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An Introduction to the Study of Modern of Geography.

BY

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Since the days when Thales of Miletus wrote some of the earliest chapters in geography down to the present atomic age when nations are reorganising themselves into a new world-pattern, there has been a tremendous evolution in the geographical ideology. The earliest geographers of pre-Biblical times were in fact Ionian philosophers. The writings of Aristotle, Hipperecus, Eratosthenes and others were dominated by a philosophic conception of the cosmogonical aspect of the physical universe as well as of the natural phenomena going on over the earth. The Greek period of natural philosophy was followed by the Roman civilsation period when the geographical thought was more dominated by the utilitarian spirit of the Romans than by the philosophic spirit of the Greeks. The Roman geographers led by Strabo, Ptolemy, Pliny and others, developed a descriptive and practical geography which was nothing more than itineraries and topographical dictionaries, motivated by a commercial interest and a spirit of colonial expansion. After the fall of Roman civilisation the Arabs in the East Mediterranean became the heirs of Hellenistic culture and an impulse to spread their religious and commercial sphere gave an impetus to the pursuit of geographical science by them. The Arab geography was conspicuous in its emphasis on the 'human aspect' in contrast to the physical aspect of geographical study and in its greater accuracy and precision over that of the Greeks and Romans. Ibn Khordad-beh, Yakubi, Masoudi, Idrisi, Ibn Batuta were all notable traveller-geographers of the Arab-world since the 9th century, writing descriptive and physical geography, while Albiruni's contribution included explanations of many of the physical phenomena and Ibn Khaldun, a pioneer in social science gave comprehensive analysis of human civilisation from a geographic view point. The Chinese had also contributed to the store-house of general geographical knowledge through many of the travel talks and anecdotes written by notable Chinese travellers like Huen Tsang, Fah Hien, etc. After this 'old period' of geography no significant contribution in geographic literature was made until the early part of the 19th century when a renaissance of 'new geography' dawned upon Europe under the guidance of two great German scientists, A. Von Humboldt (1769-1859) and Karl Ritter (1779-1859). They established the 'new geography' on a firm scientific footing, placing most emphasis on the idea of relationship between the facts of physical world and the activties of man. Through their masterly contributions and interpretations they set forth the foundation of those branches of geography which were to take the form of physical geography and human geography in subsequent times. The fundamental point in the new geographical ideas of the 19th century was that it approached the study of geography from a methodical and scientific standpoint and that it regarded man as the central objective of the subject, his earthly life having an unbroken causal relationship with the forces of natural environment. The inception and growth of this basic conception in the new geographical thought owed much, as Dr. Newbigin tells us, to the influence of the contemporary Darwinian outlook, which indicated that "there is a delicately adjusted balance between

organisms and their surroundings, taken in the widest sense". But while Darwin's emphasis was on the fundamental relationship of evolution of all biological organisms to their environment, Ritter, 'more a historian and a philosopher than a scientist', went still further in his theory that the fundamental principle in geography must be "the relation of all phenomena and forms of nature to human race". Ritter conceded that the influence of climate and physical features were not only predominating in the individual and group life of man but also over human race, and as such racial traits and characteristics were controlled by diverse environmental factors. This idea was prevalent in the scientific thought of the last century but is now losing ground in the face of systematic investigations.

The scholarly contributions of Friedrich Ratzel, Professor of Geography at Leipzig, about 20 years after Ritter and Humboldt, gave a strong stimulus to the growth and development of the humanistic side of geography which in subsequent years was to culminate as Human Geography in its widest sense. Ratzel revived the traditional method of understanding humanity and human activity as geographic facts in a new angle. But while his predecessors conceived only a relationship between man's activity and his milieu, Ratzel followed mainly and developed more precisely the contention of his illustrious master Ritter and asserted that every phase of human activity in his quest of food, shelter, and security was strictly controlled by the physical environment in which he lived, and as such natural environment was to him a dictator of human activities. 'He saw human groups and human societies developing always within certain natural limits (Rahmen), occupying always a certain definite place (Stelle) on the globe, and needing always, in order to nourish themselves, to subsist, to grow, a certain space (Raum)'. Ratzel was in fact the founder of the 'deterministic school of thought' in geography and followers of this school, the most notable of them being Ellen C. Semple of U. S. A., approached the study of geography definitely from the environmental standpoint. For, they would argue, are not the people of Russian Steppelan essentially nomadic, those living by the side of Staffordshir coalfield mainly miners, those of Yangtze valley essentiall rice growers, and those living near the Japanese coasts fisher men? Even the modes of life, types of culture and forms of social institutions of man according to the Ratzelian school of 'geographical determinism', are rigidly determined by the physical environments in which he lives. Ratzel's own contributions also enriched the physical and social side of geography to some extent and he organised and edited a valuable collection of writings by such scholars as Heim, Krummel, Penck and Hann.

Modern Geography—Physical.

The early decades of the 20th century saw the dawn of 'modern geography' which subsequently found its expression in two positive channels - physical, and, cultural and humanistic. Physical geography was so long without its own separate entity and was in fact an amalgamation of studies in astronomy, geophysics, geology, meteorology, botany etc., each of them aiming at the study of the superficial environment of the earth from its own standpoint. Since the days of Hindu Pre Vedic sages (3000—1500 B.C.) who propounded 'The Samkhya cosmogony and since Kant—Laplace's hypothesis on the evolution of the universe, there has been a revolutionary evoulution in the realm of physical science. Since the last century, T. C. Chamberlain, F. R. Moulton, H. Jeffreys and lately Sir J. Jeans and many others threw much light on the origin of the solar system and the development of the earth as a planet. Brilliant contributions from eminent scholars like Wegener, Argand Suess, du Toit, Daly, Hobbs, Geikie in the field of geology, Humphreys, Bruckner, Simpson, Shaw and Bjerknes in the field of meteorology and from scientists like Murray, Darwin, and others on various aspects of oceanography no doubt enriched the physical side of geography from time to time. But they lacked a systematic integration and a positive outlook of its own in scope and content in a definite field of natural science. It was in the 20th century that the foundation

was gradually laid in the systematic study of the physical geography which subsequently found its expression through a number of separate branches of study thus giving it a distinctive entity in the realm of natural science. The important branches of the modern physical geography which thus came into being are Geomorphology, Pedology, Mathematical geography and Bio-geography each of them dealing with a particular element in the entire natural environment of man.

Geomorphology

Since the inception of the doctrine of 'uniformitarianism' as enunciated by James Hutton in 1795 and subsequently illustrated and developed by John Playfair and Charles Lyell, there was been a gradual evolution in the concept of the origin and development of landforms. Later investigations in American fields by J. W. Powell, C. E. Dutton and G. K. Gilbert all confirmed the validity of the Huttonian principle of slow and gradual development of landforms and added significantly towards the concept of base—levelling of the landmass as the ultimate stage in its degradational changes. It was by the lifelong investigations and an original mode of approach by the late William Morris Davis (1850-1934), the doyen of physical geography in the United States, that the whole discourse on geomorphic study was systematised and a new life was infused to the conception of the evolution of landforms. He revived the study of landforms from the throes of 'uniformitarianism' and accorded a philosophic interpretation and a logical explanation to the entire life-history of landscape. Landscape, the central objective in geomorphic study, was interpreted by him in terms of complex reaction of rock materials, climatic conditions and geologic movements and as such the central theme of geomorphology according to him involved the study of the origin, development and decay of landscape under the influence of climatic forces over the earth and geologic forces beneath it. His theory of the 'cycle of erosion' conceives the existing type of landscape as a function of geologic structure, process of erosion and a definite stage in its life history, and every landform passes through a stage-cycle of youth, maturity and senility from its newly uplifted state to an ultimate levelled plain, called 'peneplain' by him. This process of upheaval and peneplanation is going on eternally over the surface of the earth 'having no prospect and no end'. The logical outcome of his theory is that the same kind of rock material under the same erosive process and of the same stage would produce identical topography in different parts of the earth, whereas under the same geological structures and erosive action but in different stages, landforms would be quite dissimilar. This introduction of 'time-element' in the study of landscape has infused a new life to the dynamic aspect of geomorphology and has made it a dominating theme in physical geography. Many French, Dutch, Scandinavian, Finnish, Swiss and Italian geographers and geologists have conceded to the American school of thought as expressed by Davis and through their intensive investigations and scholarly interpretations of landforms along Davisian line have built up a magnificent store house of geomorphic literature. Of them the most important would be E. de Martonne of France, S. Passarge and J. Walther of Germany, Prof. H. Bauling of Strasbourg, C. A. Cotton of New Zealand and W. W. Atwood, N. M. Fenneman and O. D. Von Engeln of U.S.A. But the German school of thought as initiated by F. Von Richthofen and Prof. Albrecht Penck and subsequently developed by young Walther Penck pursued an independent approach to the study of landform and W. Penck openly challenged the fundamental concept of the Davisian School on the charge of over-simplification and divorcement from geology. Penck attacked Davis on the sequence of stages in the evolution of landscape, that is was not cyclic as Davis maintained but was a continuous degradational sequence, and that conditions envisaged by Davis were very special cases in denial of the diastrophic character of the landmass. Though the German viewpoint has won very little acceptance, Penck's criticisms surely brought to light certain aspects of geomorphic study hitherto neglected. Similar systematic studies on the evolution of landforms under desertic, glacial and marine erosion have been made in the present century. J. Walther, S. Passarge, W. M.

vis and A. C. Lawson studied the erosion-cycle under ertic conditions; W. M. Davis, D. W. Johnson and E. de artonne made significant contributions on the evolution of shorelines and coastal topography under marine conditions; while the development of landforms under conditions of past and present glaciation has been studied by Davis, Johnson, de Martonne, Von Engeln, Garwood, Flint, Anters, Demorest and others. Thus a separate sub-branch of study—'glaciology'—studying he conditions of past and present glaciation and their attended andform and drainage-pattern from a scientific stand point is n the offing. All of them have thus added significantly to the eneral geomorphic study of the earth's crustal face making it n outstanding and ever widening branch of physical eography.

Climatology.

Next to geomorphology, the study of climates may be ken as an important topic in the realm of physical geography Next to landscape, climate is the most important environmental lement that influences, if not controls, directly or indirectly very physiographic process over the earth and every phase in he life of biological organisms. In fact, climate has been the great dictator in human life-physical or cultural, since the pre-historic days and many a lost kingdom and seat of culture, now buried under the thick sandy wastes of Arabian desert, Indus Valley or Central Asian highland bears eloquent testimony to the avages of a progressively inhospitable climate. Prof. . Huntington of Yale has made a wonderful study of the ecline of the early Eurasian civilisation consequent upon e changes in climatic condition and after a painstaking investiation on the quantitative relation between the two, maintains hat there is an optimum climatic condition of a minimum inter temperature of 40°F and a maximum summer temperture of 70°F with a variable cyclonic weather which promotes aximum human energy and physical efficiency and as such egions of such climatic optima are regions of maximum material culture and progress. The general contention of Huntington's theory of geographic control of the present day material civilisation has been corroborated by later investigations in applied climatology, social demography and in various problems of colonisation. The overwhelming supremacy of climate as a geographic element dictating its laws upon the organic life of man, animal and plants has led to an elaborate and systematic study of climates over the entire earth. Two German geographers, E. Supan and W. Koppen can be taken as the founders of the science of climatology while Dr. J. Hann of Vienna, E. de Martonne of Sorbonne, E. W. Thornthwaite of U. S. A. are some of the foremost exponents of the science. Koppen's work was monumental in its scope and application, in being the first systematic classification of the world climates after Supan, based on some quantitative criteria of temperature and rainfall in association with certain significant indices in the vegetal kingdom. But Koppen's system has been lately an object of criticism in being too rigid a scheme often lacking scientific validity and incapable of accounting for local climatic differentiations. As late as 1931 C. W. Thornthwaite of the United States Department of Agriculture proposed a new scheme of classification of climates based on 'precipitation effectiveness' and 'temperature efficiency' as being two significant geographical criteria in the organic life of plant and man. His scheme seems to be more scientific in approach, though often too mathematical and more in consonance with the response of vegetation and soil distribution to climatic conditions and it claims to establish a quantitative relationship between the two. A clear realisation of the predominating role of climate on the growth of plant and on raising of crops has lately stimulated studies in 'agro-climatology' as applied to the agricultural occupance of man, towards which a number of climatologists including R. de C. Ward, C. E. P. Brooks, S. S. Visher and G. T. Trewartha of the United States, G. Taylor of Australia and Prof. Kolaskov of U. S. S. R. made notable contributions.

Soil Geography-Pedology.

Pedology, or more precisely 'soil-geography' is another aspect of physical geography having its inception only in the present century. With increasing knowledge and interest in the soil-mantle of the earth as being a geographical element in the natural environment of man upon which about three-fourth of human race is ecologically bound for subsistence, studies in the morphology, genesis and environmental relationship of soils had attracted attention of scientists of Europe since a long time. Since Berzelius' and Liebig's classical studies on the 'chemical theory' of soils, studies in soil science was motivated only by its productive utilisation and its fertility. It was in Germany that the studies of Sprengel and Fallou conceived soil as a separate 'natural body' in the natural environment and pedology an independent science quite distinct from physics, chemistry or botany. But the German school as initiated by Fallou and followed by Werner, Berendt, Ramann, Hilgard, Richthofen and others, laid emphasis on the chemical or geological aspect of soil development and failed to grasp the significance of a set of distinct soil-forming processes in the evolution of soils. It was due to the pioneering work of the great genius V. V. Dokuchaev, the founder of the Russian school in pedology and of his Russian followers N. M. Sibirtzev and K. B. Glinka, that the supreme role of 'pedogenic process', a complex physico-chemical process conditioned by the climato-floral-biotic conditions, in the evolution of the soil profile and in giving a complete expression of the character of the soil was recognised and consequently Russia has been hailed as the cradle of modern pedological thought. A number of pedo-geographers of Russia, D. G. Vilenski, S. S. Neustreuev, Y. N. Afanasiev, A. Yarilov and others worked subsequently on the geographic aspect of the genesis, distribution and classification of soils, and in the third decade of the present century, C. F. Marbut, the leading American pedologist being influenced by the Russian school of thought through Glinka's work, made some significant contribution to the 'geographicity' of soils, that is to say geographical aspects of the genesis and distribution of soils over the earth as a whole and over the United States in particular. In short, in modern pedology the role of geographic environments, especially the climatic milieu in the origin, evolution and distribution of the major soil-types over the face of the earth has been scientifically established and a true picture has been drawn which shows a complete concordance between them. Among the numerous scientists who contributed towards the geography of soils in one form or other, reference may be made to the works of A. Yarilov, Y. N. Afanasiev, S. S. Neustruev, J. S. Joffe, B. B. Poluinov of Russia, A. A. J. De Sigmund of Budapest, G. W. Robinson, E. J. Russell of Great Britain, H. Stremme of Germany, C. E. Kellogg, H. H. Bennett and L. Wolfanger of the United States, C. F. Shaw of China, and R. L. Pendleton of South-East Asia. It is strongly felt that 'soil geography' is soon going to expand in its scope and content as an important field of study along with the rapid progress in the realms of colloidal chemistry, plant ecology and climatologic sciences.

Bio-Geography.

Another branch of physical geography may now be recognised - 'biogeography'. Studies in the geographic control of the growth, distribution and association of different species of plants and animals form the subject matter of biogeography. Since the classical investigations on plant geography in Germany by Humboldt, Haeckel and others in the last century, until the 20th century, studies in ecology of plants, such as by Schimper, Warming, Clements, Campbell and others, the environmental control of the physiologic and morphologic characters of plants and their communities have been too significantly recognised. As a result, plant geography has occupied an important place in the physical side of geography. More recently studies in crop-geography, have been undertaken in order to ascertain the relation of crops to their specific environments. Same is true in the animal kingdom, though the principles here are more flexible. Interest in the geographical influence on the biological life is rapidly increasing in recent times, especially in view of the importance of forests and wild-life resources in the agricultural economy of a nation, so wonderfully noticed in the U. S. A.

Mathematical Geography.

Since the days of Vedic sages, studies on the origin and nature of the earth and its role in the solar system have been

dominating topics in the field of natural philosophy. As far back as the Vedic ages in India (about 1000 B. C.) the Rig Veda conceived the earth to be of globular shape 'suspended freely in the air' and there is evidence in it of the axial rotation and annual revolution of the earth about the sun. In the West, Aristotle (4th century B. C.) gave an idea of the shape of the earth; Eratosthenes (3rd century B. C.) measured its radius and Ptolemy (2nd century A. D.) prepared the earliest map of the world in detail and introduced the idea of latitude and longitude to indicate the location of places on the earth's surface. Since then there has been tremendous development in field astronomy and techniques of geodetic measurements and as such mathematical geography has become a positive science leading towards a better understanding of the shape, size and nature of the terrestrial planet. Since Snellius carried his first observation in 1615, a series of geodetic surveys ultimately led to a clear conception of the exact shape and size of the earth. But geodetic measurements in France by Bouguer, Delambre and Mechian, in India by Everest, in Scandinavia by Struve, in Central-Europe by Gauss and Bessel, in South Africa by Maclean and in the U.S.A. by Hayford yielded slightly different values and the question of adopting a standard value of the 'figure of the earth' is still a debatable one. Gravity analyses made by Helmert in 1915 threw some more light on it. Recent gravity surveys under the sea by the eminent Dutch scientist Dr. Vening Meinesz, as well as gravity calculations by Heiskanen in connection with 'isostatic compensation' yielded some valuable data in the problem of finding the exact shape of the earth. A set of 'new geodetic tables' for ascertaining the 'figure of the earth' was proposed by A. R. Hinks, F. R. S., in the Congress of International Union of Geodesy and Geophysics at Madrid in 1924, which aroused some unusual interest in the problem. Mathematical geography has had its supreme importance in the exploration of unknown lands and untrodden heights. Recent Soviet exploration in the Soviet Arctic in search of raw materials, that by U. S. A. in the Canadian Arctic for studying polar meteorology, Rear Admiral R. E. Byrd's epic adventures in the frozen land round the South Pole, Col.

Ellsworth's founding of Little America on the fringes of fiery Antarctica lands, archaeological excavations in the sandy wastes of Central Asia and Arabian deserts or climbing of craggy Alps and assailing the virgin peak of Everest, to mention only a few, were all conducted on sound mathematical principles of geography. Since the days of Mercator and early Spanish navigators, there has been a revolution in the techniques of map-projection and scores of unusual map-projections have been developed lately by rigorous mathematical treatments, such as those by Sir C. Close, Col. Craster, E. A. Reeves, P. Goode, A. R. Hinks, W. Boggs, H. Poole and others, each of which gives some specific advantages in representing the earth's face for some specific purpose. Recently very unusual and rigorous types of map projections have been developed in connection with trans-world air navigation. Topographical survey and map-making received tremendous stimulii from the two world wars of modern times, for maps were the very fundamental basis of any action of artillery, air bombardment, invasion, or reconnoissance. Latest achievements in high-speed Aerial Survey, Air Cartography and Stereophotogrammetry, as developed in Holland and Germany before the war, have opened up a new vista before geographers in their task of delineating the exact picture of the surface of the earth.

Modern Geography Cultural or Humanistic.

The humanistic side of modern geography made a rapid stride since the beginning of this century, being revived and nourished under the systematic care of two eminent French scholars, Vidal de la Blache and Jean Brunhes. Indeed, France can be looked upon us the birth-place of modern Human Geography, a legitimate branch of cultural geography which challenges the deterministic outlook of Ratzel, approaches the study of geography from the stand-point of man and regards man as a striving master of Nature and not as her slave. Blache's wonderful studies of economic activities of man in different natural regions of France and Brunhe's field studies in Europe, Egypt and Asia Minor have brought to light most explicitly the insuperable linkage binding the human activities-economic and cultural with his natural environment. But in doing so, they insist man's activity is never dictated rigidly by Nature, but that man adjusts his mode of life and adapts to the demands of physical milieu and often goes even to modify his environment to suit his own taste and talent. So they would point out, how the life of peasants in an Alpine valley, or that of farmers in Ukrainian farms, or of gardeners in the high plain of Champagne, or of a mining community near Lorraine coal-pits is nicely adjusted to the specific demands of their respective environments. Almost every phase of their activity, their mode of living and the types of settement are all adjusted to the physical environment, but they are never rigidly controlled by Nature, as conceived by Ratzel. For, to them, such examples as the clearance of vast tracts of deciduous forest lands and expansion of agriculture in the Central European plain, dyking and reclamation of vast areas of low lands from the invasion of sea waves in Netherlands, mining of nitrate in the barren highlands of Chile, or quarrying of iron-ores in the forlorn Manchurian plain are too significant facts pointing towards a modification in the natural landscape wrought out by man himself. In each of these cases man has effected a change in his natural landscape according to his own economic and cultural demands and has adapted himself to this new natural conditions. Thus, the French school would conceive a proceess of conscious adaptation and modification of physical milieu of man rather than admit the dictatorial influence of Nature over his entire life. Lately writers of Europe and America like Newbigin, Huntington, Valkenburg, Bryan and others have concurred with this idea of adjustment, adaptation and at the same time of conquest of Nature by man which idea seems to dominate the trend of geographical throughts of our present time.

But while Brunhes refused to include the influence of environmental forces on man's social and political spheres under the scope of human geography, preferring to declare them as beyond the pierres d'e'preuves of true geography, the tendency of modern geographers in the U. S. A. is to recognise a subtle but an insuperable linkage between the forces of natural environment and almost every aspect of man's life—economic, social and political. They accept the truth of the dictum of relationship between environment, function and living organisms, constituting the 'fundamental biological triad' and are in favour of the term Human Ecology as proposed by Prof. Harlan Barrows of Chicago implying thereby the entire field of humanistic side of geography. Human Ecology according to them rejects the idea that man's economic, social and political urges are inherent and intrinsic in him and asserts that every activity and institution of man is purely extrinsic in character, being only the external forms and devices for adjusting man to his natural environment. 'The process of adjustments of man to his natural landscape, the active exploitation of one or more environmental elements, the capitalisation upon those natural factors which aid in promoting social solidarity and political safety—all these processes of adjustment consisting of selection and adaptation constitute the central theme of Human Ecology'. Prof. Fleure's study on various aspects of 'anthropo-geography' clearly conforms to these basic ideas of Human Ecology as being the mutual adaptation and adjustments between the group-life of man and his physical milieu. Lately, American geographers seem to recognise three broad divisions in the entire field of Human Ecology—economic, social and political, corresponding to three main types of human responses to the conditions of his entire natural environment.

Economic Geography.

Economic geography is solely concerned with the productive occupation of man in quest of his food, shelter and comforts, based on an analytical approach to the problem of why, where and how utilization of natural resources takes place over the surface of the earth. The main task of economic geographers lies in analysing the degree of influence of such environmental factors as climate, landforms, soils, flora, mineral resources, hydrology, geographical location, transport facility, economic

background etc. on the economic occupance of man in different segments of the earth, as also in a positive indication of the scope of economic exploitation as also of conservation of natural resources in the different geographic regions of the earth from agricultural and industrial standpoints so as to arrive at a balanced state of economic development.

Economic geography had a sweeping progress in its background in course of the present century and has gradually assumed high national importance in more advanced countries of the world. It has gradually undergone a radical change in its character from a mere analytical study to a synthetic science with a positive outlook of its own. It not only analyses the facts, it now fits them together and points towards the prospect of a balanced industrial and agricultural economy on a regional basis without regard to artificial boundaries and towards solving many of the maladjustments and economic ills in man's national life. Intensive specialisation in the different aspects of economic geography has resulted in the inception of a number of newer branches of study.

'Agricultural Geography' studies the genesis, properties and classification of major soil types of the world, problems of soil erosion, depletion and conservation, and aims at indicating the best type of agricultural utilisation of land under different climato-edaphic environments. The Land Utilisation Survey of Great Britain, Soil Conservation Service of the U. S. A. and various other organisations in many other countries of the West, are engaged in the study and solution of these problems. Soil erosion, the gravest menace to the entire agricultural economy of the land, is receiving more and more attention of geographers, agriculturists, economists and statesmen and a very extensive as well as intensive study of the processes and control of soil erosion has been carried on in the United States. Recent 'climograph-isopleth' studies in the problem of yield of crops, as in the United States, and research in 'agro-climatology' as in Soviet Russia have helped immensely to visualise the geographic control of crop production and in effecting a system of 'permanent agriculture' under various climatic regimes. Rapid development of soil science and climatology in the years to come will surely make agricultural geography an important branch of cultural science.

Studies in 'Industrial Geography' have recently made its way in the United States where the distribution of raw materials, problems of manufacturing, specialisation, and marketting of manufactured products are all studied in a geographic perspective together with its socio-economic background. It also claims to indicate the best way of exploiting the industrial resources under a particular geo-economic environment with a view to achieving maximum industrial efficiency with maximum economic advantage. Problems of utilisation of 'power resources' of the country to its fullest extent as well as of distribution of mechanical energy over the entire land with a minimum of loss under the particular geographic condition also come under the purview of industrial geography. Thus, in short, all the geographical aspects of the problem of utilising the natural resources of the country in the best interests of society, as well as their conservation in the best interests of national economy, under a particular climato-floral environment and against a particular population-pattern form the scope of modern economic geography. It has a dynamic character and along with extension of frontiers of habitation and unearthing of new resources on lands and with increasing emphasis on the economic development as being the only means to human progress and welfare, it is sure to play a dominant role in the cultural life of man.

Social Geography.

Studies in Social Geography have been lately evoked in the western countries though the underlying idea dates back to Ratzel's time. Social geography seeks to indicate a strong link of relationship between the ecology and the human society - whether primitive, rural or urban. It asserts that while human society under a particular geographic environment carries on a struggle for space, food, shelter and control over natural

resources, 'the nature of the struggle and character of environment determine the main traits and aspects of the society'. Is not the pattern of social organisation as well as the fabric of the social life of a logging community in the Canadian coniferous forests, of wage-labourers in the tropical rubber-plantations of Malay, of a mining community in a Lancashire coalfield, of herdsmen in Mexican highlands or of a peasant family in the agrarian Hungarian plain—all related to and shaped by their respective environments? Also, the marked contrasts in the pattern of social life and wide divergence in social psychology between rural and urban settlement areas form an interesting part of social geography. Further, much of the importance of social geography lies in its relation to economic geography, for the character of the economic occupance is reflected on the social life of the community. Transition from 'nemoricultural stage' to 'saxicultural stage' in the economic ecesis is attended by a gradual change in the social demography and in the psychological framework of the society. Social geography also studies the population pattern over the land, together with its repercussion on the socio-economic fabric of the country and often aims at integrating or disintegrating the population-burden evenly over the land, to bring about a regional balance in the national life of man. Recent movements on 'rurbanisation' by way of erecting 'synthetic cities' and of checking the random growth of urbanisation in the U. S. A., are some of the positive steps to bring about a refreshing change in the social life of man by changing his immediate environment. Social geography is no doubt going to be a fruitful branch of study of humanistic geography along with the increasing complexities in the socio-economic life of man under a progressively trying world situation. No wonder, proper studies on social geography of different terraines of earth may one day point towards solution of many of the discontents in man's economic, social and national life.

Political Geography.

Though studies in political geography date back to the time of Ratzel, it was not until the morrow of the first world war that modern 'political geography' was finally born. In essence, 'the

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particular objective of political geography is an investigation of the extent to which the nature of the States, together with their organizations and inter-relations, is influenced by and adjusted to conditions of geography' and as such political geography assumes tremendous importance in the realm of cultural sciences engaged upon the study of the humanity. It has to be admitted that each of the geographic factors of spatial extent of the country, her physiographic layout, natural resources and fertility of her land, racial composition of population, and more particularly her disposition in respect of adjoining oceans and lands tends to influence her political framework, nature of government, as well as her diplomatic attitude towards her neighbouring countries. Thus, the Chinese Republic suffers from internal political friction and instability of government due to the extreme racial, linguistic, cultural diversity of her inhabitants in different segments of her vast stretch; the rugged Balkan lands prohibiting intermixing of Turks, Serbians, Greeks, Bulgars, Wallachs, Yugoslavs and fostering their linguistic, social and religious differences within each of its sheltered valleys, induce constant political quarrel in denial of national unity; absence of a strong physical boundary in the Polish plain or in Belgium plain had a significant effect on their diplomatic relation with Germany and decided their fate in two world wars; while the complete insularity, limitation of productive lands, dire want of foodstuffs, a vast reserve of iron and coal and a pressing burden of population in Great Britain induced her to expand beyond the seas with an imperialist policy. Cramped and over-populated Germany with her limited sea-frontiers and lack of any facility of territorial expansion accounted for her long-standing political discontent and her recurrent violent upheaval against her commerial competitors; the lack of any oceanic outlet and good sea-frontage in the Baltic as in the Mediterranean has a significant repercussion on the foreign policy of Soviet Russia, as shown by her forcible annexation of all the Baltic states in 1940, and her pressing for a revision of the Montreaux Convention with regard to Dardanelles; while the fear of Russian power in east-Mediterranean blocking Britain's sea-link with the Far East prompted Britain to back

Turkey against Russia with regard to the opening up of Dardanelles, 'Monroe doctrine', in fact, signifies foreign policy of the United States to safeguard her economic interests over southern and Latin Americas against any possible Axis politico-economic influence. In fact the second world war broke out due to the blunders committed in Versailles and to a policy of continual denial of Japan's economic demands against her 'geographic realities'; thus, humiliated and downtrodden Germany sprang to her feet to unite all the German-speaking population of East Prussia, Austria and Sudeten lands, consolidated her power and resources and triumphantly marched over the Slavic nations of the South-East to have an access to the Black sea and Asia Minor-the gate-way to the East; there is no denial of the fact by neutral experts that Japan's foreign policy and ultimate hostility with western powers is a 'geographic reality' and 'her behaviour is in harmony with the geographic environment; being seriously handicapped in the supply of raw materials, in the extent of arable land, with an alarming increase in her starving population and skilled and technically advanced as they are, the Japanese should naturally look to the fertile virgin lands of Munchuria, untapped iron-ores and coal reserves of Shansi, Shantung and Yunnan and to the uninhabited fertile islands of the Pacific; but everywhere they received an obdurate opposition and an unreconciling attitude which led to the Sino-Japanese conflict and precipitated the second world war of the Pacific. More recently at the wake of the second world war, countries in south-east Asia, shaken by a wave of national consciousness are reorganising themselves in to a new pattern of free states along with the changeover from colonial to national economy. This political transformation of such a vast stretch of land with such a prolific man-power, agricultural and industrial resources is a significant fact in the political geography of Asia, and will no doubt have a strong repercussion on the permanance of peace of the future world. A host of geographers in the Continent and in the U.S.A., such as A. P. Brigham, C. B. Fawcett, Sir T. H. Holdich, O. Maull, R. Hartshorne, W. Fitzgerald, D. Whittlesey and others have written on geographic aspects of world politics, stressing particularly on easing the international political tension and discontent by removing the geographical inequilibria and disharmonies.

A few more lines of modern geographic thought which have come into being along with the progress in the systematic study of geography may now be enumerated as follows.

Historical Geography.

'While such historians as Gibbon, Prescott, Motley and Guizot have recognised the influence on human history of geographic conditions' through their writings long ago the systematic study of historical geography is of more recent date. Historical geography had its early growth at the close of the 19th century and sought to establish mainly the influence of geographic conditions on the historical destiny of nations. Though in enacting the full drama of history, many accidental situations and personal merits of rulers and statesmen play an important part, it has become undeniable that such geographic conditions as topography, insularity or continentality of landmass, geographic isolation, physical barriers, spatial extent of the State or territory conquered, all in a way determine the historical destiny of a country. In fact, the whole course of the chequered history of the Eurasian landmass, beginning with the days of the Nile-valley civilisation and subsequently followed by the expansion of the Saracen Empire from the Oasis-land of Arabia, the rise and fall of the Hellenic empire as a Mediterranean sea-power, the building of the empire of Charlemagne, from whose base Crusaders were sent to the Holy Land, the conquest of England by the Normans, down to the rise and fall of the Napoleonic empire in Europe can be truly interpreted in terms of geographic conditions of relief, configuration of the landmass and the disposition of the oceans. Similarly, while the Tigris and Euphrates plain, the Oxus valley and the winding mountain pass in the North-Western gate of India led to an Indo-Hellenic cultural impact, and while the open seas of the Bay of Bengal flooded the islands of Java, Sumatra, Bali and other Pacific islands with the light of Buddhism, the colossal

Himalayan rampart strongly inhibited any diffusion of Aryan culture to the mystery land of Tibet. Of the early writers who established basic ideas of relation of history to geography, H. F. Helmholt edited 9 volumes of work on historical geography (1899-1907), E. Reclus wrote 6 volumes on history of man from the geographic standpoint (1905-1908), H. P. Brigham (1903) and E. C. Semple (1913) traced out geographic influence in American history, and Sir Cunningham's voluminous work has long been an important source of historical geography of India and the adjoining countries.

Military Geography and Geo-strategy.

Closely following the geographical study of history is the study of 'military geography', which seeks to establish the influence of geographic character of land and sea on the strategy of warfare, whether carried out in land or in ocean. In the wide panorama of history such incidents as the expedition of the Persian Army under Xerxes to outflank the Athenians in Aegean waters, the campaign of Macedonians under Alexander to overpower the Greeks and Phoenicians, the epoch-making march of Hannibal from Carthage to oust the Roman supremacy in the Mediterranean, as well as almost all of the heroic battles that Napoleon fought in North Italy, France and Prussia, were all conducted in true appreciation of the geographic character of the land and sea, so as to seize upon maximum military advantages against the foe. This appreciation of the influence of geographic character of land and sea on the conduct of warfare gained ground during the first world war and decided the fate of the battle on many a front. This study of military geography received a strong stimulus from the veteran Army generals and Naval chiefs and a systematic field of study ultimately came into being. 'Geo-strategy' is a legitimate child of the old military geography born at the advent of the second world war, but is more wide in outlook and more comprehensive in scope than the former. For, the second world war has become a war not only of men and steel but a 'war of strategem', economic, demographic and political. 'Geo-strategy', in essence, studies the issues of warfare in the wider perspective of the economic foundation, man-power resources and the pattern of land and sea of a particular nation so as to capitalise upon maximum strategic advantages against her. Thus, in international political conflict strategic warfare often decides the issue far quicker than an armed attack. In the second world war the very strategic blunder of opening the two fronts—east and west by Germany doomed her fate inspite of her initial advantages. The Allied landing in Africa and their northward march through Italy to encircle Germany, tightening of Anglo-American grip on Middle-East oil regions against any possible German control, seizing upon the island chains in the Pacific and opening up of a 'back door' to China as a gateway to Japan's heartland as well as the programme of continual destruction of Axis industrial nerve-centres and stepping up of Allied man-power-hour by all concerted efforts are some of the highlights in the geostrategy of the second world war. And inspite of the advent of 'air-age' 'atomic era' 'geo-strategy' has been a valuable aid in bringing the second world war to a successful finish by the Allies. Sir Halford Mackinder was the first geographer to put forth the basic ideas of geo-strategy through his brilliant ideas on manpower resources, demographic pattern and economic foundations of regions in the context of an armed conflict. In the 2nd global war a number of American and British geographers rendered valuable services to the Allied war effort and no doubt contributed to Allied victory through their active help as geographer-advicers to Strategic Warfare, Economic Warfare and Military Intelligence and all such services.

We now come upon the last aspect of modern humanistic geography - 'geopolitik', a 20th century offspring of political geography.

Geopolitik.

After the first World war, political geography underwent an important transformation from its static retrospective aspect to the dynamic futuristic outlook and the foundation-stone of this changeover was laid by Sir Halford Mackinder in 1919 through one of the most important books of the time. He interpreted the whole drama of European History since the dawn of civilisation in a geographic perspective, conceived Asia - Europe - Africa as a 'World-Island', having a 'Heartland' in it from Volga to Manchurian highland and Arctic to the Himalayas, the key to which was the Slavic countries of eastern Europe, and asserted that "who rules the Heartland, commands the World-Island, who commands the World-Island commands the World". He relegated the Allied victory in the last war to the German blunder of fighting in two fronts, east and west, and advocated a boundary revision and territorial resettlement in east-Europe in consonance with the racial, economic and geographic conditions, so as to end the age-long German-Slav dispute and the creation of a 'tier' of independent States in east-Europe as a territorial buffer between Germany and Russia prohibiting Germany's access to the Heartland. Geopolitical studies received a hectic stimulus in Germany after her defeat in the first World war and Major-General Professor Dr. Karl Haushofer of the Munich Institute of Geopolitik became the leader of the 'German school of Geopolitik' with the rise of Nazism. The principle maintained by the school of which Dr. Haushofer is the exponent is in essence that 'even as Geography has conditioned the political history of the world, so it is possible to deduce from geographical factors the future course of that history'. Dr. Haushofer and his followers built up a 'science' that subscribed to the political creed of the Nazi party and have sent their all concerted geographical intelligence to the propagation of Nazi doctrines on Lebensraum, reconstruction of German territories, revival of germanic culture, mastery over Europe against Anglo-American influence and the likes; in fact, 'geopolitik' during the third Reich became a pseuodo-scientific discipline built up on arrays of vital geographic facts and intelligence and became a potent weapon to achieve Germany's political ends in Europe.

It is said in all the matters of international politics Hitler had his strategic inspiration from Dr. Haushofer who mainly founded his theories on Mackinder's forceful writings, but 'dangerously oversimplified and distorted' them which ultimately led to the downfall of the German Wehrmacht. Geographers of all the countries including many German geographers of fame have been condemning such illfounded and dangerous outlook of German geopolitik and are more in favour of diffusion of knowledge of fundamental geographic conditions, in the solution of international disputes and conflicts rather than to submit to the political theory of any party in any land.

Once again all the nations of the world are meeting together to bring down upon this earth a lasting era of peace, and this is the time for the statesmen, leaders and chiefs of the United Nations to remember that the peace of the world rests on fundamental national independence, equality in resources, adequacy of living-space, and an equitable share in the balance of power and that reconstruction of the world order must reckon with 'geographical realities'; and geographers, who must 'see into the life of the things' should be the torch-bearers in this mission of peace and reconstruction to usher in a new dawn over the earth.

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The Origin of the Waltair Highlands.

BY

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INTRODUCTION.

The Waltair Highlands, extending over an area of about four square miles, and rising almost abruptly above the sea level to a height of over 150 feet at places, form a conspicuous land mark of Vizagapatam area. The origin of these highlands forms the subject of investigation of this paper.

The problem has now been tackled mainly by sedimentary petrographic methods, supplemented and supported by detailed field work.

PHYSIOGRAPHY OF THE WALTAIR HIGHLANDS AND ENVIRONS.

The Vizagapatam area lying between (Lat.) 17° 39′ - 17° 46′ and (Long.) 83° 12′ - 83° 21′ may be divided into four distinct physiographical-units, namely, the hill ranges to the North and South, the broad central low lying plain, the Waltair Highlands of the south-east, and the beach running in the north-east and south-west direction (Vide. Map, Plate IV).

Hills:—Bordering the area to the north, and running roughly east to west are the hills of the Kailasa Range that stop sharp at the beach, the continuity of which are represented by isolated stacks in the shallow waters further eastwards. The range, rising to a height of about six hundred feet above the sea level and standing out in marked contrast from the adjoining peneplain, forms a bold relief of the area. From the eastern promontory at about four hundred feet, the range rapidly rises to a height of 1600 feet above M. S. L. towards west as at "Thomas Folly" and attains a maximum height of 1663′ at its extreme western end, to the east of Simhachalam Temple. The continuity of

the range is broken by an abrupt gap, about a mile west from its eastern promontory, near Venkojipalem. Though the stream Hanumanthavakagedda flows through this, a greater part of it remains dry throughout the year forming a wind gap through which runs the road leading to Bhimili.

The northern flank of this range is generally steep but slopes gently towards the south. A layer of mantle rock and talus conceals the bed rock at many places and supports shrubby vegetation. The western hills of the range are covered by thick foliage and orchards due to the presence of many seepages and springs that trickle down the flanks. Many ephemeral streams take their origin in these hills.

Adjacent to the range there are a few buttes as at Kapparada and Tikkavadipalem which were obviously the spurs of the main range, now isolated by denudation.

The Yarada range also having an east to west run and separated from the Kailasa Range by the tidal scour basin, the low lands of Vizagapatam and Waltair Highlands forms the southern boundary of the area. It has roughly a height of about 500 feet above M.S.L. over a greater part of its run, attaining a maximum height of 1170′ as at Yarada Konda. This range projects prominently into the sea, this promontory being popularly known as Dolphins Nose.

A few isolated monadnocks and hogbacks represented by Soona Metta, Santa Metta and Attiredi Metta to the west of the back-water creek and Ross hills to the north of this creek, rise in sharp relief from the surrounding tidal scour basin. From their present disposition it is probable that these formed a ridge in continuity with the hill now covered up by the dune that stands in the heart of the Vizagaptam town on which K. G. Hospital and Medical College are situated.

The hills of these above ranges are of the relict type, being the remnants of what once must have been a great tectonic mountain system.

Plains:—The central part of the area bounded by the Kailasa Range in the north, Yarada hills to the south, and by the Waltair High lands to the south-east, is occupied by a low lying plain running west to east which is broad on its western end but narrows down towards east, terminating in Lawsons Bay. It can be divided into northern and southern plains separated from each other by the B. N. Railway line. The northern plain that extends from the extreme western end of the area to as far as Lawsons Bay, is the only fertile region of this part of the country. The southern plain is covered over by saline marsh and tidal scour basin giving rise to alkaline soils, barren of vegetation.

High Lands:—The waltair highlands fringe the coast and rise almost abruptly to form a plateau. These are formed of thick red-loam deposit and cover a considerable part of the area, attaining locally a height of about a hundred to hundred and fifty feet above the plains. These highlands have a fairly high gradient on all sides and scarps of red loam deposits are exposed at some places (Fig. 1, Plate I). The area, occupied by the highlands, is nearly continuous in its central part, with thick vegetation though not without undulations. The peripheral region, barren of vegetation is much dissected by gullies, valleys, and deep and winding gorges (Fig. 2, Plate I) made by pluvial water courses and transient streams that drain the area, giving rise to a typical badland topography. At a few places, the deep gorges of red loam have exposed rocky substrata, though generally the red loam seems to persist into depth.

This loamy deposit, on account of its loose texture and absence of any binding material, lends itself to be easily eroded away. This rapid erosion is a great menace that needs immediate attention for the safety of many buildings constructed on it and the roads laid over it.

Coast:—Fringing the entire south-west—north-east border of the area is the Vizagapatam beach that may acquire great economic and strategic importance on account of the occurrence

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PLATE I.

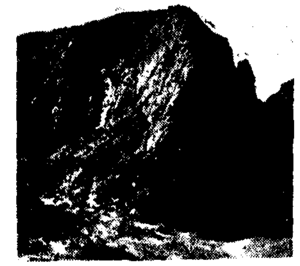


Fig. 1. Erosion scarp, Waltair Highlands.

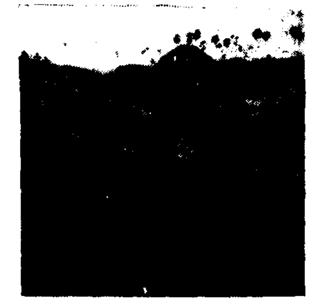


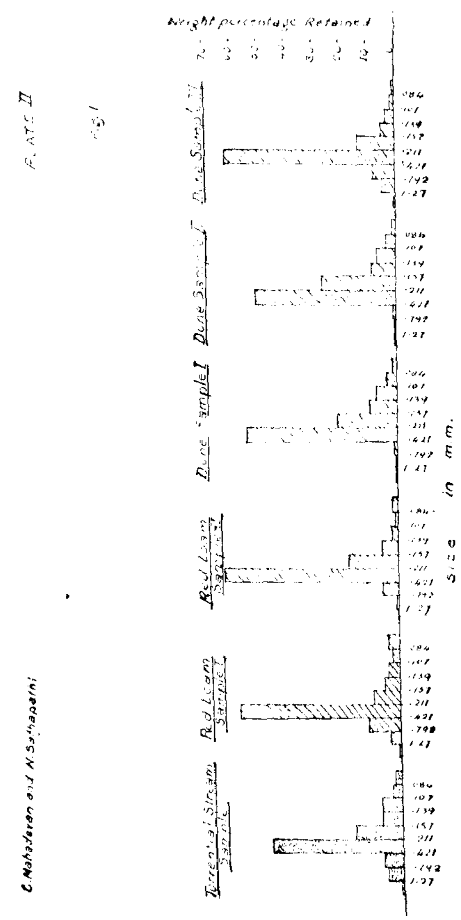
Fig. 2. Bad land topography with beach in foreground.

Fig. 3. Sea caves & sand dunes, (Note the effects of wind and wave erosion).

Fig. 4 Migrating dunes or buildings.

Fig. 5. Migrating dunes destroying crops.

Fig 6. Gravel bed in the red loam. (Dreikanters, eoliths & palaeoliths with water worn pebbles).



of ilmenite, magnetite, zircon and especially monazite in its sands (Mahadevan and Sriramadas, 1948). The beach has on an average a width of about 50 to 100 yards, fluctuating within wide limits due to variation in currents and tides, causing local erosive transgressions and encroachments of the sea. The beach has almost a straight course from the harbour entrance to as far as Jalaripeta to the north-east of Waltair. At this point, it takes a bend and continues as a crescent shaped curve upto the Kailasa Range, being known as Lawsons Bay.

Scattered along the beach are numerous outcrops and mounds of rock; these being within the reach of the wave action have been sculptured into blow-holes and other peculiar forms. At some places as at Kailasa Range and in the vicinity of Yarada village, sea caves occurring at heights about 20 feet above the M. S. L. are seen. (Fig. 3, Plate I).

Dunes:—Along the entire length of the coast, dunes of varying sizes from small wind ripples to large hills are of common occurrence. Sand hills, occupying considerable area are to be seen at Maharanipeta, and to the N. W. of Scandal Point, by the side of the Ootagedda stream. These sand hills are formed over isolated hillocks which offered a local obstacle and resulted in the deposition of the sand carried by the strong winds. The Vizagapatam Medical College and King George Hospital are situated on a sand dune formed on the rib of a hillock that is exposed only in part, on the western side of the dune. The direction of the wind in this area, according to the observations made by Mackenzie (1899), oscillates between N. E. and N. W. According to the observation made by one of us (Mahadevan, 1929) the present disposition of the prominent dunes of the area, are in accordance with this directional activity of the prevailing winds. The dunes of this area migrate at an average rate of 20 feet—50 feet per year and cause great havoc by the dumping of unwanted sand near buildings (Fig. 4, Plate I), across roads and in fertile fields (Fig. 5, Plate I).

Streams:—The area is not drained by any major rivers, though numerous intermittent streams take their origin in the neighbouring hills and highlands and flow through the plains. These streams transport talus and soil from the hills, which undergo further weathering before they are carried into the sea, after several phases of halts. Of the various rivulets, Hanumanthavakagedda to the north of Waltair Highlands and Ootagedda joining the sea at Scandal Point and separating the Waltair Highlands from the Maharanipeta Midland, form the main drainage channels, effecting the transportation of greater bulk of sediments to the sea. The materials of the beds of the streams vary in texture and composition, being coarse and rich in heavy minerals with undecomposed rock fragments at or near their origin, with a medium grained, good concentration of heavy minerals and ferruginous clay at and in the neighbourhood of Waltair Highlands, and white sand near the beach with local patches of black sand concentrates rich in magnetite, ilmenite, sillimanite, zircon, garnet and monazite.

GEOLOGICAL FORMATIONS.

The geological formations metwith in this area are as follows:—

(1) Sand and alluvium (Recent - present)

(2) Laterites and Red loam (Pleistocene - Recent)

(3) Charnockites and granites (Peninsular complex)

(4) Khondalites (Dharwars ?)

Khondalite:—It is a paragneiss with quartz, felspar, garnet, and sillimanite as the essential constituents and magnetite, zircon, apatite and cherty silica as its accessories. Localised streaks as well as disseminated flakes of graphite occur in the rock. It forms the country rock and constitutes the prominent hills of the area.

Charnockites:—These rocks bear an intrusive relation to the khondalites and constitute the hillocks of the plain in association with granites, leptynites and khondalites. Basic charnockites

are more common than the acid types. These are composed of hypersthene and basic plagioclase felspars (andesine-labradorite), with accessories like ilmenite, magnetite and biotite. The leptynites appear to have resulted from the reconstitution of the normal khondalites as a result of later intrusions.

Granites:—These rocks, like the charnockites, are not found at high altitudes; they are also intrusive into the khondalites. These are composed of quartz and felspar as the primary constituents, with accessories like garnet, magnetite and tourmaline. Veins of pegmatites cutting through the khondalites are probably differentiation products of the granite magma.

Laterites:—The lateritic soils are of common occurrence in the area, but typical laterites are of limited distribution. The true laterites are dark red to brownish red in colour, compact and hard, with vermicular cavities. They are found capping khondalites, most probably formed by the alteration of these rocks that are rich in oxides of iron. Weathering of other rocks like charnockites which are the intrusives of khondalites, also contribute in part to the formation of these laterites. Some of the outcrops of laterites are seen near the road leading to Lawsons Bay from Pedda Waltair and at the cutting on the Waltair side of Ootagedda stream which has exposed a good section showing the alteration of khondalite to laterite in successive stages.

Red Loam:—A light, red loam deposit with as much as 30% of ferruginous clay occurs extensively in the area forming a great part of the High lands of Waltair. It is composed of quartz and opaque iron ore minerals, the latter group of minerals being found as streaks and patches along the beds of the streams draining the High lands.

Sand And Alluvium:—The beach constitutes an extensive deposit of sand in the area with minor sandy deposits in the beds of the streams. The sandy marl of the tidal scour basin is formed partly from the material washed down from streams and partly from what had been swept in from the coast by tidal waters.

Sandy deposits of aeolian origin are of frequent occurrence along the coast though some of them are found in some places in the heart of the town of Vizagapatam.

Local patches of silty deposits are seen along the beds of streams and at their mouths.

METHODS OF WORK.

The methods of work employed in the present investigation fall into two categories, namely field work, and laboratory study consisting of petrographical study of representative materials collected in the field. The object of this study is, as already indicated, to account for the origin of the Waltair Highlands.

Field Work :—The area under report was carefully traversed and the following data obtained :—

(1) Sea caves of considerable sizes and at heights of about 20 feet from the present average beach level, referred to already, are seen near Kailasa promontory and in the vicinity of Yarada.

(2) After a thorough examination of the red loam deposit, it was found that it is devoid of animal and plant remains.

(3) The red loam formation does not show any lamination or current bedding.

(4) There is no gradation of the particles constituting the red loam material.

(5) The finer material like clay is found intimately intermixed with the coarser detrital sand.

(6) Scarps in the badland topography where occasional outcrops of rocks are revealed, were carefully examined if there were gradational alteration from bed rock to the over lying loamy cap. There is no such gradation and the junction between the rocky substratum and loam is quite sharp.

LABORATORY STUDY.

Technique, procedure, results and computations :—Two red loam samples from two widely separated points, obtained by groove sampling, three samples from three prominent dunes obtained by grab sampling and one torrential stream sample (Hanumanthavakagedda) taken by pit sampling were collected from this area.

These samples were freed from all suspended impurities by repeated washings and the heavier fractions were subjected to mechanical analysis by using I. M. M. sieves. In the case of red loam samples, the finer fractions below 300 I. M. M. were divided into three fractions namely fine sand, silt and clay by the use of standard beaker method (Wood, 1920). The results of the analyses are given in Table I on page 34.

All the mechanial fractions of one red-loam sample, one dune sample and the torrential stream sample were subjectd to heavy mineral separation using Thoulet solution ($K_2 Hg I_4$) of 2. 9 sp. gr. The heavy fractions so obtained were further subjected to magnetic separation, using a strong permanent magnet, thus dividing each of the crops into magnetic and non-magnetic fractions. These data are given in Table II on pages 35 and 36.

From each of the non-magnetic fractions, convenient amounts of very carefully sampled material were taken and mounted on micro-slides. All the minerals present in the micro-slides were optically examined and their respective numbers were obtained by counting according to standard petrographical methods (Milner, 1940) under the microscope with the help of a mechanical stage. The percentage by number of each of the mineral species present in each of the slides was obtained and the results are given in Table III on page 37.

The weight percentages of different mineral species present in various mechanical fractions of the samples were calculated from the above data in the following manner.

TABLE I.

Description of the sample.	Weight of the sample.	Distribution by grade size (in weight percent) > 1·270 mm.	1,270 - ·792 mm.	·792 - ·421 mm.	·421 - ·211 mm.	·211 - ·157 mm.	·157 - ·139 mm.	·139 - ·107 mm.	·107 - ·084 mm.	< ·084 mm.
Torrential stream sample ...	99·98	1·24	5·35	7·12	48·15	17·38	7·40	7·27	3·81	2·26
Sand Dune (sample 3) ...	99·65	0·00	4·93	7·61	62·87	13·20	4·53	3·61	1·91	0·99
Sand Dune (sample 2) ...	100·02	0·00	0·00	0·62	51·96	27·14	8·84	6·81	3·27	1·38
Sand Dune (sample 1) ...	99·96	0·00	0·00	0·79	55·46	21·47	9·58	7·46	3·43	1·75
Red loam (sample 1) ...	100·02	0·00	3·60	11·47	59·09	9·59	5·31	4·05	2·81	4·10
Red loam (sample 2) ...	100·02	0·00	0·73	5·41	64·33	18·78	6·22	2·39	0·91	1·25

Sand Dune (sample No. 3) :—Situated to the East of Beach Hotel, Waltair.
Sand Dune (sample No. 2) :—Situated by the side of Beach Hotel, Waltair.
Sand Dune (sample No. 1) :—By the side of Ootagedda Stream.
Red loam (sample No. 2) :—To the South of Waltair Club, Waltair.
Red loam (sample No. 1) :—By the side of University Staff Quarters, (Southern side), Waltair.

TABLE II.

Sample.	Size limits in mm.	Wt. in grams.	Wt. of light fraction*	Wt. of heavy fraction†	Wt. of magnetic minerals‡	Non-magnetic heavy minerals§	Percent of heavy minerals.
Torrential stream sample.	>1·270	1·24	—	—	—	—	—
	1·270 - ·792	5·35	—	—	—	—	—
	·792- ·421	7·12	—	—	—	—	—
	·421 - ·211	48·15	14·48	33·67	15·80	17·87	37·12
	·211 - ·157	17·38	3·88	13·50	8·261	5·239	30·14
	·157 - ·139	7·40	1·698	5·802	4·205	1·598	21·60
	·139 - ·107	7·27	1·491	5·779	4·297	1·482	20·39
	·107 - ·084	3·81	0·936	2·874	2·284	0·591	15·52
	<·084	2·26	0.953	1·307	0·916	0·392	17·33
Red loam (sample No. 2).	>1·270	0·00	—	—	—	—	—
	1·270 - ·792	0·73	—	—	—	—	—
	·792 - ·421	5·41	—	—	—	—	—
	·421 - ·211	64·33	62·768	1·562	1.328	0·234	0·364
	·211 - ·157	18·78	17·781	0·999	0·873	0·126	0·670
	·157 - ·139	6·22	5·697	0·523	0·426	0·097	1·568
	·139 - ·107	2·39	1·905	0 485	0·384	0·102	4·258
	·107 - ·084	0·91	0·465	0.445	0·362	0·083	9·122
	<·084	1·25	0·603	0·647	0·524	0·123	9·797

Sample.	Size. limits in mm.	Wt. in grams.	Wt. of light fraction*	Wt. of heavy fraction†	Wt. of magnetic minerals‡	Non-magnetic heavy minerals§	Percent of heavy minerals.
Sand Dune (Sample No. 1).	>1·270	0·00	—	—	—	—	—
	1·270 - ·792	0·00	—	—	—	—	—
	·792 - ·421	0·79	—	—	—	—	—
	·421 - ·211	55·46	55·069	0·391	0·067	0·324	—
	·211 - ·157	21·47	19·638	1·832	0·682	1·150	5·357
	·157 - ·139	9·58	7·980	1·600	0·566	1·034	10·79
	·139 - ·107	7·4	5·209	2·271	1·167	1·102	14·76
	·107 - ·084	3·43	1·396	2·034	1·124	0·911	26·56
	<·084	1·75	0·282	1.463	1·005	0·463	26·47

* All minerals having Sp. Gr. less than 2·9.

† All minerals having Sp. Gr. greater than 2·9.

‡ Minerals attracted by a strong permanent magnet.

§ All minerals having Sp. Gr. greater than 2·9, other than magnetic minerals.

Red loam (sample No. 2) :— To the south of Waltair Club, Waltair.

Sand Dune (sample No. 1) :— A sand dune situated by the side of Ootagedda Stream, Waltair.

TABLE III.

Description of the sample.	Size grade limits in mm.	No. of grains counted.	Distribution by size grades (in percent by number).									
			Zircon.	Monazite.	Sillimanite.	Garnet.	Magnetite.	Kynite.	Pyroxene.	Andalusite.	Tourmaline.	Biotite.
Torrential stream sample ...	·421 - ·211	291	0·00	1·72	22·00	37·45	38·84	—	—	—	—	—
	·211 - ·157	667	0·45	2·40	34·63	23·54	37·67	—	—	—	—	1·35
	·157 - ·139	459	1·53	3·70	35·73	16·56	42·48	—	—	—	—	—
	·139 - ·107	773	2·33	4·14	39·32	13·19	41·02	—	—	—	—	—
	·107 - ·084	1442	3·40	12·48	40·29	6·31	37·52	—	—	—	—	—
	< ·084	786	7·51	28·25	45·81	0·13	18·32	—	—	—	—	—
Red loam [sample 2] (from the southern side of Waltair Club) ...	·421 - ·211	900	11·90	9·67	20·45	0·56	50·56	4·67	0·67	1·56	0·00	—
	·211 - ·157	913	14.89	12·27	28·36	0·44	39·54	2·30	1·53	0·55	0·11	—
	·157 - ·139	2647	10·73	14·17	30·87	0·11	38·69	2·46	1·13	1·47	0·38	—
	·139 - ·107	1595	9·47	12·16	32·92	0·00	39·50	2·63	0·94	1·63	0·69	0·06
	·107 - ·084	1150	16·17	9·13	38·43	0·00	33·05	2·70	0·44	0·00	0·09	0·00
	< ·084	2258	21·21	2·92	43·27	0·00	31·49	0·84	0·13	0·09	0·04	—
Sand Dune [sample 1] (On Western side of Ootagedda Stream) ...	·211 - ·157	622	4·66	10·13	44·21	20·42	11·73	0·16	8·36	0·16	0·00	0·16
	·157 - ·139	586	4·27	6·99	44·88	19·80	10·58	0·68	12·46	0·00	0·34	0·00
	·139 - ·107	526	3·61	4·75	41·63	18·06	16·35	0·00	14·45	0·19	0·95	0·00
	·107 - ·084	732	10·65	6·15	36·89	16·93	10·92	0·14	18·03	0·14	0·14	—
	< ·084	972	17·08	8·23	22·84	13·48	24·79	0·00	13·58	0·00	—	—

The relative volumes of all the minerals present in each of the mechanical separates (representing small amounts of each of the mechanical fractions) of a sample are taken to be the same and consequently the percentages by number are supposed to represent the relative volume percentages of the different minerals.

The percentages by number of all the mineral species in each of the mechanical separates of a sample were multiplied by their respective densities, to obtain the relative weight percentages.

The product of densities and percentages by number of different mineral species of each of the mechanical separates for a sample were totalled and for a total of one, the relative weights of each of the mineral species present in each of the mechanical separates of the sample were calculated. From these, the weights of each of the mineral species in the total non-magnetic heavy crops of different grades of the sample were calculated in the manner indicated below.

The relative weights of each of the minerals of each of the mechanical separates of the sample, obtained above were multiplied by the weights of non-magnetic heavy crops of the respective mechanical fractions of the sample. The products give the required absolute weights of the mineral species in each of the non-magnetic mechanical fractions of the sample.

From the above data, the distribution of each of the minerals in various size grades of the sample was obtained in the following way.

The weights of similar minerals present in all the non-magnetic mechanical fractions of the sample were totalled and weights of each of the minerals in various mechanical fractions were determined for a total of one hundred. In the same way the size distributions of magnetic minerals, and the light minerals, each of them being considered as a single mineral, were obtained.

The distribution of different non-magnetic minerals in various size grades of the other two samples were determined according to the above outlined method. The results are given in Table IV.

TABLE IV.

Mineral.	Sample.	Weight of the mineral in the sample in grams.	Distribution by size grades (in percent by weight)					
			mm. ·421-·211	mm. ·211-·157	mm. ·157-·139	mm. ·139-·107	mm. ·107-·084	mm. <·084
Magnetic. minerals.	Torrential stream sample.	35·76	44·19	23·11	11·75	12·01	6·39	2·56
	Red loam sample No. ?	3·896	34·09	22·42	10·92	9·85	9·28	13·46
	Sand Dune sample No. 1	4·544	0·00	15·01	12·47	25·68	24·73	22·11
Zircon.	Torrential stream sample.	0·256	0·00	18·82	20·78	28·95	15.30	16 14
	Red loam sample. No. 2	0·211	30·95	17·03	9·49	9·06	11·41	22·12
	Sand Dune sample No. 1	0·457	0·00	16·35	13·58	13·36	29·64	27·08
Monazite.	Torrential stream sample.	1·[illegible]65	42·18	18·18	9·14	9·32	10·17	11·00
	Red loam sample No. 2	0·199	29·48	16·44	14·69	13·63	7·54	18·15
	Sand Dune sample No. 1	0·535	0·00	33·65	21·10	16·63	16· 6	12·36
Sillimanite.	Torrential stream sample.	10·235	52·41	25·48	8·56	8·59	3·19	1·73
	Red loam sample No. 2	0·322	24·57	14·97	12·60	14·53	12·51	20·82
	Sand Dune Sample No. 1	1·902	0·00	26·25	24·18	26·04	17·40	6·13

TABLE IV *(Continued)*

Mineral.	Sample.	Weight of the mineral in the sample in grams.	Distribution by size grades (in percent by weight) mm. ·421-·211	mm. ·211-·157	mm. ·157-·139	mm. ·139-·107	mm. ·107-·084	mm. < ·084
Garnet.	Torrential stream sample.	15·13	78·30	15·19	3·48	2·53	0·44	0·004
	Red loam sample No. 2 †	—	—	—	—	—	—	—
	Sand Dune sample No. 1	1·127	0·00	26·53	23·34	24·73	17·48	7·92
Pyroxene.	Torrential stream sample. †	—	—	—	—	—	—	—
	Red loam sample No. 2	0·008	29·82	30·12	17·23	15·45	5·27	2·38
	Sand Dune Sample No. 1	0·608	0·00	15·10	20·43	27·51	25·87	11·09
Light minerals (Sp. Gr. 2·9)	Torrential stream sample.	23·438	61·79	16·55	7·25	6·36	3·99	4·07
	Red loam sample No. 2	89·23	70·36	19·93	6·39	2·14	0·53	0·67
	Sand Dune sample No. 1	89·578	61·48	21·93	8·91	5·82	1·56	0·32
Kyanite.	Torrential stream sample †	—	—	—	—	—	—	—
	Red loam sample No. 2	0·037	54·46	11·80	9·74	11·29	8·53	3·93
	Sand Dune sample No. 1 †	—	—	—	—	—	—	—

* All those attracted by a strong permanent magnet.

Red loam (sample No. 2) :—To the south of Waltair Club, Waltair.

Sand Dune (sample No. 1) :—From a sand dune situated by the side of Ootagedda Stream, Waltair.

† The size distributions of these minerals have not been determined as these are present in only a few mechanical fractions.

Representations:—Two principal methods of representing the mechanical composition of a sediment are in vogue in the realm of sedimentary petrography: The one known as histogram, is considered to possess characteristic form indicative of the agency that effected the mechanical composition of a particular sediment represented by it; the other, known as cumulative curve, represents the size distribution of the particles of a sediment in a more natural way. But the use of the form of a histogram of a sediment to particularise the unknown agency that deposited the sediment has been pronounced to be unreliable to a great extent by experienced sedimentary petrographers like Twenhofel and Tylor (1941). As such, in the present state of our knowledge in this field, it is not possible to attach any such significance to the form of a histogram of a sediment.

In the present case, the number of mechanical fractions into which the sediments were divided is restricted to six. The usual method of representing the mechanical composition of a sediment by a histogram is adopted and the histograms of various samples are shown in Fig. 1, Plate 2.

SIGNIFICANCE OF LABORATORY RESULTS.

Mechanical Composition of the Sediments:—From the histograms of the samples shown in Fig. 1, Plate 2, it is seen that the histograms of the red loam samples have certain amount of resemblance with those of the dune samples as well as with that of the torrential stream sample. The similarity between the former set seems to be more than between the latter set. These histograms indicate that all the samples have predominantly particles whose diameters range between ·2 mm. and ·4 mm.

Mineralogical Composition of the Sediments:—Mineralogically the red loam sample and the dune sample are more or less the same, but these differ from the torrential stream sample. The former two samples contain opaque iron ore minerals, sillimanite, garnet and monazite that are found in the latter sample, and in addition, such minerals as pyroxene, biotite, tourmaline and kyanite.

In the present case from a study of the relative positions of various rocks and the sediments of the area, the drainage pattern and the distances through which the sediments have been transported, the above differences in mineralogical compositions of various sediments can be attributed greatly to the differences in the mineralogical composition of their source rocks though other minor factors such as:

(1) the way in which the source rocks are disintegrated, (2) the absolute and relative rates of mechanical wear and chemical disintegration of different minerals during transport, (3) the absolute and relative rates of transportation of different minerals and different size of same mineral, and (4) the hydraulic or atmospheric conditions that existed at the place and during the time of deposition, can also effect the mineral composition of a sediment. For this reason, the torrential stream sample, which represents the material brought by the stream from the talus of the adjacent hills, contains minerals characteristic of the khondalites. The monazite being found in association with the minerals of khondalites might have also been derived from the same rocks.

The red loam sample, obtained from the highlands of Waltair that fringe the coast in a favourable position to receive the decomposed rock matter derived from the neighbouring hills of khondalites and from the hillocks of the plain consisting of charnockites, granites and leptynites, contains minerals characteristic of all these rocks.

The material of the dune being derived from the beach sands which represent the sediments brought by the streams that originate in the hills and flow on the plains of the area, contains minerals representative of all the rocks of the area.

C. Mahadevan and N Sathapathi

PLATE III.
Fig. 2

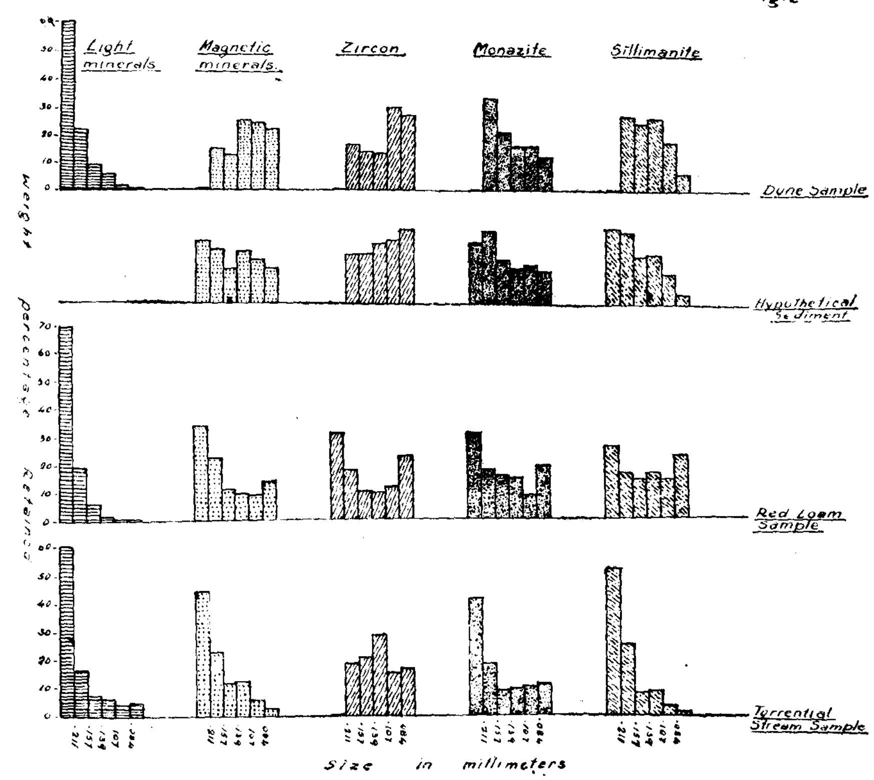
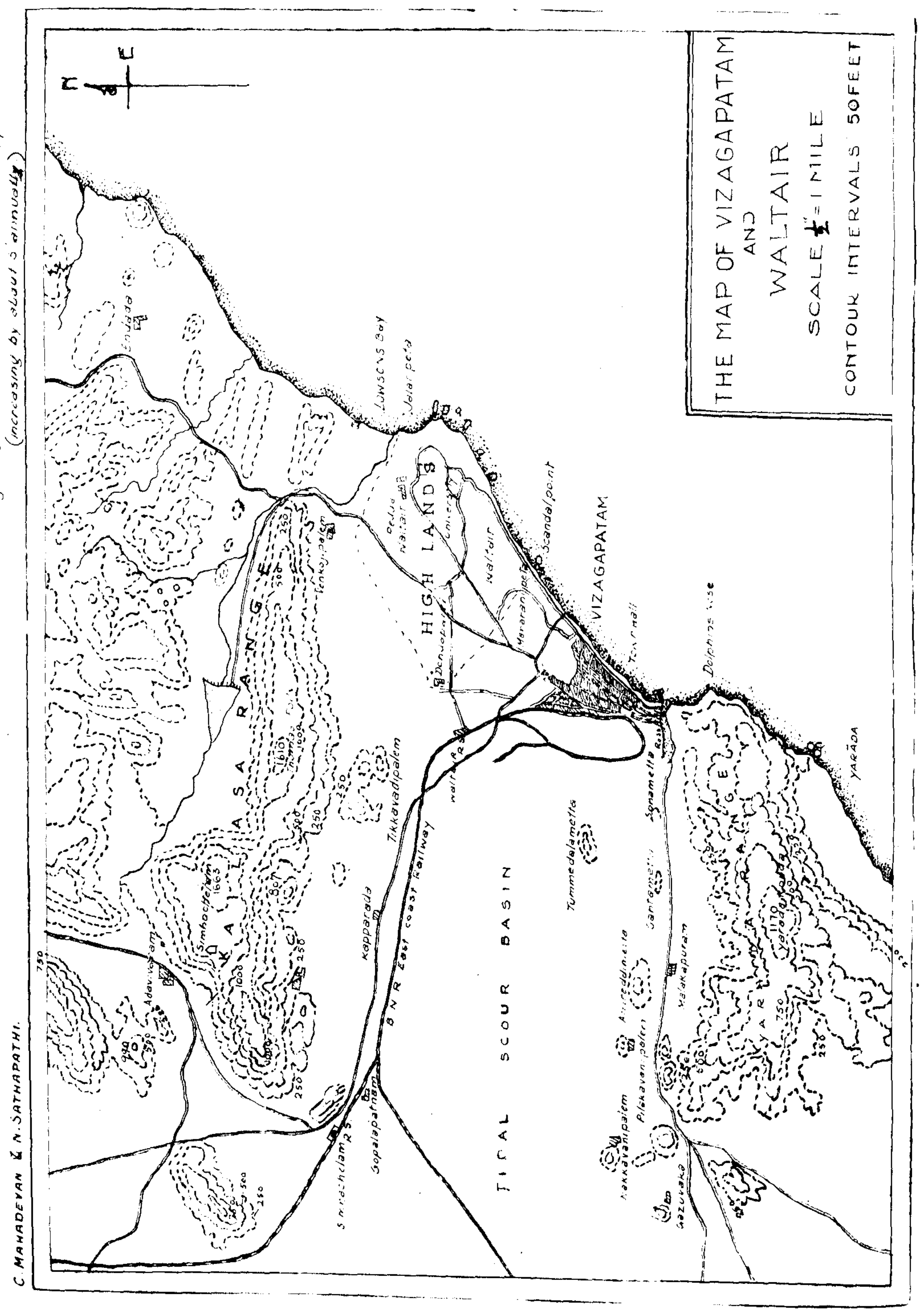


PLATE IV



According to the information obtained from the Harbour authorities, there is another source for the sands of the beach, besides what is brought by the streams, namely sands brought by the shore currents from the south. This factor might have also effected the mineralogical composition of the beach sands consequently of the dune sample. But to what extent this factor might have effected the mineralogical composition of the beach as well as the dune sand is not known precisely.

MECHANICAL COMPOSITION OF THE VARIOUS HEAVY MINERALS.

From the mineralogical composition of the sediments represented by the samples, it has been shown that these are genetically related. It is also known regarding the mode of formation and agency of transportation of the materials of the dune and torrential stream samples. But it remains to be known about the agency that deposited the red loam by comparing certain physical characters of its material with those of the other.

The comparison of histograms of the red loam samples with those of the other two, has not yielded any fruitful information regarding the agency of transportation of the red loam, but a comparison of the histograms of various minerals that are common to different samples is made to see what light it throws on the problem.

The histograms of different minerals of the samples, constructed from the data given in Table IV are shown in Fig. 2, plate 3.

From Fig. 2, plate 3, it is seen that the histograms of various minerals of a sample are not the same as those of the corresponding minerals of the other samples. But the histograms of different minerals of any one of the samples seems to be indicative of some factor effecting the distribution of different minerals in various size grades.

The histograms of minerals like magnetite and zircon of the dune sample indicate that these minerals are more in the sample in the finer grades than in their coarser grades, while the histograms of monazite and sillimanite show that these are abundant in the coarser grades rather than in the finer grades of the sample.

On the other hand, magnetite, zircon, monazite and sillimanite of the torrential stream sample are present in greater amounts in the coarser grades only, as is indicated by their histograms.

The histograms of the above minerals of the red loam show that these minerals are present almost in equal proportion in the coarse as well as fine grades.

Due to various field considerations effecting the mineralogical composition of the sediments, already alluded to, and the differences in the factors controlling the distribution of each of the minerals in various size grades, the conditions under which the red loam was deposited and the medium through which it was brought to its present position might have been different from those of the dune and torrential stream samples.

But so far, the histograms of the minerals of red loam have not been compared with the histograms of the corresponding minerals of a material deposited by the agencies of wind and water though there are greater chances for the formation of sediments through the combined work of wind and running water in such places as Vizagapatam where both these agencies are equally active. To have such a comparison between the histograms of minerals of red loam material and the histograms of minerals of a sediment in part aeolian and in part fluviatile origin, the following procedure was followed.

The weight percentages of each of the minerals of the corresponding size grades, of the dune sample and the torrential sample were added and for a total of one hundred, the weight percentages of each of the minerals of different size grades were calculated. The results are given in Table V on page 46. The histograms of minerals constructed from these are shown in Fig. 2, Plate 3.

From Fig. 2, Plate 3, which shows the distribution of different minerals in various mechanical fractions of a hypothetical sediment formed of the material brought by the wind and stream, it is seen that the form of the histograms tend to exhibit a similar distribution of minerals in different mechanical fractions as the red loam sample. It should be borne in mind that the proportion, in which various minerals of different sizes of the wind deposit and stream deposits are present in the hypothetical sediment, will not be equivalent but will have some amount of similarity in the size distribution of minerals of a similar material formed by the cumulative work of the two agencies and deposited at a place where the red loam is now found.

However, within certain limitations, the mineral distribution of the hypothetical sediment points out that the mineral distribution of the red loam sample might be due to the same cause as that of the hypothetical sediment.

THE MECHANICAL COMPOSITION OF FINER MATERIAL OF RED LOAM.

The red loam sample contains as much as 21% fine matter (below 300 I. M. M.) composed of 6.3% of fine sand, 42.8% of silt and 50.8% of clay. Field evidence and theoretical considerations do not favour the assigning of an aeolian origin to this material of the loam; there is a greater probability of its being of fluviatile origin.

The absence of any gradation of the particles of the red loam and the presence of clay in an intimate association with the coarser sand, point to the fact that the material of the red loam might have formed due to the combined action of wind and water.

TABLE V.

Mineral	Sample	Weight of the mineral in the sample in grams.	Distribution by size grades (in percent by weight) mm ·421-·211	mm ·211-·157	mm ·157-·139	mm ·139-·107	mm .107-.084	mm <·084
Magnetic minerals*	Torrential stream sample	35·76	44·19	23·11	11·75	12·01	6·39	2·56
	Sand Dune sample No. 1	4·544	0·00	15.01	12·47	25·68	24·73	22·11
	Hypothetical sediment		22·09	19·06	12·11	13·84	15·56	12·33
Zircon	Torrential stream sample	0·256	0·00	18·82	20·78	28·95	15·30	16·14
	Sand Dune sample No. 1	0·457	0·00	16·35	13·58	13·36	29·61	27·08
	Hypothetical sediment		0·00	17·58	17·16	21·15	22·47	26·61
Monazite	Torrential stream sample	1·565	42·18	18·18	9·14	9·32	10·17	11·00
	Sand Dune sample No. 1	0·535	0·00	33·65	21·10	16·63	16·26	12·36
	Hypothetical sediment		21·09	25·91	15·12	12·97	13·21	11·68
Sillimanite.	Torrential stream sample	10·235	52·41	25·48	8·56	8·59	3·19	1·73
	Sand Dune sample No. 1	1·902	0.00	26·25	24·18	26·04	17·40	6·13
	Hypothetical sediment		26·20	25·86	16·37	17·31	10·29	3·93

* All those attracted by a strong permanent magnet.

Red loam (sample No. 2):—To the south of Waltair Club, Waltair.

Sand Dune (sample No. 1):—Situated by the side of Ootagadda stream, Waltair.

DISCUSSIONS OF RESULTS.

A Review of the Earlier Theory:—The earliest reference to the geology of this district giving some observation on the origin of the Waltair Highlands is "the Geological Sketch of the Vizagapatam" by King (1886). King in an analogy with the red sandy and gravelly formations of the coastal plains of South India that have yielded numerous palaeolithic stone implements which according to him belong to the older or post-pliocene alluviums, considers the red loam formations of Waltair to be of the same kind and age as the above coastal formations. He is of the opinion that the present position and topographical features of the Highlands may be either due to denudation of a great sand bank which formerly extended north-wards across the Hanumanthavakagedda stream and on to Bhimilipatam hill or due to the formation of localised sand banks around the then sunken hills in the post-pliocene times, with a subsequent elevation of the land to a height of about 200 feet. The relative movement of land and sea is assumed by him in accordance with the evidence afforded at many other places in Madras low country, particularly by the great shingle banks far inland in the right bank of the Penner river in the Nellore district or the much greater and thicker ones gathered round the foot of the Nagalapuram hills north-west of Madras.

VALIDITY OF EARLIER THEORY IN THE LIGHT OF AVAILABLE DATA.

According to King, if the red loam formations of the highlands were to represent denudational remnants of a great sand bank of the post-pliocene times, or isolated banks formed around the then sunken hills, during the post-pliocene times, it should contain indications such as lamination, current bedding, gradation of the particles of the sediment and molluscan remains of a marine origin. However, the formations do not afford any such evidence to support the above theory.

Again, according to him if there were an upheaval of land subsequent to the formation of the sand bank or banks to a height of about 200 feet above the M. S. L. then there ought to be sea caves or other wave sculptured rocks at heights of about 200 feet at favourable spots along the coast. Though sea caves and other kinds of wave sculptured rocks are met with at some places along the coast, these do not occur at such heights as King (1886) postulates but are confined to a maximum height of about 25 feet and appear to be of very much earlier geological age, when the beach itself was nearly up to that elevation.

THE ORIGIN OF THE HIGHLANDS.

From the preceding discussion, it is clear that the red loam formation is not a raised beach. Field evidence does not point to such a possibility.

The sea caves that stand at a height of about 20-25 feet above the present beach may not be due to any elevation of land but most probably due to simple erosion and denudation of the coast.

From a consideration of the mineralogical composition of the sediments of the area, it was shown earlier, that these have an intimate genetic relationship so far as the sources of these sediments are concerned.

From a comparison of the histograms of minerals of the sediments detailed earlier, it is inferred that the red loam sample represents an admixture of aeolian and fluviatile material formed by cumulative work of wind and running water.

It seems most probable that the red loam was formed of the materials brought by the streams carrying highly decomposed and disintegrated products of the khondalites, charnockites, granite and pegmatites and those brought by wind from the coast, the materials of which mostly consist of the sediments brought by the above streams, and to a minor extent, the sand brought by the shore currents beyond the beach area.

THE AGE OF THE HIGHLANDS.

A careful examination of the scarps and profiles now exposed either along the margin or amidst the badland

topography reveals, imbedded gravels (Fig. 6, Plate 1), most of which show rounding of the edges in a matrix of red loam. These appear from their disposition and shape to be of fluviatile origin. In some of the upper layers of the red loam were picked up some palaeoliths, in the lower parts of the red loam some of the gravels appear to be eoliths. Some of these polished, water worn pebbles which show facetting appear to be dreikanters. If this evidence is properly assessed it appears that the Waltair Highlands were formed during the pluvial period coming close on the heels of pleistocene age. It is conceivable that for the rapid growth of the table land far in excess of its denudation there had been a heavy accumulation of sediments brought by streams. The existence of such a pluvial period in India as elsewere is well recognised. Simultaneously with the accumulation of sediments, aeolian sand brought by strong winds must have got deposited in the alluvium and built up rapidly, the Waltair Highlands. All the evidence available confirms this inference.

The cutting up of the highlands into a badland topography and the rapidity with which this has been taking place in the immediate past are indicative of certain amount of arid conditions, with torrential rains which favour denudation far in excess of deposition. So, the age of the Waltair Highlands may thus be considered as late and post-pleistocene, synchronising with the history of the development of the early man.

SUMMARY AND CONCLUSIONS.

The Waltair Highlands occupying over an area of about four square miles and rising to a height of 150 feet at places is formed of a thick red loam deposit collected around isolated hillocks composed of khondalites, charnockites, granites and pegmatites. These highlands running roughly parallel to the coast are in an advantageous position to receive material brought by streams from the talus covered hills of the north and sand from the coast by the wind.

From a comparison of the mineralogical composition of the red loam of the Waltair Highlands with that of a stream and a dune sample obtained from the area, it is inferred that the red loam of the Waltair Highlands is derived from the decomposed products of the rocks of the area.

The histograms of the minerals like magnetite, sillimanite, zircon and monazite of the red loam, dune and stream samples, reveal that the red loam was deposited under different sets of conditions than the materials of the other two deposits.

The histograms of various minerals of the hypothetical sediment obtained by taking the average percentage values of corresponding size grades for each of the minerals of dune and stream samples, tend to show that the red loam might have formed as a result of the cumulative work of wind and running water.

The red loam deposit being devoid of lamination, current bedding, gradation of the particles and marine shells, points to the fact that it was not a pure fluviatile or an estuarine or a lagoon or a shallow water deposit which has been subsequently uplifted. The Highlands are shown to have been formed by the cumulative action of streams and wind.

The notion that the Highlands are a raised beach is incomprehensible due to the above reasons. The occurrence of sea caves at height upto 20-25 feet may be due to simple erosion of the coast and not due to any relative movement of land.

The red loams is shown to have formed of the materials brought by the streams from the decomposed products of the rocks of the place and the sand brought by wind from the coast. From the presence of some palaeoliths in the gravels imbedded in the red loam, it is suggested that the Highlands were formed during post-pleistocene times, as a result of the pluvial conditions, and this event synchronised with the history of development of the early man.

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*Prospects and Potentialities of East Punjab.

BY

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The task of delimiting the boundary line between the East and West Punjab was naturally difficult on account of the divergent claims put forward by various parties. In fact it became more complicated due to the existence of the canal systems and rail-road communications both of which had developed under a single administration. As a result of the Radcliffe Award East Punjab includes Jullundur and Ambala Divisions and the Amritsar District of Lahore Division. Gurdaspur and Lahore Districts of Lahore Division have been divided between the East and West Punjab. In the case of Gurdaspur District, Shakargarh Tehsil which lies west of river Ravi was allotted to the West Punjab, while Pathankote, Gurdaspur and Batala tehsils which lie east of the river Ravi became part of the East Punjab. In Lahore District, whole of the Chunian and Lahore tehsils were included in the West Punjab, while Kasur tehsil has been divided between the two new Provinces, the line of demarcation following village boundaries from the point where the Upper Bari Doab canal enters the Tehsil to a point just west of Khem Karan station at the village of Masteke.

* Address delivered at the inaugural meeting of the Delhi Branch of East Punjab Geographical Society.

East Punjab is a new province, and it is a small province. It is the westernmost province of the Indian Union and hence is of great military importance. It contains only the eastern thirteen districts of the old Punjab out of a total of 29 and is now only a land of two rivers as compared to the former 'Land of Five rivers'. The area of the East Punjab is a little over 30·5 thousand square miles and according to the 1941 census its total population comes upto about 1·3 crores, although the next census may have quite a different story to tell. The millions that have been uprooted from their soil are yet unsettled and it may be some time before we can get correct population figures.

Do we like the name 'East Punjab'? I submit that it is nothing more than a misnomer. The Punjab as the 'land of the five rivers' remains no more. It is idle to stick to unpleasant memories. 'Satlaj Pradesh' seems to be quite a useful and workable suggestion.

The province is not a homogeneous territory. In its north-east lie the hill ranges of Shivalak and the Kangra Valley; the Jullundur Division contains rich alluvial soils while parts of Ambala Division or Hariana Prant are dry and waterless tracts. Linguistically too, the Province presents lot of variety. In most of the Simla Hill States (Himachal Pradesh), Kulu and Kangra, the language spoken is Pahari'. To further south in the districts situated on the south bank of River Jamuna *viz*; in the eastern half of Ambala, Karnal, most of Hissar, Delhi and Gurgaon, the language spoken is not Punjabi, but some form of Western Hindi known as Harianvi. In the rest of the districts, the language spoken is Punjabi.

Like the rest of the country the province has three seasons, popularly known as winter, summer, and the rainy, although the last named can be called a 'season' only by way of courtesy as the actual amount of precipitation is totally unsatisfactory. The temperature conditions as a whole present extremes, the annual range varying from twenty to

even forty degrees farenheit in the various regions of the province. Rainfall is dominated by the South-west Monsoon but owing to topographical conditions, the amount of rainfall is little in spite of the fact that it receives the advantage of both the Arabian Sea and the Bay of Bengal branches. In winter some rainfall due to the cold weather disturbances comes from the North-west. Only the hill slopes near Dharamsala and Dalhousie get a heavy rainfall, about 80". On the other hand there are places that get as low as 10". The condition in Ambala division is most alarming as the margin there is so small that except where artificial means of irrigation exist, any material diminution in rainfall may mean famine.

At present frankly speaking, the economic outlook of the province is quite gloomy, although it is well known that this backward state of affairs is certainly not due to any lack of resources. When the western districts of the United Punjab could be developed in all spheres, there was no reason for letting this area rot. It was all due to the wrong policy of the former governments. All the thirteen districts of the province offer tremendous possibilities of development. Agriculture is the staple industry of the people. Our main difficulty is lack of irrigation water. More of canals and tube-wells are urgently needed.

It has been estimated that with the construction of Bhakra Dam, the famine-stricken areas of Rohtak, Hissar and Gurgaon will be turned into thriving and flourishing canal colonies. The project contemplates the construction of a dam about 480 feet high to store water in the monsoon season at Bhakra on the Sutlej river. Bhakra is situated in Bilaspur State in the Himalayas, forty miles north of Rupar where the river leaving the mountains enters the plains. It is estimated that the dam will be able to store 4·3 million cubic ft. of water of which 3·5 million cubic ft. will be live storage capable of being released during 270 days, at a mean discharge of 6,000 cusecs. The capacity of the dam is more than three times the storing capacity of the famous Aswan dam on the river Nile in Egypt.

The dam, with its 200 miles of lined main canal and net work of distributaries, irrigating an area of 4½ million acres, will turn the East Punjab into one of the most flourishing granaries in the world.

The work on the Dam has started but it will take a few years to complete the scheme. Hence for the time being we will have to depend on percolation wells. A scheme to dig about thirty thouand wells in the course of four years is under active consideration; in fact a sum of ten lakhs of rupees has already been set apart for the purpose.

In order to provide adequate agricultural training, temporary arrangements have been made with the Khalsa College, Amritsar. The question of establishing a permanent Agricultural college is also engaging the active attention of the authorities. In fact many sites have already been examined for the purpose.

Agricultural machinary like tractors are already in use in some areas of the province and more will soon be in action. Soil erosion has been a great menace to the prosperity of the area. Soil deterioration is equally rampant. The first problem is already under examination of the experts. The problem could be tackled by means of two channels, firstly by the reclamation of usar land and secondly by protecting the areas of probable damage. A sane policy of gradual afforestation specially in the upper catchment areas of the rivers and a good drainage system are two healthy cures.

Use of proper manure is advocated to check soil deterioration. Greater use of dung as manure is advisable and this will need a substitute fuel. The department of agriculture is distributing more than a thousand maunds of Ammonium Sulphate. Green manuring and compost making are also being advocated.

Forests are a great national asset and are indispensable to the economy of human life and prosperity of the country as a

whole. They provide many amenities of our daily life. Indeed the value of forests to any country is far more potent than commonly realised.

The proportion of forests to the total land area in the East Punjab is about 6 per cent only. Generally these forests fall into two broad types; *viz.* the coniferous forests in the hills are most important economically and cover a very large area in the hills. They yield valuable timber. In the Plains we have the scrub forest.

The Government have kept the following objects in respect of their forest policy :—

(*a*) To maintain the maximum amount of regeneration for the protection of the hill-side against erosion and to preserve rainfall in order to secure a more equable flow of water in the main rivers.

(*b*) To provide for the domestic and agricultural requirements of the population in the hills.

(*c*) To secure for Government the maximum income possible from the sale of timber and other forest produce.

(*d*) To associate the villagers with Government in schemes for the development of the village waste through the formation of forest societies.

The irrigated plantations, *Chhanga Manga*, *Chichawatni*, *Khanewal* and others, which were valuable source of fuel supply to large consuming centres have gone over to the West Punjab. With the transfer of these plantations, and the increased demand of fuel resulting from the influx of refugees, the Forest Department was faced with the problem of acute shortage of fuel. To meet the shortage advance fellings were ordered in Kangra, Amritsar and Gurdaspur and also in Government *Birs* in Karnal district. With a view to raise firewood plantations in the East Punjab extensive nurseries are in the course of formation and the afforestation of the village waste lands and canal avenues is being speeded up.

The mineral and power resources are of little, or no significance. Slate is the only item worth mention. It is obtained in Kangra Valley near Dharamsala and at Rewari in Gurgaon District There is no coal and no petroleum. Either coal should be imported or hydro-electric power developed. The Mandi Hydro Electric Station gives about 36,000 Kilowatts. It will give more when fully developed. But the difficulty is that quite a big part of energy generated here is sold to West Punjab. If we could have all of this power, things will surely improve. The Bhakra Dam will give about one lakh, and sixty thousand kilowatts of power. The Bhakra and Nangal schemes will open up the south-east portion of the Province for starting new industrial projects.

In the industrial field the East Punjab has great potentialities. Besides having the resources for hydro-electric projects, it is endowed with natural wealth of forests. Even today, the East Punjab has textile mills in Amritsar and Bhiwani, a big woollen mill at Dhariwal, and a silk industry at Amritsar. Ludhiana is the centre of hoisery industry and is regarded by many as the Manchester of India. We have a paper mill at Abdullapur, a carpet factory at Amritsar and nuts and bolts factories at Jullundur and Ludhiana. Amongst the small-scale cottage industries, handloom is the most important and is centralised in Hoshiarpur, Jullundur and Ludhiana.

The existing industrial structure of the province is pyramidal in character, with a very wide and durable base of cottage industries, and fair sized body of small-scale and organized industries. A striking feature of the industrial pattern of the province is an uneven distribution of industrial activity. Industry is mainly concentrated in the border districts of Amritsar, Gurdaspur and Ferozepur. Over half of the registered factories and about 60% of the workers engaged in organised industry are concentrated in these three districts.

Onthe other hand in the south-eastern districts of Gurgaon and Rohtak and the mountainous district of Simla there is hardly any industry.

Another notable feature of the industrial system of the province is that 75% of the registered factories work throughout the year. Amongst them, textile and hosiery mills, foundries and engineering workshops, paper and glass factories, flour mills and chemicals are the most important. The Dhariwal Woollen mills in Gurdaspur district is one of the two biggest woollen mills in India and manufactures about half of the total woollen cloth made in the whole of the country. The other industrial concerns of note in the province are embroidery mills, absorbent cotton and antiseptic dressing factories, glass and several carpet factories at Amritsar, metal foundries at Batala and Jullunder, paper and pulp mills, starch sugar factory at Abdullapur, plywood factory at Ludhiana, factories for the manufacture of nuts and bolts at Jullundur and Ludhiana, steel rolling mills at Amritsar, Khanna and Ludhiana, tanneries at Jullundur, factories for the manufacture of apparatus at Ambala and Amritsar, fruit preservation plants at Pathankot and Ambala and chemical factories at Amritsar.

The small-scale and cottage industries are numerous and varied. Handloom weaving including manufacture of blankets and rugs at Panipat, hosiery industry at Ludhiana, utensil making at Rewari and Jagadhri, tanning and wood working in Jullundur and Hoshiarpur rank probably the foremost amongst the cottage industries. Recent development in the industrial life of the province has been the expansion in sericulture which has attracted a large number of agriculturists in the sub-montane tracts.

The disturbances following the partition have adversely affected the industrial life of the province. At present hardly any industry is working to its maximum. Skilled labour has been displaced and is not available. Markets have been dislocated and banks are not functioning normally. It will take sometime before the industrial life of the province can be restored to the pre-partition days.

It cannot be, however, denied that in spite of the partition the province offers tremendous opportunities for industrial development. In pursuance of the policy of planned industrialisation of the country a number of organised industries were earmarked for this part of the Punjab. With the rapid restoration of normal conditions in the province it should now be possible to develop most of these schemes. A review of the old position would be profitable in order to understand the background of the new policy and programme to be followed in the East Punjab.

A rapidly growing industry in the Punjab was the cotton textiles. The future of this industry has been rendered highly problematical by the partition of the province. The major long staple cotton growing areas are mostly situated in the canal colonies in the West Punjab. The right type of raw material has been lost to us. The other factors *viz.*, a heavy demand for cloth, adequate capital resources and the supply of labour, however, still continue to be favourable. And as things are at present, it will not be possible for the West Punjab to utilize its entire production of raw cotton in the manufacture of cloth. Given peaceful conditions between the two Dominions, we should not ignore the possibilities of building up a cotton textile industry. The raw material could be either imported from the West Punjab or from the rest of the Union of India. There is also the probability of an increased out-put of cotton in East Punjab on account of our development plans like the Bhakra Dam project.

The prospects of the woollen textile industry have not been impaired in any way by the partition of the province. Our mountainous districts should provide excellent grazing fields for sheep breeding and the woollen industry can greatly develop in times to come.

In the scheme of planned industrialisation of India, the Punjab was regarded as very favourably placed for the establishment of a factory for the manufacture of artificial silk.

Beas in Amritsar district or some other suitable place in Kangra district should prove an excellent site for a factory for manufacturing artificial silk.

We have at present only one factory in the East Punjab, located at Jagadhri which produces about 7000 tons of paper and this quantity was considered sufficient for meeting the internal requirements of whole of the Punjab. In actual practice, however, about 5000 tons of paper were imported every year from Bengal and almost the same quantity was exported. The raw material used *viz.* Sabbai grass does not grow in East Punjab in sufficient quantities to meet even the existing requirements.

The manufacture of newsprints could, however, be profitably developed in the East Punjab in a centre like Beas.

Before the partition, the Government of India approved the establishment of two new sugar mills in the Punjab and both the sites selected for this purpose *viz.* Tanda Urmar (Hoshiarpur district) and some place near Dhariwal (Gurdaspur district) are situated in East Punjab. As a sugar factory can be economically fed on cane grown within 10 or 15 miles radius of its location, the establishment of two new mills can even now be considered as a perfectly sound venture, so for as the supply of raw material is concerned. The large quantities of sugar which the province has imported during the period of control on sugar also prove that there is an assured market in the province for this commodity.

The principal raw materials for the vegetable ghee industry which were found in the united Punjab were cotton seed and groundnuts. Of these, the former is grown mostly in the West Punjab but the latter is available in the East Punjab in abundance. Recently a controversy has been going on about the nutritive value of vegetable ghee and it is now generally agreed that its use should be discouraged. However, in interest of food production in the Punjab it may be useful to establish vegetable oil refineries instead of vegetable ghee.

The prospects of development of the cement industry have appreciably diminished by the partition of the province. We have at present two factories situated in the territory of the East Punjab States, one with an output of 40,000 tons at Dalmia Dadri in Jind State and the other producing about 2,00,000 tons annually at Surajpur in Patiala State.

In order to meet the heavy needs of the East Punjab in view of the plans for building a new capital and extension of existing cities, the production of cement in the East Punjab will have to be increased heavily.

These are some of the industries which could be profitably set up in the East Punjab. We have to develop the provincial life in all its aspects and the industrial field offers unlimited opportunities to industrialists.

The above facts clearly prove that there is absolutely no cause for despair although to enter a state of respectable self-sufficiency we have to plan, and work seriously and sincerely. Our main wealth, besides the natural potentialities of course, lies today in the refugee camps. It is they that made Lyaallpur and Lahore, and Rawalpandi. The canal colonies that today abound in all sorts of agricultural produce are the result of labour put in by those who, today are called refugees. And we shall see very soon that this small province of ours will have better canal colonies, and factories and towns. Here I would like to say a word of caution. 'Do not repeat the mistake of having only centralised development.' By losing Lahore we have lost all that we were proud of. Let our efforts be decentralised and distributed all over.

There is today a demand for the creation of linguistic provinces. I feel it is a very dangerous move. No doubt we should redraw the provincial boundaries, but they should be drawn according to geographical and economic considerations. Narrow provincialism may bring results similar to those brought about by Communal Award. I have been working on the subject of redrawing provincial boundaries from the geographical angle. And in my scheme, East Punjab gets the districts of Saharanpur, Muzzafarnagar and Meerut. A province thus constitued will be the richest province in the country and will never look to others for help.

The Ecology of Erosion and Landslips*

BY

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(A paper read before the Geology and Geographical Section of the Indian Science Congress in January, 1949).

Soil erosion and landslips in Northern India as elsewhere in the world are generally believed to be caused by disturbing the original cover of vegetation. Thus, gully erosion and cho formation in the Hoshiarpur Siwaliks have been found by most workers, notably, Gorrie (1938; 41; 46; etc.), Glover (1941; 44; 44a), Coventry (1928), Glover and Hamilton (1935), and Hamilton (1936) to be related singly or collectively to such variable factors as disforestation, excessive grazing and burning of vegetation, high rainfall, steep topography or sandy nature of the rock.

Owing to its great economic importance the problem of erosion has been extensively studied in India as in other parts of the world, and a voluminous literature has accumulated during the last two decades. The menance of chos and erosion, in the Siwaliks Hills, however, has steadily increased and the area now presents a striking illustration of "deserts on the march".

Disforestation, and destruction of vegetation has occurred in other parts of the country as well. As a matter of fact, the spread of modern towns has gone parallel to the destruction of vegetation in the vicinity and at places where there used to be thick forests there is not a bush left now. Here, although,

*Published with the permission of the President, F. R. I. Professor C. Mahadevan, Mr. J. Coates and Mr. B. S. Sitholey have kindly gone through this paper and made useful suggestions. Mr. C. R. Ranganathan, President, F. R. I. showed a special interest in this paper and the author wishes to thank him for his helpful criticism.

disforestation has been more complete than in some parts of the Siwaliks, erosion of the land has not been the rule. Similarly, the effect of common erosional factors on land has also been not so serious in other areas as in the Siwaliks. In the Siwalik Hills the rate and spread of erosion is so great and complete that even a casual observer cannot fail to notice the crumbling of the entire hillside before his very eyes. Surely, there seems to be in the area some other factor, which in combination with disforestation has brought havoc, disturbing the organised agricultural life of the people.

A critical examination of the vast literature in the light of my observations in the Hoshiarpur Siwaliks seems to suggest that none of the external causes usually considered is perhaps singly potent enough to bring about erosion on such a large scale; and it is probable that some internal factor inherent in the structure of the region is fundamentally involved. The present note therefore, attempts to discover (1) the fundamental factor responsible for soil erosion in these hills and (2) suggests a right method for checking further deterioration of land.

The Siwaliks are a chain of low, much dissected hills running in an east-northwest direction parallel to the Himalayas on its southern side, constituting a foot-hill feature of the lofty ranges to the north. They are composed of alluvial detritus, derived mainly from the inner ranges, such as sand-rock, clays, poorly bedded sand-stones and conglomerates, and are more or less homogenous along their entire length, and believed to have been deposited contemporaneously. Different names have, however, been given to these deposits in different parts of the country. The elevation of the Siwalik Hills varies from 1,500-2,000 feet above sea level. In composition these Hills are generally similar in character to recent alluvial deposits, except that they are more compact, having undergone intense folding and faulting by post-Tertiary orogenic movements. They generally dip to the south and southwest, and "it is almost certain that the Siwaliks extend down for several miles underneath the alluvial cover of the Indus and Ganges Valley"

(Krishnan, 1943, p. 468). The Siwaliks at Hoshiarpur are composed of soft and friable sandstones with occasional thin bands of clays and/or conglomerate. The strata of the sandstone dip conspicuously to the south and south-west at high angles.

The Siwaliks which are now formed of sparsely forested valleys and spurs, probably bore a very luxuriant vegetation in pre-glacial times, in view of the rich and varied fossil fauna and flora discovered from wide and distant localities in them. The present poor population of plants and animals of this region as a whole (here I am not referring to the strikingly barren state of Siwaliks which have been disforested in historically recent times) may be due to inherent ecological changes in the soil and the organisms themselves. It is a well known fact that "the organisms produce vegetational change through their effects upon the environment; and by the production of new forms, varieties, species through evolution. The environment brings about changes in vegetation, because it, too, is undergoing constant change, partly inherent in itself but in part caused by the action of the vegetation upon it" (Cooper, 1926, p. 398). There is ample evidence (Wadia, 1931; 1932; 1936; 1938a; Pascoe, 1919; Pilgrim, 1919; Oldham, 1917, etc.) to show that large scale environmental changes have occurred in Northern India during the recent geologic past. For example, changes in the courses of main rivers in the plains in front of the Siwaliks and folding, faulting and thrusts in the Himalayas behind these hills must have produced a great change in the environmental factors in this region. During the Pleistocene period large stretches of north-western Himalayas were glaciated. A cycle of four Glacial advances with three intervening Interglacial periods has been shown to have occurred in the Kashmir Himalayas (Wadia, 1938; 1940; De Terra and Paterson, 1939). Contemporaneously with the glaciation the Himalayas were uplifted more than once, and these orogenic movements produced considerable effects on the vegetation of the region (Puri, 1947, 1948, 1948a, 1949). At this time conifers invaded our mountains from the west (Sahni, 1931; Puri, 1945, 1947) and constitute now a dominant element in the vegetation of the Himalayas. The Himalayas are still rising, and it is probable that this uplift is further initiating large scale ecological changes not only in the Siwalik Hills but also in the whole of Northern India. Almost certainly these would bring about changes in regional climate and determine to a great extent the development of soil and vegetation in local areas. The present phase of erosion in low-lands below is, therefore, apparently the result of regional changes outlined.

The Siwaliks as a whole dip generally to the south at fairly high angles; it is probable that with the further rise of the Himalayan region the internal structure of these Hills was so affected as to favour accelerated erosion along the southern dip slopes. There is some evidence from other areas to show that such was probably the case. For example, in the main Himalayas rise of the land surface rejuvenated rivers and streams giving them an impetus in cutting through the strata of the rocks with greater vigour and force. The comparative intensity of erosion on the southern slopes of the Siwaliks, vis-a-vis the northern (on which erosional damage by torrents is little) may, perhaps, be due to this factor.

Thus, it follows that the Siwaliks as a whole are predisposed to severe erosion, which is a consequence of inherent geological activity in the region. The products of erosion contribute towards the building of fresh deposits in front of these foot-hills, which might well form yet another hill in front of the Siwaliks. Grabau (1928) and West (1937) consider that the activity bringing about thrusts in Northern India has been shifting southwards from the Himalayas since Tertiary times, and at present "the locus of activity is along the southern margin of the hills or even further south out in the plains". (West. *loc. cit.*, p. 18). It is highly probable that this migrating geosyncline now operating in the Siwalik Hills is instrumental in the slow disappearance of these hills by erosion. The present trend of geological changes at any rate would indicate such a possibility, and "it seems logical to infer that in time the alluvial deposits immediately in front of the Siwalik

Hills will themselves be folded, thrust faulted and uprised to form yet another range of hills in advance of the Siwalik Hills, and yet another accretion to the southern face of the great mountain range" (West, *loc. cit*). The materials for the formation of such a future range would inevitably come from the erosion of the Siwaliks.

The entire Siwalik Hills as compared to other regions in the extra-Peninsular or Peninsular India are geologically predisposed to erosion. But, even then the rate at which the erosion in the Hoshiarpur Siwaliks has proceeded during the last two or three centuries is far greater than the speed of a normal geological erosion. Geological structure and orogenic activity are operating since the very inception of these hills, but the severe phase of erosion hardly dates back to two or at the most three centuries. During this brief period there does not seem to have occurred any perceivable geological change or metamorphism in the structure of the country. It appears, therefore, very likely that this unprecedented scale of erosion has been caused by some external factor which in combination with favourable internal structure has acted as a "trigger" factor. These external factors may be topography, slope, a high rainfall and disforestation.

Of all these external factors topography and slope seem to have a little effect in these hills though any one of these may have conceivably locally accelerated the speed of erosion. Discussing the causes of soil erosion in the Siwalik Hills, Hamilton (1936, p. 10) remarks "For the most part the Hoshiarpur Siwaliks have a gradual slope from the edge of the plains to the crest, a rise of 600 to 800 feet in from three to five miles, and externally they appear unlikely to cause serious torrents". That topography and slope are not vital factors in causing land erosion in these hills is evidenced by the fact that the northern slopes, though, steeper than the southern, are much less eroded. These observations are in agreement with those of Glover and Hamilton (1935) who stated that "On the northern slopes the process of destruction has proceeded more slowly.

....(though on these) slopes the torrent beds are steeper". The difference in the magnitude of erosion on the northern and southern slopes is, as will be shown below, due to the dip of the strata and the direction of the monsoon winds. However, it is abundantly clear that steepness of the slope by itself is not the cause of erosion here.

Reasons against a high incidence of rainfall in these hills aggravating soil erosion are apparent from the following facts. During the years 1862 - 1930 rainfall has steadily decreased from 36·70 to 26·61 inches per annum but the areas spoiled by erosion have increased in the same proportion. The following data taken from the report for the year 1943 of the Director, Central Irrigation and Hydranomic Research Station, Poona, are of considerable interest in this connection* :—

In 1852 chos areas near Hoshiarpur was	....	48,206 acres.
In 1884 chos areas increased to	....	80,057 acres.
In 1897 chos areas increased to	....	94,236 acres.

The present area under chos is approximately 150,000 acres.+

The data for the above four dates have been plotted in Fig. 1 and a smooth curve given by the equation

$$Y = 49{\cdot}8785\ (1{\cdot}0136)^{x-1852}$$

fitted to them. The fit is reasonably good. Although it is not advisable to extrapolate such curves, either backward or forward, beyond the observed range of years, namely, 1852—1936, it appears reasonable to conclude that rate of erosion is gathering increased momentum.*

Although the amount of rainfall here does not seem to be of much significance in aggravating soil erosion, a consideration of the direction of the rain bearing winds with respect to the general position of the Siwaliks promises to be of considerable

*Unpublished report is filed under G/261/Gn. ledger files of the Silviculture Branch, F.R.I.

+From Hamilton, 1936, p. 15.

*I am grateful to Dr. K. R. Nair, Statistician, F.R.I. for his expert help.

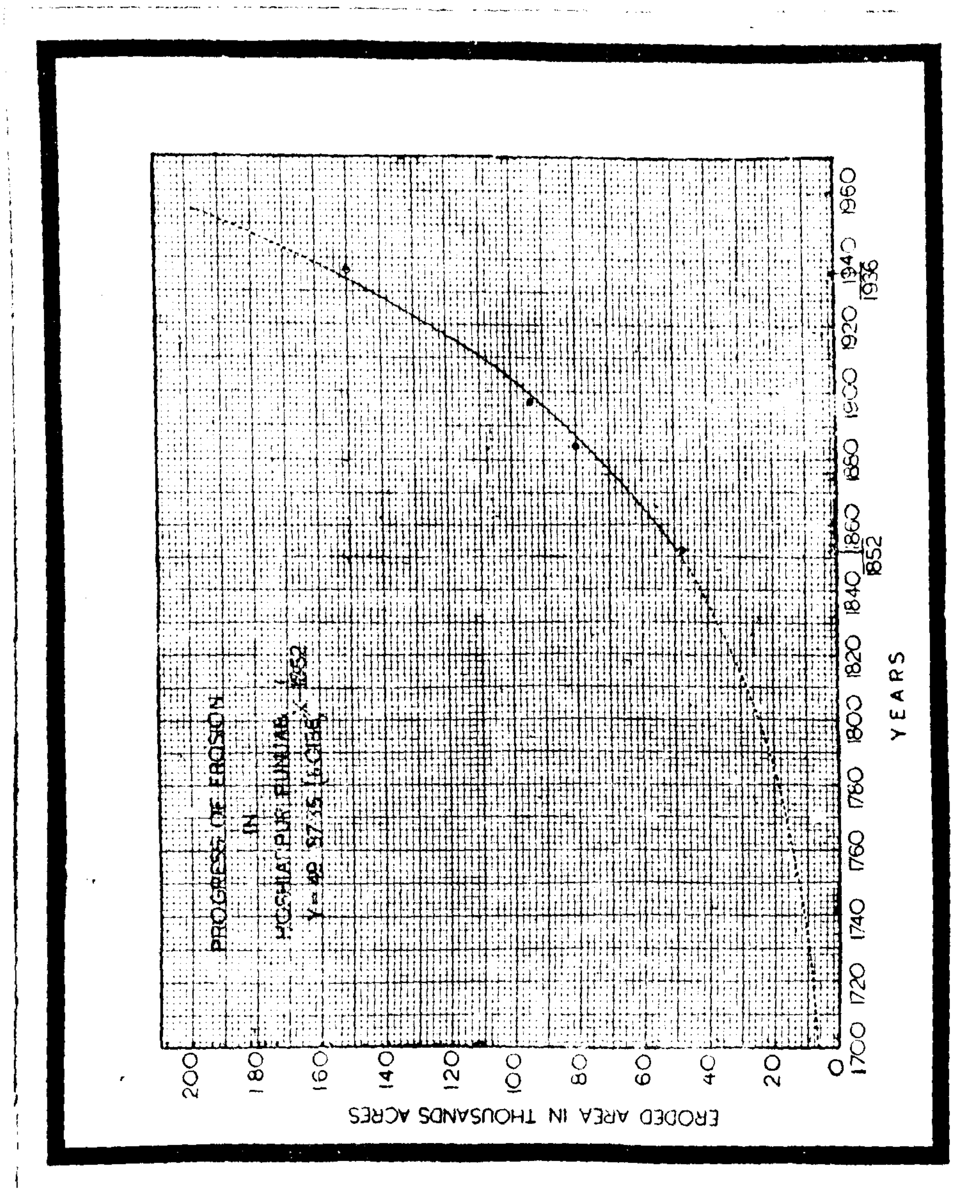

FIG. 1.

interest. Most of the rainfall in these hills is brought about by southern monsoon winds, which strike the southern dip slopes with initial vigour. Much of their force is spent on this side before they reach the northern slopes where owing to lack of strong air currents due to mountain barriers, the slant of rainfall is more parallel to the hillside than against it. Rain-drop splash is, therefore, reduced on the northern face and in consequence the damage is less. The direction of the rain bearing winds, is thus an important external factor that works in combination with the internal structure of these Hills to bring about greater erosion on the southern slopes.

The third and perhaps the most important noticeable factor is the natural plant cover. There is ample evidence to show that vegetation has been subjected to severe destruction in these Hills by man and domesticated animals during the last 100 years. Depending upon the type of soil, the removal of tree vegetation has invariably led to the loss of soil fertility, apart from exposing it to the destructive forces of nature. From the point of view of vegetation, experience in forestry practices has shown that on poor, sandy soils clear felling has led to the domination of shrubs, and development of a more xerophytic type of vegetation. In terms of succession, " the influence of man, however, almost without exception is retrogressive" (Cowles, 1911 p. 179). The other and, perhaps, the most serious effect that clear felling has on the soil is that it subjects it to the severity of rain-drop splash. The continuous hammering of rain drops on soil poor in humus, erodes it away. From the point of view of the development of new vegetation, erosion also produces results similar to the biotic factor and " as might be expected, the influence of erosion generally is destructive to vegetation, or at least retrogressive (*i.e.* tending to cause departure from the mesophytic)" (*loc. cit.*, p. 171). It becomes evident that soil erosion which is inherent in these hills and is accelerated by human influences produces a xerophytic type of vegetation and the activities of man further accelerate this natural trend in vegetational degradation. Human agency is, therefore, largely blamable in this case and has played the most gnoble part in this destruction of mother earth. A glance at fig. 1 shows that erosion in its uncontrollable form dates back to the end of the last century - and coincides with the period when the vegetation was severely destroyed under the early British rule. It seems to gain momentum decade after decade and if nothing is done to check it, it may erase the entire hillside out of existence.

The only remedy against this lies in the binding of the soil by vegetation. Arresting of succession of vegetation when it is in a mesophytic stage may be a solution of checking soil erosion. What may be feasible now may not work after another ten years. Afforestation which is generally considered to be a remedy against erosion may not work at all if it becomes too late. Because the ecological changes in the soil and vegetation are continually working towards xerophytism and it is likely that the planting of xerophytic species—the only ones that can at all be planted under existing conditions would not produce the desired effect of combating erosion.

It has perhaps already become too late in some places and the futility of afforestation of the kind practised as a measure against erosion in these hills is being felt by such eminent authorities as Glover and Hamilton (*loc. cit.*, p. 65). They observed about 12 years ago that "it is obvious that the usual methods of countering erosion and reafforestation are impracticable in these hills, as owing to the extreme friability of the sand-rock and the enormous quantities of sand degraded, terracing of the slopes and the training of the small ravines by *bunds* is impracticable apart from the prohibitive expense". Hamilton (*loc. cit.*, p. 12) further regretted that "the training of chofloods in their present state of violence becomes an engineering impossibility, except perhaps, at a fabulous cost". This shows convincingly that erosion in these hills has reached a stage when it cannot be effectively checked by the existing practice of afforestation, and it needs extensive and intensive measures, planned on strict scientific basis to control soil deterioration.

It therefore follows that erosion in the Siwaliks is fundamentally the result of general geological activity in the area and the stratigraphy of the rock. (*It has, however, been aggravated during the last one or two centuries by destructive activities of man in the Hoshiarpur area.*) On this view it becomes easy to explain (1) the relatively greater intensity of erosion on the southern slopes than on the northern, (2) a sudden rush of water in chos after a little rain (3) a gradual lowering of water-table in the area, (4) extinction of chos after a few miles from these hills and (5) the relatively greater fertility of Jullundur and trans-Jullundur areas.

As it has already been pointed out, the strata of the rock in this region generally dip to the south and southwest, and form gullies and chos in the direction of the dip. The northern side of the hills is an escarpment. It will be seen from fig. 2 that rain-water falling on the northern scarp would seep through the strata to the south, rising to the surface where the rock is fractured or the strata meet the level of the ground.

On account of this structural feature (1) the scarp slope becomes dried up soon even after heavy rain and (2) irrespective of the amount of rainfall at lower parts of the dip slope water would gush through the strata in a flood causing severe erosion in the sandy rock. This explanation agrees with the observational data collected in the region by other investigators and may with reasonable accuracy answer the query of Hamilton *viz.*, "The question may be asked how it is that with so slight a gradient the chos have been able to acquire sufficient force to do so much damage". It also helps to visualize the truth of the statements "the rush of water across the plains has to be seen to be believed" and "the flood subsides as suddenly as it starts and the immense volume of water, much of which might have been stored in the hills and sub-soil of the plains, is lost". On account of the friable and porous nature of the sandstone, rainwater falling on the dip slope at once percolates in the sub-soil, where it is subjected to two forces; one taking it downwards, and the other carrying it along the dip of the strata.

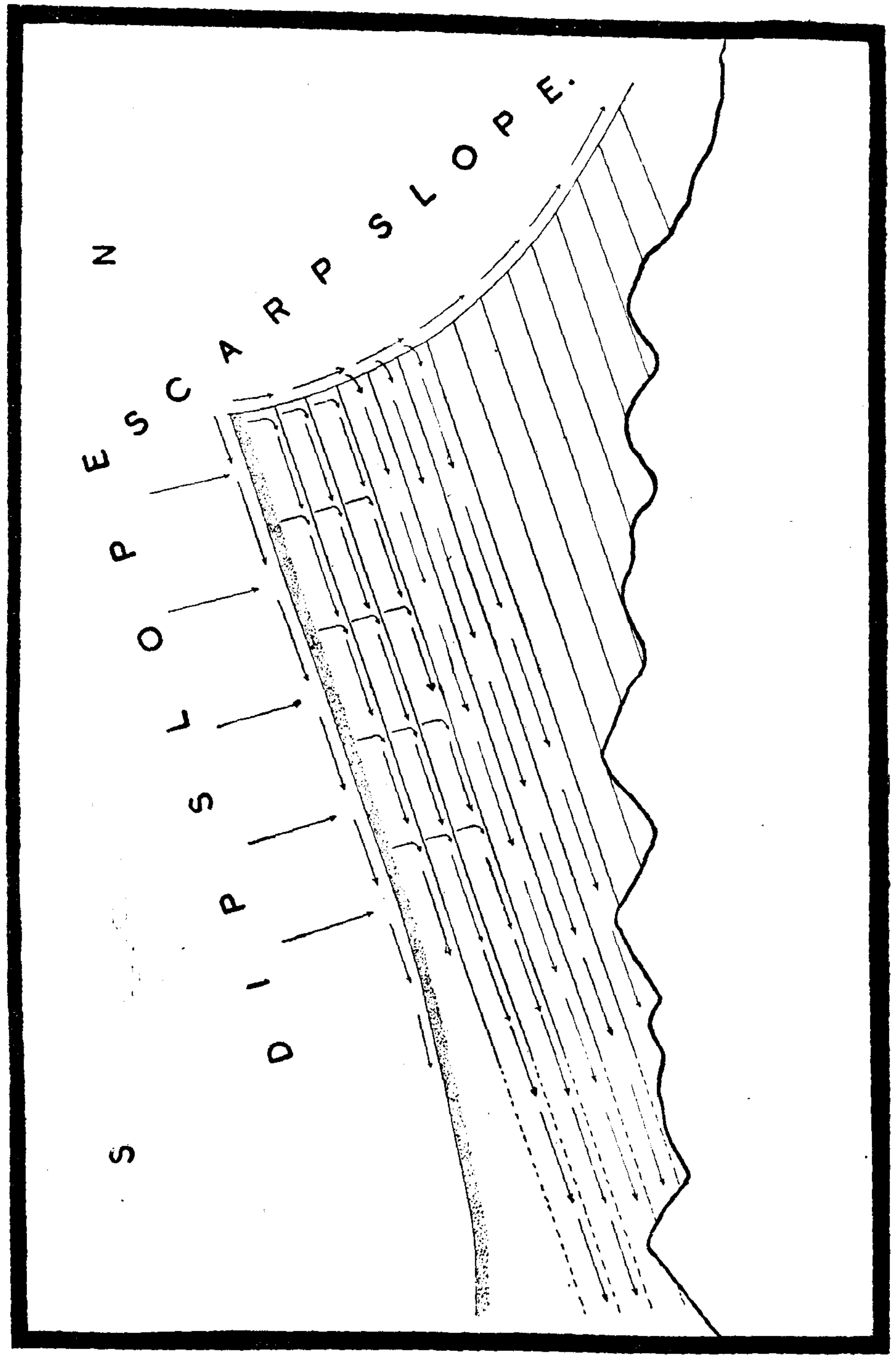

FIG. 2.

As a result of this, it produces a shallow horse-shoe shaped frill on the surface, the open end of the frill facing towards the dip. This surface frill is widened and deepened into a gully, which cuts back deeply into the strata of the rock as it proceeds. It is, therefore, not surprising that along 80 miles there are more than 100 chos which must have originated in the same way.

The Siwalik Hills in other areas are similarly traversed by perennial or semi-perennial torrents along their southern slopes. For example, in a distance of about 50 miles in the Saharanpur Division there are as many as 60-70 streams and the number of smaller torrents is much more. The scarp slope in this area is thickly forested and has saved the soils along the dip slope from destruction.

On account of the soft and friable nature of the sand-stone in the Hoshiarpur Siwaliks chos had branched, ramified and united to form a system which it is difficult to follow at places. The entire hills are now cut into a chain of spurs and buttresses with intervening valleys or chos plains. Along the side of some of the larger chos the strata of the rock are steeply cut showing clearly their composition and the angle of the dip.

At some places where the strata of the sandstone enclose an impervious layer of clays, the entire mass of overlying sandstone, lubricated by seepage waters slips down leaving a gap in the body of the steep-cut side of the ravine. It is almost impossible to check these landslips by planting trees along chos or in the flood plains where they grow naturally on freshly deposited silt.

At upper parts of the dip slope and along bottom of ravines vegetation is fairly rich and thick and conditions being favourable for its growth, artificial planting leads to magnificient results. Trees of *Lannea grandis*, *Dalbergia sissoo*, *Casearia tomentosa*, *Ougeinia dalbergioides*, *Bauhinia racemosa*, *Ehretia laevis*, *Cassia fistula* with shrubs of *Hamiltonia suaveolens*, *Woodfordia fruticosa*, *Diospyros tomentosa* were naturally present in such places. At higher elevations on these hills and on upper parts of the spurs there occurred *Dodonea viscosa*, *Adhatoda vasica*, *Carissa spinacum*, *Flacourtia ramontchi* etc. with planted *Acacia* spp. Planting of suitable species in these places would result in still better results.

On most of the spurs which are steep and more resistant to weathering there is relatively little tree vegetation. These probably correspond to scarps. Here *Bhabar* grass and *Acacia* spp. were planted, but were not closed to graziers. *It is here that intensive planting is necessary to check the erosion of the soil.*

Preliminary observations on the vegetation of this area indicate that generally dip slopes at higher elevation and lower levels in numerous valleys bore a better cover of vegetation, and that here a little more effort in planting is necessary to meet local requirements of fuel and fodder. The conditions for natural reproduction, provided there was a controlled and scientific interference from the biotic factor, are favourable.

For places where afforestation would be most essential in checking erosion a reference may again be made to fig. 2. To check the inflow of water through the strata it would be advantageous if the scarp slope is covered with vegetation. Experience in other areas along the Siwaliks shows that a thick cover of vegetation on the scarp can exercise beneficial effect by utilizing rain water and can to a great degree slow down the rushing in of water through the strata. *It is, therefore, highly important that large scale and planned afforestation measures should be applied on scarp slopes to counteract the erosion.*

SUMMARY.

From the above discussion it follows that the Siwalik Hills, on account of their structure, composition of the rock and the inherent geological activity in Northern India, are predisposed to erosion and landslips on their southern dip slopes. So a certain amount of erosion normally occurs in these hills. Erosional gullies are formed by the action of rain which percolates in the sub-soil and seeps through the strata issuing on the dip slope with a force depending upon the density of vegetation. A dense vegetation on the scarp slopes and at higher elevations on the dip slope provides a protective cover against the physical and chemical action of rain in accelerating the normal geological erosion. Evidence is re-stated to show that the present state of erosion in the Hoshiarpur Siwaliks was the result of irrational and nonecological uses (rather misuses) of vegetation, dating back to the last one or two centuries.

While no amount of emphasis is necessary on the value of afforestation to check the erosion it is suggested that (1) a planned and determined programme of planting of scarp slopes and higher elevations on the dip slope with suitable species be launched without delay; (2) the methods of forest exploitation in other areas in the Siwaliks be carefully examined in the light of ecological data presented in these pages; (3) extensive and intensive ecological studies of forests be made in the Siwaliks with special regard to soil conservation and spots susceptible to erosion be forthwith tackled by special afforestation parties.

The suggestions made here may be viewed in relation to a paper* submitted by me to the Ministry of Agriculture in June 1947. The need for an organized and intensive ecological research is most urgent for tackling the problem of soil erosion in India now, more than it was ten years ago.

* *Puri, G. S.* (14 June, 1947) "A plea for the establishment of Ecological survey of India to conduct researches in applied plant ecology in relation to forestry, agriculture and soil conservation".

A reference may be made to the letter No. F. 42 (3)/48-A dated 25th November 1948, from the Indian Council of Agricultural Research, New Delhi to the President, F.R.I. Dehra Dun and copy to me, on this subject.

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EXPLANATION OF FIGURES.

Fig. 1. A graph showing trend of erosional damage in the Hoshiarpur Siwaliks since 1852.

Fig. 2. A diagrammatic section across the Siwalik Hills, showing the dip of the strata of the sandstone. Rain drops and their seepage through the strata is indicated by arrows.

Some Aspects of the Regional Geography of Tamilnad

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(Continued from Vol. XXIII, No. 4, October—December 1948, Page 33).

IRRIGATION

General

The situation of India in one of the hottest regions of the world, modified though by monsoonic rainfall, has made the management of its water supply a live problem from early times. But by virtue of Man in India having been of high culture from antiquity, he has been tackling that problem from age to age with great success. Nearly all the methods of irrigation in existence and in use at present have come down from those early days. Some of those ancient canals have been renovated and are in duty even to-day. A good number of them are found in Tamilnad.

The source of all water is rainfall. The common methods of irrigation use the run-off from the streams and rivers as well as the underground water which is reached by wells. The use of capillary water introduces a new type of irrigation called Dry Farming, by which is utilized for growing crops the moisture conserved in the soil. So far as Tamilnad is concerned there is great scope for introduction of dry farming, especially in the Tirunelveli plains, where the rainfall is scanty and the soil is responsive.

The sources of irrigation as they now stand are usually classified under three heads, canals, tanks, and wells. Canals and tanks are generally linked with river systems; but in places too, which are not served by rivers, there are numerous small rainfed tanks. Both these are public irrigation sources. It is

only in the Cauvery valley and the Periyar area and parts of Tambraparni, where there is an assured and continuous supply, that there is direct irrigation from canals. In other places where the supply is not so continuous, water is taken through canals in flood seasons from the anicuts across the rivers and stored in tanks for irrigation purposes. The canals and the canal-fed tanks together form one group, being linked with the principal river systems. The minor rainfed tanks also have their origin in the drainage system of the region being one below the other so as to form a series of tanks. The general feature of the canal-cum-tank irrigation and purely rainfed tank irrigation is that a bund is put across a drainage trough (which becomes a river where it is well defined) and the seasonal flow in the trough is arrested and stored directly in the case of rainfed tanks and through anicut canals in the case of other tanks.

Principal Irrigation Systems

The main river systems serving the public irrigation works referred to above are the Palar, the Pennaiyar, the Vellar, the Cauvery, the Vaigai, the Tambraparni and the Kodayar.

The Palar Systems:—The river Palar with its two important tributaries Cheyyar and the Poini form the northernmost of the principal river systems of Tamilnad. Channels taken off from masonry anicut across these rivers feed numerous chains of tanks in this part of the region. The anicut across the Poini is constructed three miles below the Ponnai village and supplies several tanks in Chittoor, Puttur, Walajah and Arkonam taluks. The Cheyyar anicut four miles above Vazhaippandal village irrigates Cheyyar and Wandawashi taluks. The anicut across the main river is constructed six miles below the town of Arcot. The water is led from the anicut by a channel known as Kambakkal to numerous tanks in Walajah, Arkonam, Cheyyar, Kanchepuram and Sriperumbudur taluks.

The Pennaiyar System:—The Pennaiyar is dammed at Nedungal in Krishnagiri taluk and water is led and stored in the great Barur tank which lies at the head of a shallow valley, bounded on the east and west by low ridges. Two contour canals on these ridges carry water from the tank and irrigate the lands between them. The next important irrigation work across the river is the Tirukkoilur anicut four miles below the town of that name, irrigating 30,000 acres in Tirukkoilur, Vizhupuram and Cuddalore taluks.

The Vellar System :—The important works on this river are the Tozhudur project and the Shatiatope anicut. A regulator combined with a road bridge carrying the Madras-Tiruchirapalli road is built at Tozhudur and water is led by means of a channel 3½ miles long to the Willingdon Reservoir which irrigates 25,000 acres. The Shatiatope anicut diverts the Vellar waters through Raja Vaikal and its branches to irrigate 34,000 acres between Cuddalore and Porto Novo. The two large tanks, the Walajah tank and the Perumal tank belonging to this system are fed by this Raja Vaikal.

The Cauvery System :—There are two big reservoirs on the river Cauvery, the Krishnarajasagar in the Mysore state outside the region, and the other at Mettur within the region. The chief aim of the Stanley reservoir at Mettur is to store up water flowing to excess in the southwest monsoon floods and to pass it down later when the natural flow of the river falls. A lake 60 sq. miles in area holding 893,500 million c. ft. of water when full, is formed by a masonry dam, a mile long and about 214 ft. high. In addition to irrigation advantages electricity is developed both at Mettur and in Mysore. The benefits of Mettur reservoir to landholders in Tanjore delta are manifold. The reservoir acts as a flood moderator and protects the Tanjore ryots from the ravages of the Cauvery floods in the southwest monsoon season to which they were subject hitherto. It secures to the ryots the benefits of early supplies in June and ensures steady and regular flow throughout the irrigation season.

In Salem District, the river runs in a deep bed with land rising steeply on either sides, so that even with the help of the Mettur reservoir, extension of irrigation is not possible there.

Irrigation is restricted only to a narrow strip of land on either side of the river by mean of *korambu*[118] channels. But these lands are among the richest as an almost perennial supply of water is available. Proposals are however under the consideration of the government to provide irrigation for about 40,000 acres of lands in this district by pumping from the river Cauvery.

In Tiruchirapalli district the land slopes north and south towards the river Cauvery which flows in the middle of the district. Therefore the only lands that could be irrigated with ease are those very near the river.

In this district in the western portions water is available for more than ten months. The channels get practically all the summer supplies by means of korambus. The channels in the central portions of the district benefit by the Kattalai Bed Regulator, a low wall put across the Cauvery. A number of old canals have now been given a combined head by means of the South Bank Canal, which takes off from the river above the Kattalai Bed Regulator. In order to facilitate further extension of irrigation, a high level channel has been constructed taking off from the South Bank Canal and carried at a much higher level. North of the Cauvery, the North Bank Canal has been constructed taking off a little farther above the Kattalai Bed Regulator and benefits by the backing up of the river due to it. Thus the lands in the central portions of the district get a long and steady supply owing to the Kattalai scheme. In the eastern portions of the Tiruchirapalli district the summer supplies are not available for irrigation and the canals have longer periods of closure. Thus the duration of irrigation lessens as one goes down the river.[119]

118. These are temporary dams made of earth, branches, bushes and grass buil from the head of the channels when the supply of the river falls low. Each fresh sweeps them away and as often as the river falls they have to be renewed. Where the rivers are deep, they are often very substantial and strengthened with logs and bamboo wattle. Some of them are more than a mile long, take a thousand men a week to construct, and require divers to lay their foundations. This was the ancient way of impounding and canalising flood water for feeding tanks in series, coming from at least the Pallava times.

119. From official sources.

the dry eastern slopes flowing into the Bay of Bengal. A huge dam, 170 ft. high is put across an inaccessible gorge 3,000 ft. above the sea level in an almost impenetrable and malaria-ridden jungle and from the lake so formed the water is led by an open cutting to the watershed. A tunnel 5,700 ft. long has been bored through the ridge and the water is carried to the Suriliyar, a tribuatry of the Vaigai by the Vairavanar, a tributary of the Suriliyar. About 12,700 acres in the Suriliyar valley are irrigated with this water. The Peranai regulator across the Vaigai about 80 miles downstream from tunnel, diverts the water into the Periyar Main Canal, about 35 miles long, which runs due eastwards and branches into twelve channels and irrigates the lands to the south of it in the Nilakottai, Madura and Melur taluks. In the Suriliyar valley in Periyakulam and in Nilakottai, irrigation is almost all direct by means of channels, whereas in Melur, the water is led into the numerous tanks and stored and used for irrigation. In Madura taluk, there is some tank irrigation linked with the Periyar system, though the irrigation is mainly direct from the channels. This is because in the upper reaches, the water supply is more assured and there is no necessity for storage. In the lower reaches it is less assured and hence the necessity of storing in tanks, when the supplies are available.

The Periyar irrigation suffers from two disadvantages. One is that the soil of the tract is not made fertile by annual silts as under the cauvery, as the river water has been trained on to it only in recent times; and the other is that this water, too, runs practically clear, from high hills. Alkalinity is hence a great problem owing to the general rise of the sub-soil water.[122]

A peculiar feature of the Periyar lake is the fact that a large proportion of the water it impounds is not available for irrigation purposess, being required mainly to raise the remainder to the level at which it can be delivered on the further side of the watershed. The level of the watershed through which water is drawn is only about 50 ft. below the crest of the dam. A proposal has been made to drive a second tunnel at a much lower level and draw off part of the present ineffective storage. The excess quantity thus set free will be nearly 50% of the present effective storage. In addition to this by starting the present crop season a month earlier, it would be possible to provide a flow of 400 cusecs for a hydro-electric scheme without affecting the existing irrigation. During the non-crop season this water can be diverted through a channel taking off from the Vaigai above the Peranai on the right side and utilised for extension of irrigation of summer crops in Tirumangalam Taluk.[123]

122. R. C. Wood, Irrigation, Mad. Ag. Dept. Bull. IV. No. 71, p. 9.

The Tambraparni System:—The parched plains of Tirunelveli owe a great deal to the river Tambraparni, though one need not go so far as to say that Tirunelveli is the gift of the Tambraparni as Egypt is said to be the gift of the Nile. There are eight anicut across the river, all of which except the lowest at Srivaikuntam, are ancient works. From these, water is conveyed to the fields either directly by means of channels, or through tanks. Under the first two anicuts almost all irrigation is direct, and under the middle anicuts, small tanks, most of which require several fillings in a season, are used to irrigate about an equal extent, with channels. Under the last two anicuts Marudur and Srivaikuntam, channels account for only one-third of the irrigation and the tanks are larger in size, and a few of them if once filled can hold enough water to bring a crop to maturity.[124]

The Marudur anicut, the last of the old anicuts and by far the largest of them, provides irrigation in Srivaikuntam and Tiruchendur taluks. Srivaikuntam anicut is of modern origin (1873). Two channels take off at this anicut on either side, on the left, the north main channel after feeding a series of tanks finally empties into the Morumpallam tank which supplies

123. Madura District Gazetteer, Vol. I, p. 100.
124. Tinnevelly Gazetteer, Vol. I, p. 170.

Tuticorin town. On the right, the south main channel takes off and supplies the large Kadamba tank and a series of tanks below it. Irrigation under the system extends as far south as Tiruchendur. It irrigates 25,000 acres.

The Government of Madras have now constructed two dams across the Tambraparni between Banatheertham and Papanasam falls with a view to generate hydro-electric power. Though it is mainly an electric project it will no doubt rectify the deficiency of water supply at Marudur and Srivaikuntam anicuts in the southwest monsoon season.

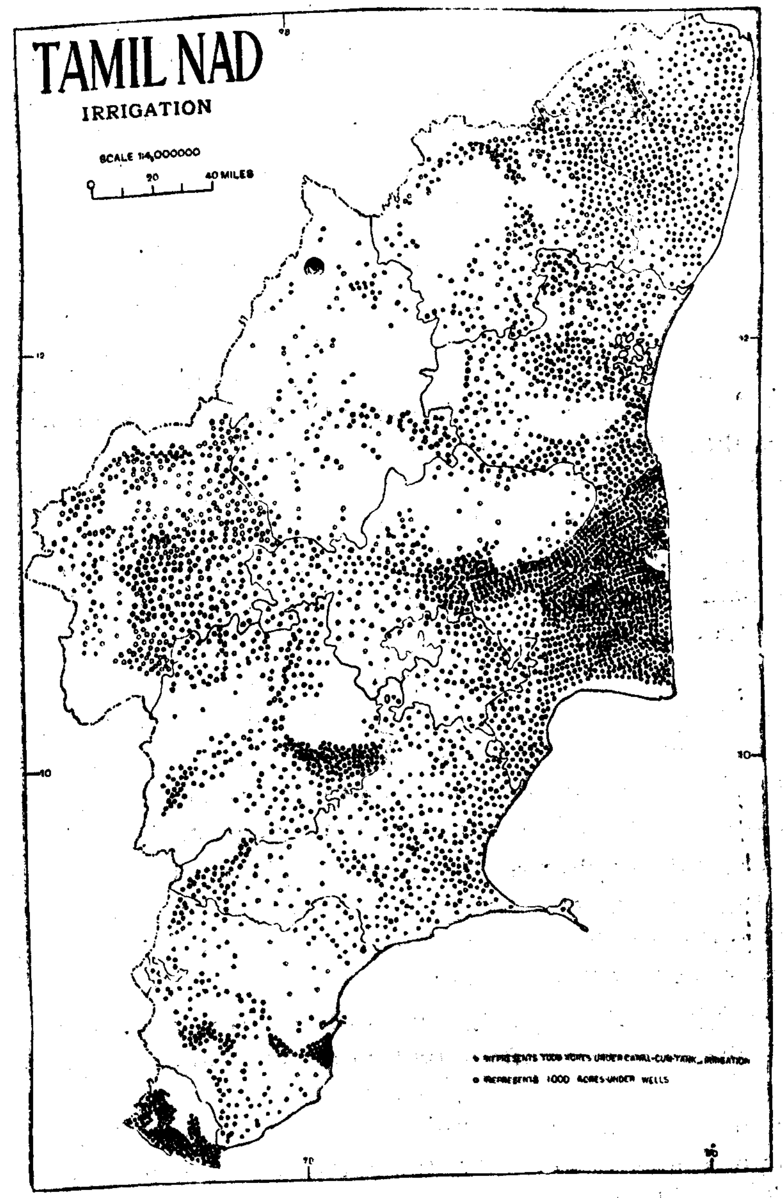
The important tributary of Tambraparni, the Chittar, has 18 anicuts crossing it. Unlike the Tambraparni, the southwest monsoon supplies are ample only in areas close to the ghats, and lower down on the plains water is assured only during the retreating monsoon season.

The Kodayar System:—The Kodayar irrigation system serving the Nanjanad area of Travancore State is the most important irrigation work in the State. The river Kodayar is crossed near Pachipara by a masonary dam 115 ft. high at its highest point and 1525 ft. in length along its crest and a reservoir called Kodayar lake about 7 sq. miles in area has been formed. The channel taking off on the left bank tails into the Paralayar just above the Puthen dam on that river on its right bank; and the water flows across to the left bank and there enters the off-take to the Padmanabhapuram Puthenar and Pandiyan channels, similar to the Coleroon water being taken across the Vellar river above the Shatiatope Anicut. The total length of the canals under this system is over 300 miles and the area irrigated is about 50,000 acres.[125]

Some general features of tank irrigation

The area under canal-cum-tank irrigation is least in the western upland tracts, where it is mainly confined to the river valleys, while in the plains to the east, it is most extensive and a general feature. The size of the tanks also generally

125. Travancore Administration Report, 1938-39, p. 150.



MAP 9.

increase from west to east. For instance, in Salem and the western parts of North Arcot District each tank generally has only a capacity of irrigating under 300 acres while in Chingleput, South Arcot and the eastern parts of North Arcot, tanks, each irrigating over 500 acres are numerous. The Chambarampakkam, the Madhuranthakam and the Veeranam tanks, which are the largest in the region, are all situated in the coastal plain.

The most important problem connected with tank irrigation is silting which is going on, year after year, unchecked. The most obvious remedy would seem to lie in a great extension of forests in the catchment areas and a more strict conservation of those already reserved. As this is practically impossible Mr. Clerk suggests two palliatives which may go some way to lesson the rate at which silting is now going on. First, he recommends that dry cultivation round the margin of tanks should be discouraged as far as possible, and that when circumstances permit a fringe of waste land should be maintained round the water-spread of each tank. On this the growth of jungle should be encouraged and in fact it should be treated as reserve forest. The second one he suggests is that in reserve forest areas, especially in sub-colline tracts where the gradients are not too steep, numerous small rough dams of wood and a few boulders may be put across the smaller water courses, in order to arrest the silt and to encourage a deposit behind the obstructions. These dams would serve a double purpose. They would retain some of the silt which would otherwise be carried into the tanks, and on this deposit would spring up a thick growth of vegetation, for in these areas, the principal cause of scanty vegetation is the shallowness of soil.[126] This suggestion if carried out will augment the irrigation supplies, by not only preventing the silting of tanks but also by the extension of forest vegetation which would lessen the rapidity of run-off and make the sources of supply more certain.

126. H. E. Clerk, Preliminary Report on the Irrigation under wells in the Madras Presidency (1902), p. 133.

Spring Channel Irrigation

In addition to the anicut - canal irrigation, there is a considerable amount of what is known as spring channel irrigation. In the hot weather, many of the rivers appear to be nothing but a vast expanse of dry sands. A few inches or a few feet below the surface of the sand, water is invariably found. A channel is excavated in sands at a slope much less than the river, so that the upper end of the channel has its bed below the line of saturation in the sand and the water flows into and along it. Proceeding downstream, the bed of the channel becomes high enough to be taken through the bank of the river and continued above the ground level to irrigate lands by direct flow.[127] A succession of such spring channels, one below the other, is a common feature of the Palar river system.

Well Irrigation

Well irrigation is more important in the western upland region than in the eastern coastal plain. It is especially well-developed in the west central region[128] comprising the Coimbatore plains, Karur, Dindigul and Pazhani (Palni) taluks. Here wells are very deep and after passing through a stiff *morum* of decomposed gneiss, enter on a highly fissured stratum of gneissic rock. This rock contains a great deal of water in these fissures and the sinking of the boreholes at the bottom of wells has led to the tapping of supplies of water under sufficient pressure to rise considerably above the bottom of the well.[129] Wells in these uplands are found only in the troughs. Any one crossing these undulating barren tracts can notice the high degree of development of garden cutivation solely dependant on the wells in the troughs and all the important habitations are therefore situated in these places where well irrigation is feasible.

127. A. Chatterton, Lift Irrigation, pp. 177-178.

128. As defined by soils.

129. H. E. Clerk, Preliminary Report on Irrigation under Wells in the Madras Presidency, p. 26.

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