrigation an ancient art

The importance of rivers may be gauged from such phrases as 'Egypt is the gift of the Nile'. But experience has also shown and this was also known to early human communities that rivers need attention. First of all, there is the annual cycle : during one season of the year the rivers are filled to the brim with water, sometimes overflow the banks, and inundate the fields. Then comes the lean period when they almost run dry. The ancient peoples found that if these phenomena could be controlled, the rivers could be made to do more good than if they were left to themselves. Out of these considerations rose the art of irrigation, one of the oldest ever practised by the human community.

Irrigation in ancient countries

Irrigation in different ways was practised on a stupendous scale in Egypt, Babylon, old China, as well as in India. In fact, the existence of the community depended upon the successful practice of irrigation. In Mesopotamia, the two rivers run through a desert country and only a small fringe of land, on either side of each river, is directly accessible to river water. But the ancient dwellers of the land, the Sumerians, five thousand years ago, cut canals from the rivers and irrigated their fields, which were away from the immediate reach of the rivers. In fact, but for the net-work of irrigation canals with which the whole land was intersected, very little of the country would have been habitable. Elaborate precautions were taken by the State for maintaining the canal system from the attacks of external enemies and from the harmful effect of internal quarrels. This magnificent canal system was the cause of the great prosperity of ancient Iraq, up to 1258 A.D., when the Mongols under Hulagu Khan conquered the country, and systematically destroyed the canal system by blocking the mouths of canals and allowing them to fall into decay. Iraq, which up to the 13th century, contained the greatest cities of those times in the world (e.g. Baghdad) and was farfamed for its culture and prosperity, has never recovered from this catastrophé.

Modernization of Egyptian Irrigation

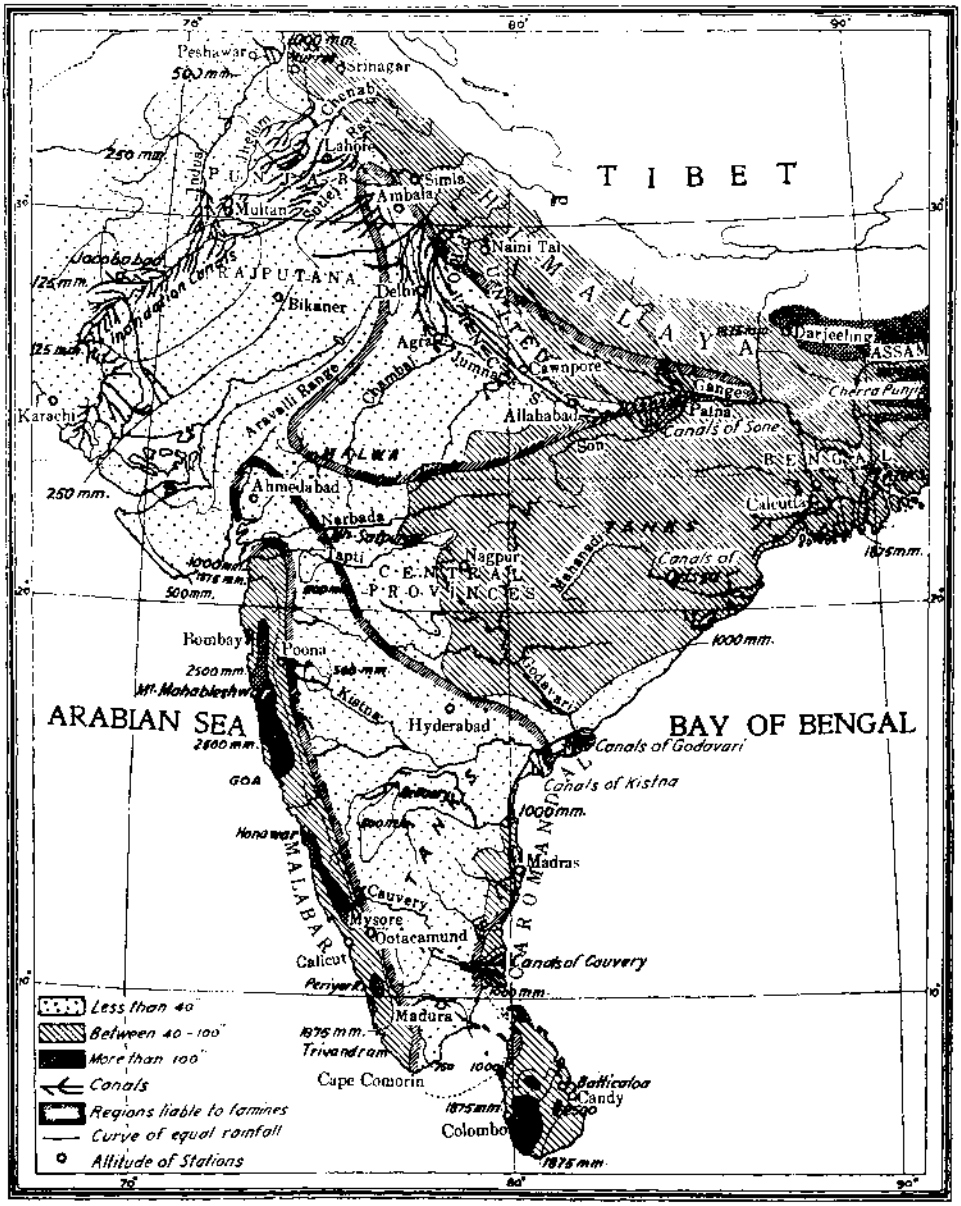
While the Babylonians practised perennial irrigation, the Egyptians practised ' Basin Irrigation ' from time immemorial. They anxiously waited for the Nile to overflow its banks which it did with clocklike regularity, and then held up the water by throwing earthen mounds round their fields. In recent years, basin irrigation, which allowed only one crop to be grown in the year, has been converted to ' perennial irrigation ' by the construction of the Assouan and other dams across the Nile. This has allowed Egypt to raise two to three crops in the year.

3. *Irrigation in Ancient India.*

It is well known to every reader of history that irrigation has been practised from time immemorial in India, but owing to the vastness of the country the system practised has not been uniform as in Egypt or Babylon. During the troublesome days which ensued after the weakening of the Mughal dynasty about 1740 A.D., and the re-establishment of settled rule under the British about 1800 A.D., most of these ancient systems had fallen into decay, but sufficient had subsisted to enable us to form an idea of the way in which irrigation was practised in different parts of the country.

Diversity of Indian Irrigation in former times

I place before you an Irrigation Map of Modern India (Map 3), just to illustrate the particular features of irrigation in different parts of the country. First of all, there are the arid areas of Sind and Southern Punjab which receive very little rainfall. Then come the precarious areas (areas of scanty rainfall)



MAP 3.
(Adopted from *Geographie Universelle*, Tome IX, 1929.)

of the Punjab. Here, in ancient times, water was tapped by canals which were cut off from the banks of the rivers. The canals were filled with water only during floods. The western part of the Ganges valley does not suffer so much from defect of rainfall, but there are wide tracts in this part which are far away from the banks of the main rivers, and from which rainwater drains off quickly. The problem is to bring water to these areas by means of perennial canals. Southern India again presents a different aspect. In the centre it is a table-land, and the rain, which falls mostly within a short period, drains off quickly to the eastern sea. Ancient rulers held up the water by throwing dams across convenient sites on river courses, and thus creating reservoirs and artificial lakes from which water could be tapped for agricultural purpose whenever necessary. This is sometimes known as storage or tank irrigation. Besides these areas, we have in India the lower basins of the rivers, where the flow is perennial, and the deltaic regions, where in addition the rainfall is abnormally large. These areas present quite different problems, but to these I will refer later on.

The successful practice of irrigation demands organization, settled government and scientific knowledge. Were ancient Indians capable of attacking the problem on scientific lines? To the western world, India was known as a land which for all ages has been full of unpractical dreamers and philosophers. It was a mild shock to the West when, in 1909, an old Sanskrit manuscript, Kautilya's 'Arthasastra', was discovered.

This book reveals a different type of Indian mentality. Prof. W. E. Clark, Head of the Department of Sanskrit at the Harvard University, says :—

The practical Indian Mind in ancient times

'The discovery in 1909 of the Kautiliya-Arthasastra has opened up an entirely different world of life and thought in ancient India from that represented by the religious and philosophical literature of the Veda. Accounts of ancient Indian civilization based entirely on this religious literature are as misleading as would be accounts of early European civilization based entirely on the Church Fathers.

'The book deals with every phase of government as regulating all matters of worldly life—a government which was not dominated by the priesthood but which was highly practical and empirical. Sections are devoted to precious stones, ores, metallurgy and mining, roads, trade routes and irrigation, medicine, trees, plant and poisons, ships and shipping, cattle, horses, and elephants, chemistry, mechanical contrivances, and other technical matters.' (*Legacy of India* by Garret.)

Irrigation under the Mauryan Emperors

We learn from this book that the great Mauryan Emperors, who in the third century before Christ ruled over a land bigger than the present British Indian Empire, maintained a regular department of irrigation and navigation. The officers looked after the maintenance of irrigation canals, levied taxes on water, and controlled navigation. An inscription found at Girnar in Kathiawar peninsula tells us that by the orders of the Emperor Asoka a great water storage tank called the Sudarshan lake was constructed by his Governor, the Persian Tusashpa, by throwing a masonry dam across a mountain pass. According to later inscriptions, it was twice repaired: Once by the Saka Satrap Rudradaman (150 A.D.) and then by the Gupta Emperor, Skandagupta (460 A.D.). Southern India is full of huge storage tanks used for irrigation which testify to the ancient rulers' solicitude for the storage and judicious use of water.

Another famous irrigation work was the Grand Anicut on the Cauvery river, where it begins to form a delta (see Map 3). This was constructed by the Hindu rulers of the First Century A.D., and was in continuous use up to the 19th century, when it was repaired by Sir Arthur Cotton, the pioneer of large-scale irrigation in this country under the British régime.

The Gangetic Delta

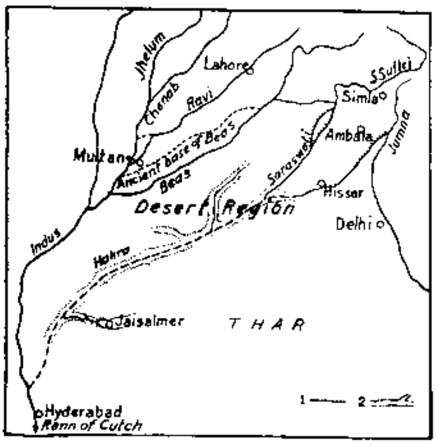
The riparian area of India consists, besides the regions mentioned above, of the lower reaches of the rivers where they begin to form deltas. The physical condition of these areas and the life of the rivers are quite different from those in the upper sections. You will have some idea of these regions if you look at the delta of the Ganges river. Up to Rajmahal, the Ganges receives only tributaries, but below it the river flows through soft soil and divides itself into a labyrinth of channels. The land is low and subject to inundations during the monsoon season. There is a great difference of opinion as to whether the ancient rulers tried at all to prevent these rivers from leaving their beds, finding out new channels and eroding villages and cities, as we find them doing now.

4. *Long Period Changes in River Courses.*

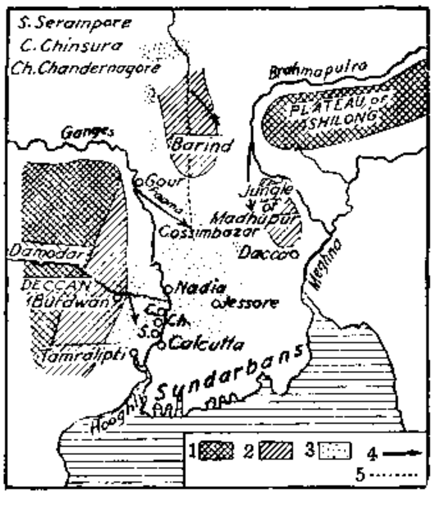
I have given you an imperfect sketch of the usual régime of rivers in ancient times. Besides the periodic changes connected with seasons, certain long period changes in the course of rivers have been noticed by competent authorities, the cause of which is still hotly debated amongst Geologists, Surveyors and Historians. You may have an idea of these long period changes if you look at the two maps before you. Map 4 represents the alignment of the Punjab rivers about two thousand years ago. You will see from this that the Punjab rivers have a tendency to change their course and that they generally move west. There is a fight going on between the deserts and the river valleys. The desert is constantly encroaching on the rivers and pushing them to the North-West. Is it due to some deep-seated tectonic action whose influence is accumulative or has there been a change in the course of the monsoon tracks of rain-clouds? There can be no difference of opinion regarding the reality of these changes. The Archæological Department of the Government of India

The Punjab Rivers

has found, besides Harappa and Mahenjodaro, a large number of cities buried under the sands of Sind and Rajputana. These cities could not have existed unless there was more plentiful supply of water in these regions 5,000 years ago than is to be found now. It has been surmised that the North-Western monsoon, which gives the Punjab a certain amount of rainfall during winter and is very beneficial for wheat cultivation, used formerly to have a more southerly course, and passed over Sind and Rajputana. It is further supposed that the rivers of the Eastern Punjab used formerly to unite in a powerful course and flow in a separate channel, parallel to the Indus, to the sea, thus giving Sind all the advantages of a land between the two rivers, the Indus on the west and the Saraswati on the east. It is surmised that the lower course of the Saraswati ran dry during Vedic times and its original course is marked by a dry channel. The other rivers have moved away from their courses generally to the west. What has been the causes of these changes in the courses of rivers which have taken place within historical times ? My friend Mr. Wadia of the Geological Survey of India who deals more extensively with these matters tells us that many of the rivers are more ancient than the land, and surmises that these changes are due to crustal movements.



MAP 4.
(Changes in the Punjab Rivers.)



MAP 5.
(Changes in the Bengal Rivers.)

It goes without saying that these changes cause great suffering to the population which is mainly dependent on agriculture. Are the changes controllable at all ? In fact the work which has been done by the engineers in recent times in the Punjab may be summed up by saying that they have tried to restore the waterways which existed in former times and fight the tendency of the country to aridification.

The Ganges-Brahmaputra-System carries largest volume of water

When we turn to the deltas of the Ganges and the Brahmaputra (Map 5), we find that throughout historical periods, constant changes have been going on in the lower courses of these rivers, changes which have exerted a far-reaching influence on the economic and political condition of the countries through which they pass. The total length of the Ganges is only 1,500 miles wholly in India and that of the Brahmaputra is 1,800 miles of which 800 miles are in India. The length of the river courses may give one a false idea of the actual importance and the stupendousness of the geological changes caused by these rivers : for though the Ganges is rather short compared with the other great rivers like the Yangtsekiang in China or the Mississippi in the U.S.A., careful measurements have shown that her peak discharge during the monsoon period exceeds that of the Mississippi and is seven times that of the Nile. The discharge of the Brahmaputra is about one and a half times greater than that of the Ganges. These circumstances, combined with the fact that they flow over a comparatively small region, have made these rivers unique objects of interest.

Recent changes of water courses in the Ganges-Brahmaputra Delta

This will be apparent from Map 5 which I am exhibiting before you. This shows you the courses of the Ganges and the Brahmaputra rivers over the lower reaches only 150 years ago compared with their present courses. You will see how great are the changes which the river systems have undergone. In fact, with respect to these lower deltaic regions, it can be said that the geography is changing markedly within the short period of a century. You find that some of the ancient water courses have entirely disappeared and new systems, which did not exist two hundred years ago, have come into existence. The Ganges and the Brahmaputra 200 years ago used to discharge their waters by two separate courses which were about 150 miles apart from each other. There was a third system of water courses between these two which, flowing through Northern Bengal, used to discharge its water independently into the sea or into one of these two rivers. But great changes occurred between 1787 and 1818, due to causes which are well known, and now the main streams of the Ganges and the Brahmaputra unite 200 miles inland. This has caused widespread changes in the topography and the economic life of these regions. These wide changes are characteristic of all the rivers in the whole of Bengal and in Assam and to a much lesser extent of the deltas of the Mahanadi river of Orissa. Are these changes partly due to some deep-seated forces or to the natural surface action of the rivers which, unable to carry their heavy load of silt, go on depositing it on their beds and banks, and are ultimately forced to seek new channels ? Scientists will take a long time in answering such questions, but it is needless to say that these changes have caused great dislocation of human life—old cities have been eroded, prosperous country-areas have been washed away, swamps have been formed and regions once populous have been ravaged by malaria. Can these changes be controlled at all?

5. *Problem of Deltaic Cities.*

Ruined Cities in Deltaic Areas

Besides causing widespread changes in rural areas, the deltaic rivers have played havoc with the ancient cities, results of centuries of patient and concentrated labour by ancient rulers and communities. Most of the ancient cities famous in tradition in this country and playing a great part in its political history grew on their banks, or on the banks of their tributaries. Nobody has yet given a full and consistent account of the causes leading to the rise and growth of these cities, nor has told us how far the phenomena of the growth and decay of states connected with them were due to the action of the rivers. We are usually apt to ascribe growth and decay of countries only to political causes, but a deeper probing into facts shows that this is not the whole story. A few examples will show. Ancient Pataliputra which was the capital city in India from the 6th century B.C. to about the 5th century A.D.—an interval of nearly a thousand years—owed its importance to its position as an important trade centre at the junction of 5 rivers (the Ganges, the Sone, the Ghogra, the Gandak and the Punpun, see *Science and Culture*, Vol. 2) at a time when rivers were the main channels of communication. It now lies buried under the present city of Patna at a depth of 17 feet below the ground level. Its destruction was due, as authenticated historical tradition tells us, mostly to destructive floods. It appears that in the deltaic regions, the level of a city gradually goes down while that of the surrounding country rises, so protective bunds have to be constructed to keep the flood water out. But sometimes, particularly if the city is between two rivers, as was the case with Pataliputra, and there is simultaneous flood in the two rivers, these bunds give way, causing destructive floods and depositing thick layers of silt. Modern excavations have shown that ancient Pataliputra used to be very often visited by floods, and ultimately disappeared under the silt deposit. It is quite probable that the disappearance of Magadhan supremacy after the 6th century A.D. in Indian politics may be due to the destructive action of rivers on the chief cities of Magadha which the rulers were unable to gauge and control.

Those who have read the story of the discovery of the Indus Valley civilization in the sumptuous volumes published by the Archæological Survey of India are aware that many prosperous cities in the lower Indus Valley had to be deserted because they used to be very often visited by floods or the rivers changed their courses and deserted the cities. The whole Indus Valley is full of dead sand-buried cities along the old course of the Indus. Another menace to great cities on river banks is the possibility of the formation of unhealthy swamps in the neighbourhood which may give rise to catastrophic epidemics. An example is

Destruction of Gaur

afforded by the story of the city of Gaur which from the 5th century A.D. to 1576 A.D. formed the capital of Eastern India. It was situated between two branches of the Ganges river, and another large tributary, the Mahananda, flowed near by. A very unhealthy swamp grew in its rear on account of changes in the river course and, possibly due to the lowering of the city level, the drains in the cities could not discharge the sewerage to the rivers properly. The result was the outbreak of an epidemic which swept away the majority of the population about the year 1575 and the vast city, which was estimated by the Portuguese merchants of the 16th century to contain a population of over two millions, now remains buried under an overgrowth of jungle.

Calcutta may share the fate of Pataliputra and Gaur

A similar fate seems to be slowly overtaking the present city of Calcutta, which is the successor of Pataliputra and Gaur as the premier city in Eastern India; its level has gone down within the two hundred years of its existence by about 2 to 4 feet below the level of the surrounding country and the drains from the city can no longer discharge their refuse matter to the surrounding river channels without pumping. The problem of Calcutta's drainage has been before the public for a long time but no satisfactory solution has been found. My friend, Mr. S. C. Majumdar of the Irrigation Department, has dealt exhaustively with this problem. Will the citizens of Calcutta profit by his advice or allow their city to run to destruction like Pataliputra and Gaur? The case of Calcutta also confirms the belief that in deltaic regions the level of cities has a tendency slowly to go down, while that of the surrounding country gradually rises. The result is that city sewerage does not flow through the drains, unless artificial methods are undertaken, and the city gradually becomes unhealthy. In fact, as has been remarked, Calcutta may be buried in the near future in its own sewerage. These slow changes therefore deserve more study and attention than spectacular catastrophes like a flood. In fact, a look at the ruins of old cities in the deltaic regions is sure to produce the conviction that a satisfactory method of city-planning in such regions has yet to be evolved.

6. *Modern Times.*

When the administration of this country devolved upon the British nearly two centuries ago, the task of maintaining all the ancient irrigation channels and storage tanks and keeping the rivers in order fell on their shoulders. From the very first the Government of India took the greatest amount of interest in irrigation work and it is estimated that a total capital of 150 crores of rupees has been invested in constructing new irrigation channels, building storage dams and repairing old works. According to the report of the Central Irrigation Board, about 30 million acres of land in India are being irrigated by these artificial canals which total nearly forty thousand miles in length. Of these, 22 millions are officially regarded as productive and the remaining 8 millions have been officially admitted to be unproductive. We have to consider whether the amount spent under irrigation has been sufficient, whether there is still room for improvement and expansion. What was the cause of a large percentage of works being unproductive ?

Further Scope for extension of Irrigation

On account of the peculiar orientation of the mountains and the seas, India is the recipient of a large amount of monsoon rainfall from the Bay of Bengal as well as from the Arabian Sea, within a short time. It is estimated that of the total rainfall on this continent, nearly 60 per cent gets evaporated, about 40 per cent passes through the river channels, and of this 40 per cent barely 6 to 8 per cent is utilized by the rural population for irrigating their fields. These figures alone show that in spite of large irrigation works already undertaken, there is still room for further expansion. The figure of 360 millions for the population of India may give the idea that India is over-populated, but the density of the population is only 200 per sq. mile, which is much less than is the case in many other countries with less resources. A careful survey of the facts shows that there are large regions in India which still require extensive irrigation works for further development. If these regions can be developed, then probably a large part of the population can migrate from over-populated areas to these regions and thus relieve the existing congestion. A greater expansion of irrigation will also result in the production of more foodstuff and other economic products and give us a better standard of living. We have further to consider in what way the existing arrangements can be improved so that a greater return may be obtained to the Government on the invested capital.

Railway Bridges over Rivers

A new factor was added to the problems already existing on account of the need which was felt in constructing bridges over these rivers. About 80 years ago, railways began to be constructed in India and it was found necessary to span rivers by means of well-designed bridges capable of carrying heavy railway traffic. Now the design of these bridges requires that the engineer should have a very accurate knowledge of the life of the rivers, its maximum and minimum discharge and their variations throughout the year, the nature of the soil and the total amount of precipitation in the basins over which the rivers pass. They had also to find out how the construction of a bridge will obstruct free flow of water through the rivers and *affect the surrounding rural area.* A further factor has arisen in recent times owing to the necessity of supplying the country with cheap sources of electrical power. To this topic, however, we return later on.

7. *Need of more River Physics Laboratories.*

The earlier engineers who were entrusted with these tasks treated the problem as they thought best and without meaning any disrespect to these early pioneers, it may be said that their actions have not always been very beneficial to rural interests. It is of course quite correct that the system of irrigation canals, which has been planned by the engineers within the last 100 years in the Punjab and the western parts of the United Provinces and parts of Madras and Bombay, has done immense good to the regions concerned and has brought prosperity and population to an otherwise waste area. But the same cannot be said of the deltaic regions of Bihar, Bengal and Orissa and parts of C.P. which contain most of the unproductive irrigation works. It appears that in the planning of canals, bridges and railway lines in these areas some very fundamental mistakes were committed. The case was very ably summarized by Sir Francis Spring, *the founder of River Physics in India.* While entrusted with the task of designing a bridge over the Ganges in Bengal, he went thoroughly into the problem and summarized the necessity of a River Physics Laboratory, in the following words :—

'As trustees of so fine a property as this—canals and railways, it might not unreasonably be expected that the State would see the importance of devoting a comparatively small annual appropriation to original research, on lines likely to be productive of a good return for the expenditure, in the form either of reduction in the first cost of its public works or of their safety and their economical up-keep when built. *Heretofore there has been no pretence of organizing any such research* in connection with the engineering of the canals and railways of India. *Engineers have gone on blundering, benefiting, rather by chance than by design, by the experience of their predecessors, and each considering himself lucky if he escapes disaster at the hands of the tremendous forces of nature—amongst which some of the most potent for good or evil are the great rivers—with which he has to struggle.* Until quite recently there has been practically no encouragement, and indeed at times there has been discouragement, to men to publish their experiences. And so, in spite of having perhaps as fine a body of scientific engineers as any country, not excluding France, has in its employment, and in spite of this body of public servants having carried out daring and extensive works of a certain character, chiefly, in connection with the great Indian rivers, on a scale unparalleled elsewhere, the State possesses the most meagre record of the history of the works carried out so successfully by its employees. In putting the chapters of this book (*River Training and Control* by Sir F. Spring) together, the author, found extreme difficulty in ascertaining what had been done, what difficulties had been encountered, and how these difficulties had been surmounted, and it has needed the expenditure of nearly.a year of research to enable him to offer to the Government of India the advice, contained in the foregoing chapters, in regard to one limited phase of the engineering of great rivers. Time will show the value of that advice, and doubtless further experience will modify the practice recommended. But meanwhile *the author would urge on the Government the importance, from a mere money point of view, of insisting on the maintenance of an intelligent record of the history of such works as those dealt with in the foregoing chapters.*'

The Consequence of lack of Organization.

'With regard to the physics of long reaches of the great rivers, the author is not in so good a position to speak. His special experience has been gained rather on short lengths of such rivers in contiguity to his works. In view of his practical inability to regulate the flow of great lengths of such rivers he has viewed the inimical consequences of the irregularities of their flow, in the form of deep and dangerous scour, as requiring to be fought by sheer irresistible force rather than by coaxing. This necessarily must be the attitude of the engineer in charge of great bridges, and perhaps to a lesser extent of those in charge of great irrigation weirs. But *they ought not, for that reason, nor ought the State, to lose sight of the importance of endeavouring, by consistent, logical and well-organized research, to learn something more definite than is now known about the physics of long reaches of rivers.* A perusal of chapters III and XXI, as well as of Mr. R. A. Molloy's Technical Section paper No. 118, will suffice to show how blindly, heretofore, in the interests of the residents on their banks, men have been fighting against the ill-will of some of the great rivers; whether on behalf of the maintenance of levees[1] whereby devastating floods are excluded from great inhabited areas; or for the conservation of the heads of inundation canals on whose integrity the welfare of many thousands of people is dependent; or *in the interests of riparian cities whose obliteration would be a blot on the administration of civilized and intelligent rulers. It is difficult to avoid the conclusion, after perusal of chapter XXI, that for lack of adequate knowledge, the engineers concerned with the interests of the inhabitants of the valley of the Indus have been obliged to work more or less in the dark in their fight with that river, and to make matters worse it has constantly happened that, owing to the climate, to the exigencies of public service, no sooner does one engineer get some small inkling of the tricks than he is replaced by one with all his experience to gain; and in six months he, in turn, is replaced by somebody else whose experience of the river has perhaps been limited to crossing it. How under so haphazard a system, anything gets done at all is a marvel*; and instead of being surprised at £100,000 worth of work having been wiped out, the State may congratulate itself if the loss is not double. However there is always the satisfaction, in the case of such expenditure as that dealt with in chapter XXI, that the whole of the money has remained in the country, and that if the taxpayer takes money out of his coat pocket only to put it into his waistcoat pocket he can always pick it out again, or its equivalent.'

Suggestion for the appointment of a River Commission.

'*The appointment, for say 10 years, of a River Commission not merely for the Indus, but for the organized study of the physics of great alluvial rivers*

---

[1] This is a word of French origin, which is used in the U.S.A. to denote embankments.

generally, would be a service to civilization and an act worthy of a great State. The Mississippi Commission have done a great deal, but their experience is not to any great extent applicable to Indian conditions. The experience of the engineers of the Rhone and the Danube and other European rivers, though valuable in its way, is even less applicable to India than that gained on the Mississippi. Mr. R. A. Molloy's attempt at a theory, as summarized very inadequately in chapter III, is the first that can be characterized as a scientific generalization of the river problem that the author has heard of in India. And even this is based on inadequate data, picked up anyhow, amidst the multifarious duties falling to the engineer to a system of inundation canals. There is need for a thoroughly scientific location, and for the automatic reading, of gauges at hundreds of places, for several years, along great lengths, selected with care and knowledge, of several of the great Indian rivers, also of some systematization of the surveys which usually are undertaken on these rivers, and of the making of fresh surveys specially designed to elucidate facts, also of an organized system of soundings and sections. The engineers in charge of the work must steadily keep in view the ultimate object of it, and must not make a survey merely for *the sake of a section. The object in view will be : To present to the scientific world, and especially to the engineering world, and more particularly to the engineers of structures in India that are subject to fury at the hands of the great alluvial rivers, such an explanation of the probable action of these rivers, under various circumstances, as will allow of such action being anticipated ; and especially, to enable the engineer to utilize fully his knowledge of the rivers,* so that he may make a servant of it, instead of being as it is now very often the case, his master. There can be no doubt at least from the author's point of view—*that more money has been wasted, for want of just such knowledge as a River Commission might provide, than would have sufficed to pay the entire cost of it many times over.* Certainly, so far as training works in connection with bridges are concerned, in rivers of the class with which the author has chiefly concerned himself, most engineers responsible for such works would probably admit that whether they spent money unnecessarily as an insurance against their inevitable lack of scientific data, or that they were unduly economical, with either disaster, or heavy annual recurring expenditure in after-years, as the result. Thus looked on from the lowest or merely commercial standpoint, the establishment of such a Commission ought to be highly remunerative.'

The Government very slow to adopt Spring's advice

Unfortunately the sound advice given by Spring has not been acted on very quickly by the Governments. But Sir F. Spring was not the only man who voiced this opinion. Mr. Reakes, who was entrusted by the Bengal Government with the task of surveying the Nadia Rivers, was so puzzled by the problem of river changes in Bengal, that he made practically the same recommendations as Sir F. Spring. But the Bengal Government has shown no intention of profiting by these advices. It is only the

Punjab Government which profited by the advice given by Spring, and has created, within the last 10 years, a well-equipped research laboratory, the staff of which contains, not only irrigation engineers, but also physicists, statisticians, mathematicians and people belonging to other branches of science, who can render sufficient help in tackling the problems of irrigation and of river control. The Central Government maintains a River Physics Laboratory near Poona, where experiments on the models of the rivers have been carried on under the able guidance of Mr. Inglis for about 10 years, and many problems submitted by engineers from different parts of India have been tackled there. But considering the vast size of the country, the diversity of the problems in the different regions, the number of laboratories is extremely small and the equipment of those laboratories which have been constructed is not sufficient. Even in the Punjab, the work done is not considered sufficient. Dr. Mackenzie-Taylor, Director of the Irrigation Research Laboratory of the Punjab, says:

'Though India is a country of mighty rivers, very little has been done here by way of experiments in the laboratories on river models. Only in recent years have some experiments been conducted at the Hydro-dynamic Research Station at Khadakvasla near Poona and at the Punjab Irrigation Research Institute, Lahore.'

The provinces of the lower Ganges valley which, more than any other provinces, require a thorough field study of their rivers, as well as investigations on river-models in laboratories prior to any work being undertaken, have hitherto shown complete indifference to the proposals of having hydraulic research laboratories. All the same, blundering projects have been pushed through, which have wasted crores of the taxpayers' money. A small fragment of these sums, spent on the establishment and proper equipment of hydraulic research laboratories, would have been of immense benefit to the country.

8. *Problems of the Lower Ganges Delta.*

I will illustrate my case by special reference to Bihar and Bengal. I have already told you that the problems in these two provinces are entirely different from those of the semi-arid areas of the Punjab and the upper Ganges valley, yet in the past works have been pushed on in these provinces which ought never to have been undertaken. The main problem as you see here is not one of supply of water in the same way as to the thirsty areas of the Punjab or of the Western U.P., but entirely different. These provinces have a copious rainfall, the peasantry here very seldom require water for irrigating their fields; the problem here is to get rid of the excess water as quickly as possible, prevent the rivers from changing their courses, minimize the effect of destructive floods, and prevent the formation of unhealthy marshes and swamps. This can be done only by a judicious control of the activities of the rivers or by river-training. Unfortunately the engineers who were entrusted with the planning of bridges and embankments for the protection of railways in these provinces, and also with the charge of irrigation, were not sufficiently familiar with the peculiar conditions of these provinces and used in the solution of their tasks their knowledge of irrigation obtained in other provinces. This has been mainly responsible for the large amount of wastage in irrigation which is marked by the department as unproductive. But it has done worse things than that. The people of Bengal have always clamoured that the railway embankment has ruined the Burdwan division. It changed the courses of rivers in this division and deprived the land of the fertilizing silt. The Burdwan division became thereby a victim to malaria which, between 1860 and 1870, carried off nearly half of her population.

Central Bengal, a country of dead rivers

The same is true of Central Bengal but here the ravages are due to the change in the course of the river. The Ganges used formerly to discharge its water through the western branches but now the mouths of these channels have been silted up and the main mass of water flows through the easternmost channel. This has made Central Bengal a land of dead rivers and swamps and a prey to malaria. The problems of Bengal have been so very ably treated by Mr. S. C. Majumdar that it is useless for me to go into great detail. By his careful survey and analysis he has also pointed out the way in which the rural conditions can be improved. He has clearly shown that this can be done only by the undertaking of a large amount of engineering work aimed at controlling the rivers judiciously. But I submit that satisfactory results can be achieved only if the problem is studied very carefully before any work is undertaken. The need here is for studying the rivers intimately. We must take observations for a number of years regarding the flow of rivers, variation of the flow throughout the year, how they depend upon the precipitation in basins, how they deposit their burden of silt and what is the action of the silt on the fertility of the soil. We have to undertake fundamental experiments, for as Dr. N. K. Bose and Mr. Lacey will tell you there are many fundamental problems in river physics which still await solution. They are still the subject of careful study by distinguished workers. It is necessary to have in each region a River Physics Laboratory where the fundamental problems will be handled by a number of expert pure scientists. In addition there is need for a properly equipped field survey department which will survey the contour and geological formation, the carrying capacity of the river-beds and ultimately, whenever any constructional work is proposed, this should be studied by a laboratory model carefully. After all these studies are completed actual work should be undertaken.

9. *Cheap Electrical Power.*

Within the last fifty years, another use has been found for running water which is as important as irrigation and navigation, viz. generation of cheap electrical power out of the energy of running water. This is a subject which is just beginning in India, but its importance has not been properly realized. I wish therefore to dwell at some length on this point.

Analysis of Professions in India

Everybody knows that India is an agricultural country. According to the Census Report of 1931, 66% of the Indian population is engaged in agriculture, i.e. are peasants, i.e. they have to spend their life in raising food. Of the remaining 34%, only 11% are city-dwellers, i.e. engaged in industries and other professions. The remaining 23% are either village artisans, merchants, landlords, or belong to other professions mainly dependent on a rural economy.

India, a land of poverty-stricken peasants

Everyone will admit that the distribution of the population according to professions reveals a very unhealthy state of affairs. In no other country of the world, excepting such backward ones as China, is there such a large proportion of peasants. And do these peasants enjoy a good living? A few huts, mostly without doors or windows, a few mats and rags, a few half-starved animals, hunger, debt, and frequent disease,—this is all they have to enjoy!

Agricultural Improvement—no solution of the poverty problem

There is a widespread desire for improving the lot of peasants and to raise the general standard of living. But how can this be achieved? Not by an exodus of the townsmen to the villages as advocated by certain persons distracted by middle class unemployment; for that will merely increase the pressure on the overcongested rural area and multiply misery. Greater efficiency in agricultural methods, which is certainly desirable, may give us more and cheaper food, and other necessities of life obtained from agriculture (like cotton), but it can never touch even the fringe of the poverty and unemployment problem. For greater efficiency amounts to the fact that the same production in agriculture can be effected by half the present number. At present, the proportion of food-gatherers is 66%. They produce food materials and other products by the most primitive methods. If improved scientific methods are adopted, larger amounts, more than sufficient for the whole nation, can be produced by 30% of the population. This will render about 36% of the peasant population unemployed. This added to the already existing middle class unemployment will render matters worse.

Industrialization the only solution of the poverty problem

If we analyse the widespread public sentiment for better living, what do we find? Everybody of course wants his food supply to be insured, but this is the least part of his demands. He wants to be better clothed and better housed; wants to get a better education for himself and his family, more rest from work, freedom from drudgery and greater enjoyment of life. Analysing this sentiment, we find that if these needs are to be satisfied, the quantity of industrial products has to be increased ten to twenty times its present level; all these works have to be organized, and a large proportion of the village population is to be diverted from the task of food-raising to industrial work. In fact, the only way to improve the villages is by drafting more villagers to the cities, and by creating a larger number of cities based on industries.

10. *India's fitness to be industrialized.*

India has sufficient resources for efficient industrialization

But all countries, even if they want to have a better living, as is reached to-day by some European countries, cannot do so on account of their intrinsic poverty in natural resources. The source of potential wealth to-day is not merely good agricultural land of all varieties, capable of yielding all kinds of food and other economic products, but also mines, capable of yielding minerals useful to man, and sources of power (coal, oil, peat and other fuel, water power). A recent writer in the *East Indian Review*, analysing the conditions of the world, finds that only three countries in the world satisfy these conditions, viz., U.S.A., Soviet Russia, and India. He traces much of the present political troubles of the world to poor resources possessed by many ambitious nations. Italy, for example, has almost no coal or iron, and very little mineral resources. Hence her desire to seize other undeveloped lands, otherwise she cannot reach the modern standard of better living. Japan is almost in an identical condition, and is further handicapped in having poor agricultural land as the country is not suited for the production of any agricultural stuff other than rice and mulberry. Cotton and oil-seeds cannot be grown on her soil. Hence her desire to seize parts of China. According to this author, China, even if she were not pestered by foreign aggressors, and could solve her own internal problems, can never attain the level of the U.S.A. or the future Russia, because her mineral resources are poor. Only India possesses all kinds of resources in abundance; she continues to be poor, only because these resources have not been developed and industrial work has not been properly planned and organized.

How to organize production and distribution of commodities essential for civilized human life

The wealth of a people is neither a gift of the heavens, nor a gift of nature. The people have to create wealth by organized labour. The more the output of work by a country, the richer it is and the higher the standard of living reached. Probably, most of our countrymen have no idea that the total work output by the average Indian is twenty times less than that of the average American and European. In previous epochs of history, all the work used to be done by human power, or animal power. But at the present time, most work is done by steam-engines, oil engines or electricity. Let us compare quantitatively the work output per man in Norway and in India. I am taking Norway because there all power is electrical and can be easily calculated.

The League of Nations' Year-book tells us that the average Norwegian consumes 1,600 units of energy per capita in the year, which is mostly derived from the harnessing of her rivers and waterfalls.

As we shall see presently, the man power and animal power probably does not contribute more than 80 units per year. Hence the total output of energy per capita in a civilized State is about 1,700 units. With less output, the standard of living would go down.

India produces 20 times less work per capita than European countries

Let us see the average output per Indian. The electrical energy per capita in this country is only 7. Steam and oil power will not amount to more than 10. Let us now calculate the work done by man and animal. A labourer working for eight hours daily produces only $\frac{6}{10}$ units and in a year of 300 working days he does not produce more than 180 units. But only one-third of men and women are active. Hence the average output per year per capita is only 60 units. Taking the work done by animal power to be 10, the total output of work per capita per year is only 90 units. This is nearly twenty times less than the work output per European, and about 6 to 8 times less than that of the Japanese.

To use figurative language: The average European has 20 slaves constantly working for him while the Indian has mostly to depend upon himself. The slaves which the European calls to his aid are provided from the exploitation of the power resources of his country. Such resources though they exist in India have not been developed and profitably utilized. This is the root cause of poverty in India.

Not only have the power resources not been developed, but the available power is extremely dear. This is one of the main causes of India's backwardness in industrialization.

Dearness of Power

How much India is handicapped in this respect may be gathered from the fact that the price of power in this country for the greater part of the country is four times that in England and Japan, except probably for steam power, which is not suited for many industries, and is not available in all parts of the country.

Thus the cheapest electrical power at Calcutta costs ½ anna—·57*d.*, the average price of power is about 1*d.* and at Allahabad—2 annas—2·2*d.*; in London electricity if bought in bulk can be had for ½*d.* per unit.

High Price of Power

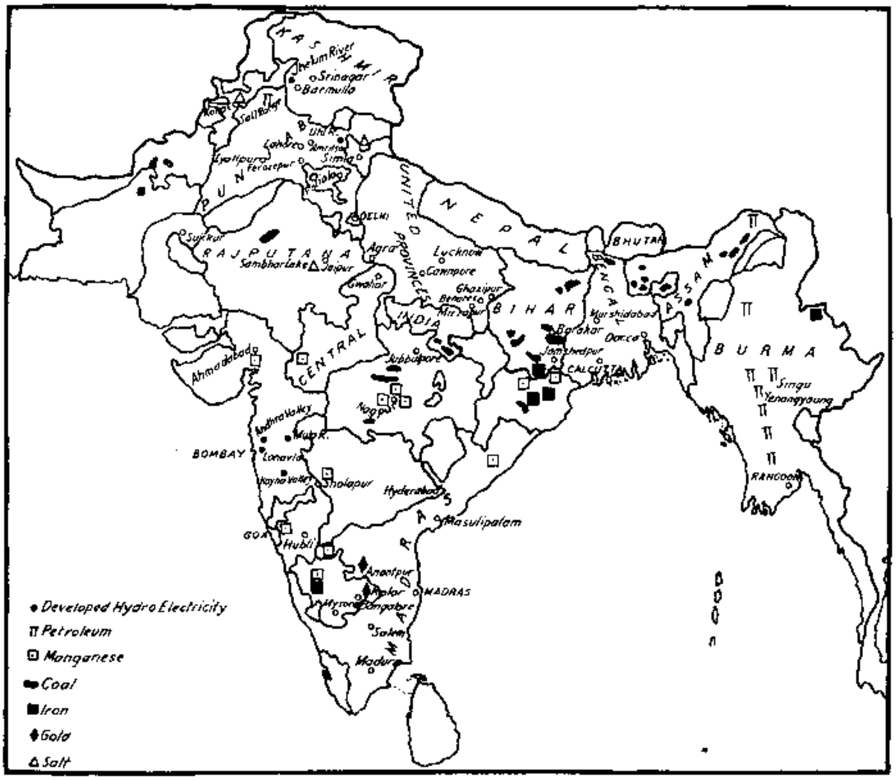
The price of petrol varies from Re.1-2 as. to Re.1-10 as., while the price in England and Japan is about 6 annas. Most of the extra cost is due to customs duty and railway freight. The landing cost is only about 4 annas. On account of the great cost of petrol, Otto engines are very expensive to work in India.

It is on account of the high price of power that industrial enterprise has so far been confined to cities like Calcutta which are near coal mines, or Bombay which possesses, thanks to the enterprise of the Tatas, cheap hydroelectric power. Other areas cannot develop unless they are provided with cheap power.

11. *How to develop power resources.*

India rich in Power Resources

But it may be asked, are there sufficient power resources in India? Like some other countries in the world, India may be intrinsically poor in power resources. Let us consider this problem in detail. The chief power resources are:—Coal, water power, oil, shale, and other fuel (peat, wood, bagasse, power alcohol and vegetable oils).



MAP 6.
(From Coggin Brown's *Mineral Resources of India.*)

I have before you a map of India (Map 6) showing the occurrence of coal deposits. You will see that these resources are present only in certain parts of Bengal, Bihar, Orissa and Assam, in other words in Eastern India. Other parts of India are extremely deficient in coal, or do not possess it at all. If India wants to be industrialized, it must develop its available water power. Let us see how much has been done in this connection.

The water power resources of India have not yet been adequately surveyed except in a few isolated regions. The work which was started under Meares in 1919 was unfortunately stopped for some unknown reason. According to this authority, the total resources amount to about 20 million kilowatts, but this may probably be a gross underestimate, as in the case of Soviet Russia.

Necessity for development of Water Power

The total power which has so far been developed amounts to about half a million kilowatts installed. Of these, ·3 million kilowatts or about 60% is due to an Indian State (Mysore) and private (mostly Tata's) enterprise, and the rest is due to the enterprise of the Provincial Governments.

These figures show that only 2·5% of India's hydroelectric power resources has been developed.

The efficiency of the undertakings which have so far been developed leaves much to be desired.

The earliest large project in India is the Sivasamudram Hydroelectric Works in Mysore which owed its genesis to the far-sighted vision of Dewan Seshadri Iyer of Mysore. It has developed nearly 50,000 kilowatts, and the cost of installation has been nearly Rs.500 per kilowatt installed. The three Tata projects near Bombay cost about Rs.500–600 per kilowatt installed, inclusive of transmission lines.

Bad beginning in hydroelectric development

The upper reaches of the Indus and the Ganges valley offer unique opportunities for hydroelectric development and there is great need for such development if these areas are to be industrialized, as there exists neither coal nor petrol in sufficient quantity in these parts. But the results obtained so far have been rather discouraging. The Mundi Scheme in the Punjab, which was launched under Government initiative against the almost unanimous opposition of the people's representatives, cost nearly Rs.3,000 per kilowatt installed ; this holds the world's record for dearness, and is about 10 times dearer than the average cost of installation of plants of this size in Europe and America. The Western Ganges Hydroelectric Scheme which appears to have caught the imagination of a large majority of our countrymen cost Rs.1,200 per kilowatt installed. This holds the second highest record for dearness, and yet such a project has been hailed as a great work by a section of our countrymen.

But the reader may ask, what have rivers to do with electrification schemes ? As has been pointed out, electrical power in most parts of India can be obtained only from water power, hence it is obvious that before an expensive scheme is launched (and all hydroelectric schemes are expensive), extensive preliminary studies are to be made. These include a summary of the water power resources showing the variation of discharge of rivers, possibility of erecting storage reservoirs, finding out the best site, and further economic survey with a view to utilization of all the power developed. Even when a site has been chosen, extensive laboratory experiments should be carried out with the aid of models on the proposed dams, weirs, reservoirs, etc. before any work is actually undertaken. If one goes critically into the history of the unsuccessful works just mentioned, he will find that the root cause of failure was that schemes were launched by enthusiasts (in many cases by amateurs in hydroelectric engineering) without adequate surveys and preliminary experiments. In the Mundi Scheme, nearly 6 crores of rupees were wasted before it was discovered that the river from which power was to be tapped almost ran dry during the hot season. If a small part of this money was spent on adequate surveys, and preliminary laboratory researches, probably the Government would have received a handsome return on their investment, most part of which has now to be written off as unproductive.

Example of Soviet Russia

Let us contrast the procedure adopted in this country with that in Soviet Russia. Before the Great War, Russia was no better than India. She was mainly an agricultural land, 70% of the population were peasants, almost as poor and ragged as the present-day peasants in India. Industries were in a backward state, and power was undeveloped and considered a luxury. The total amount of electrical energy per capita was only 15 units which, in 1919, owing to the ravages of the War and the Revolution fell to about 5 units. She was without knowledge of her power resources, without experts and technicians. It was during these dark days that Russia, under the influence of Lenin, started schemes for planned electrification for the whole country which was part of the larger scheme of complete industrialization. Now within a short period of 16 years, Russia is producing nearly 300 units per capita. Her production of electricity in 1937 exceeded that of any other country in the world, excepting the U.S.A., and if she can complete all her schemes, she will soon overtake the U.S.A. Needless to add that thanks to this intense electrification, Russia has passed from an agricultural State to an industrial one, and now 70% of her population are reckoned as industrial workers. She is on a fair way to the solution of the problems of poverty, disease and famine which perpetually haunted her peasant population of 70% before the Revolution.

There is a great prejudice in this country as well as in Europe against everything Russian, but not being a politician I am not interested in their political theories or the execution of those theories. What strikes me as a scientific man is the extraordinary use they have made of modern scientific knowledge in solving their problems of poverty and want, and the extremely judicious and businesslike fashion in which they proceeded with their schemes and co-ordinated the labours of economists and technicians. I have on my table a book written for the World Power Conference on the Electrification of Russia. We learn from this book that when the supreme council of the Soviets adopted Lenin's resolution for the electrification of the country, it was the U.S.S.R. Academy of Sciences and not a committee of bureaucrats which was requested to give a plan. Under the guidance of the Academician Prof. Krzhizhanovski the following plans were adopted: (1) Immediate establishment of a Power Research Institute for undertaking a survey of the existing

The Russian Method of Attack

power resources, coal, peat, oil, shale, and above all of water power, in the U.S.S.R. (2) Establishment of an extensive scheme of hydrological survey—so far the U.S.S.R. possesses 5,200 hydrological stations of all classes, for surveying the discharge of rivers at different points, their variation throughout the year, etc. (3) Establishment of a number of River Physics Laboratories at Tashkent, Moscow, and Leningrad and other centres where researches with laboratory models of projected weirs, dams, embankments, canals are carried out before any work is actually undertaken. (4) Establishment of a comprehensive scheme for training an army of technicians in Russia.

It goes without saying that the plan adopted by Russia is the correct one. A scheme is known by its fruits. Russia now instals every year power-stations of millions of kilowatts capacity instead of thousands. The energy produced is utilized by the properly planned industries, and in transport, and only a small percentage is utilized in agriculture. Thus within the last sixteen years, the nation has passed from a community of half-starved peasants to well-fed and well-clad industrial workers.

12. *Conclusion.*

Before I conclude, let me place before you a challenging statement from a very interesting book by Dr. Vera Anstey. In her 'Economic Development of India' (1936) she says :—

> 'Here is a country of ancient civilization, with rich and varied resources, that has been in intimate contact with the most materially advanced countries of the West, but which is still essentially mediæval in outlook, and organization, and which is a byword throughout the world for the poverty of its people.'

Then she quotes Mr. M. L. Darling :

> 'The most interesting thing about India is that her soil is rich and her people are poor' and asks herself :

> 'Can India be called "Mediæval" when it is organized under a modern form of constitutional Government, possesses a great system of mechanical transportation, a unique system of irrigation, no less than seventeen modern Universities, and has several large-scale industries producing with the most up-to-date machines that have yet been invented ?'

The answer, however galling to our pride, must be that in point of poverty, ignorance and disease, India of today can only be classed with China and Abyssinia, countries which are still steeped in mediævalism, and have paid the price for continuing mediævalism.

If we desire to fight successfully the scourge of poverty and want from which 90% of our countrymen are suffering, if we wish to remodel our society and renew the springs of our civilization and culture, and lay the foundations of a strong and progressive national life, we must make the fullest use of the power which a knowledge of Nature has given us. We must rebuild our economic system by utilizing the resources of our land, harnessing the energy of our rivers, prospecting for the riches hidden under the bowels of the earth, reclaiming deserts and swamps, conquering the barriers of distance and, above all, we must mould anew the nature of man in both its individual and social aspects, so that a richer, more harmonious and happier race may people this great and ancient land of ours. Towards the realization of this ideal, we must adopt ourselves to the new philosophy of life and train the coming generations for the service of the community in scientific studies and research.