The Maharaja Sayajirao Gaekwad Honorarium Lectures, 1952-1953

THE GEOLOGY AND MINERAL RESOURCES OF INDIA

with reference to Gujarat and Bombay State

THE MAHARAJA SAYAJIRAO UNIVERSITY OF BARODA

सत्यं शिवं सुन्दरम्

By

Dr. D. N. Wadia

M.A., D.SC., F.G.S., F.N.I.

lviser, Ministry of Natural Resources
ific Research, Government of India.

Price Rs. 2-0-0

INDIAN INSTITUTE OF ADVANCED STUDY SIMLA

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MOTILAL BANARSIDASS
DELHI 7

First edition
Copies 500
1955

Publisher :
G. H. Bhatt, M. A.
Director,
Oriental Institute,
BARODA.

Printed by Shri Kishansingh Chavda at the Chetana Press Ltd., Nava Bazar, BARODA. January, 1955.

PREFACE

The old Baroda State Government had a scheme of "The Maharaja Sayajirao Gaekwad Honorarium Lectures" under which an eminent scholar in any one or more of the following subjects was invited every year to deliver a series of lectures at Baroda and he was paid an honorarium of Rs. 5,000/–.

1. Poetry
2. Literature
3. History
4. Philosophy
5. Economics
6. Scientfic Research
7. Fine Arts
8. Social Service and Social Reform.

On the merger of the Baroda State with the Bombay State, the Government of Bombay under Education Department G. R. No. 9107 dated 28th March 1950 entrusted the management of these lectures to the Maharaja Sayajirao University of Baroda and sanctioned a special recurring grant of Rs. 5000/– for the purpose.

Some of the eminent scholars who have delivered lectures under this series are Dr. Radhakumud Mukerjee, Dr. Rabindranath Tagore, Shri C. V. Vaidya, Shri K. Natrajana, Dewan Bahadur

K. H. Dhruva, Pandit V. N. Bhatkhande, Dr. S. Dasgupta, Dr. Sir Shafaat Ahmed Khan, Dr. (Mrs.) Sarojini Naidu, Dr. K. K. Das, Dr. T. E. Gregory, Sir C. V. Raman, Rao Bahadur K. V. Rangswami Iyengar, Dr. Birbal Sahni, Dr. Sir J. C. Ghosh and Prof. K. T. Shah.

The Maharaja Sayajirao University of Baroda invited Dr. D. N. Wadia, M.A., D.Sc., F.G S., F.N.I., Geological Advisor to the Government of India, for the year 1952–53 and he was kind enough to accept our invitation. He delivered six lectures on " The Geology and Mineral Rescurces of India with reference to Gujarat and Bombay State " under the chairmanship of Prof. C. S. Patel, Dean, Faculty of Science of the Maharaja Sayajirao University, in the Physics Lecture Theatre from 15th to 20th November 1952. The lectures were highly appreciated by the audience for the wealth of information and mastery of exposition. It is hoped that these lectures will be appreciated by students as well as scholars of geology.

The Maharaja Sayajirao
University of Baroda.
Dated 25th December, 1954

B. K. Zutshi
Registrar.

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deficits and sufficiencies: Neglect of mineral industries in the past: program of exploration, mining, domestic utilization, conservation: planned exports: synthetic petroleum: ferro-manganese, titanium manufactures.

THE AGE AND ORIGIN OF THE HIMALAYA MOUNTAINS AND THEIR PLACE IN THE GEOGRAPHY AND STRUCTURE OF ASIA

The subject of the lecture this evening is the Himalayan mountain chain, the biggest, highest and the youngest mountain system on the face of the earth. It is no contradiction to state that they are the biggest and the highest because they are the youngest in age among the world's mountains. Earth features of high topographic relief are subject to the denuding action of atmospheric and meteoric agencies – wind, rain, frost, insolation, the combined result of which is seen in the loads of silt, sand and gravel carried by the rivers and streams descending from them. In the case of one single river, the Indus, the amount of sediment and silt is found to be 1,200,000 tons per day, the greater part of which being the debris of Himalayan rocks. The ceaseless denudation of geological time thus reduces mountain chains of past ages and even wears them down to their roots. The Aravalli chain of Rajputana affords a very good example of this sculpture of Time. In the pre-Cambrian age it was a mighty range rivalling the Himalayas in length and height; it is today found in a system of disconnected straggling hill masses, many of them worn down to mere stumps of the former mountains.

We shall first deal with the rise of the Himalayas from an ancient ocean bed.

At a period in the geological history of our earth which, to compare earth-history with the known human history since its earliest dawn, would be as recent as the closing years of the Moghul Dynasty, the geographical outlines of India were of the haziest description. It was then not separated from Eur-Asia by the present formidable mountain range, which so effectively barricade it from the west, north and east. One of the most clearly established facts of geological science tells us of a sea which girdled India along its north face through vast aeons of time—a true *mediterranean* sea which divided the northern continent of Eur-Asia from a southern continent, of more or less uncertain borders, but which united within its compass the present disjoined peninsulas of Africa, Arabia, India and

Lec. I] Central Himalaya Range, Kishenganga Valley—Kashmir. [Fig. 1

Australia (known to geologists as *Gondwana land*). Between the Deccan and the Siberian low-lands, as far as the Arctic Ocean there was then no mountain barrier of any importance, save the stunted and broken chain of the Aravallis and the Altaids of Eastern Turkistan. There then prevailed an ocean-way (the *Tethys*) which provided an uninterrupted intercourse and migration of marine animals, unknown in the world of today. These facts, substantiated by full and satisfactory evidence, establish the first principle of geology that our earth's geography is mobile and is constantly changing.

In this mediterranean sea, were deposited the sediments of successive geological ages from the end of palaeozoic era to the dawn of the Cainozoic, or Tertiary era of earth history, a duration measured by about two hundred and fifty million years. For this length of time the *Tethys* received no less than fifty thousand feet of sediments deposited, layer upon layer, *pari passu* with a slow sinking of its bed.

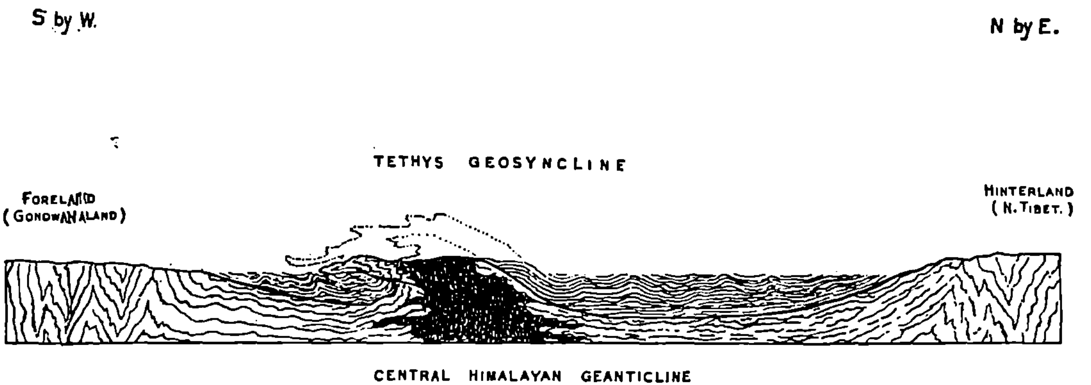
The rise of the Himalayas from the floor of this mediterranean sea is an epic of the geological history of Asia. It should be realized at the outset that contrary to our deep-rooted ideas of the strength and rigidity of our earth, it has a mobile crust, sensitive to loads and underloads, to pressures acting from the sides and from within the interior of the earth.

Paradoxical as it may seem, mountains denote the weaker belts of the earth's crust, belts that have been depressed below the sea for long ages and have received enormous deposits of marine sediments belonging to long cycles of geological ages. It is these overloaded and consequently weakened zones which respond most to the lateral and tangential earth-pressures which follow the cessation of the sinking process and become folded and upheaved into mountain-chains. Hence has arisen the well known principle of geology that where areas ot the earth have sunk the deepest, they also rise highest. The sunken and loaded belts are called *geosynclines* in geology and geosynclines have played a large part in the revolutions of the earth's past geography, stamping upon it the broader features of the continents, mountains and ocean basins. The rock records preserved in this deep sedimentary pile reveal the history of the life, deposits and earth movements of many successive periods. During the process of compression of the sunken and loaded zones into mountains they are narrowed to almost half of their original width; the formation of the Himalayas has, for instance, brought a point in Tibet nearer to a point in Bihar by 70–80 miles at least. The Himalayas represent the largest individual mountain system on the face of the earth. Geological work of the last few decades in these mountains has proved that, inspite of some local differences, there is an essential unity of structure, composition and stratigraphy from Kashmir to Assam. Thirty thousand feet of marine sediments, representative of six geological systems from the upper Carboniferous to the Eocene, with their characteristic entombed fossils, are found exposed in the mountain flanks. These were subjected to great compressive forces, as in a vice, between the stable continental blocks of the Deccan peninsula to the south and the high table-land of Tibet to the north.

The rise of the Himalayas from the sea bed was not a single event, but there were three distinct and widely separated phases of uplift; the earliest began well after the commencement of the Tertiary era and the last movement of uplift did not commence till after the very end of the Tertiary and probably after the coming of Man on Earth

(middle Pleistocene). There is a body of competent evidence, both physical and biological, to indicate that parts of the Himalayas have arisen at least five thousand feet since the middle Pleistocene, containing within its tilted beds some relics of early Man. Early man thus witnessed the growth of this northern barrier interfering more and more with his migrations and intercourse across the steppes of Asia. A great ethnic watershed thus came into being early in the human history.

We may now deal with the place of the Himalayas in the geography and structure of Asia. Let us try to realize the geographic significance of this earth feature that for 26 degrees of meridian presents a wall of twenty thousand feet mean elevation. Their width is between 100–250 miles and the length of the central axial chain "the Great Himalaya Range", 1,600 miles. The geography of a large part of the Himalayas is yet not known, because immense areas within it have not yet been explored by scientists; much, therefore, remains for future observation to add to or alter in our existing knowledge. Lately, however, the Mt. Everest and other expeditions to climb the high peaks have made additions to our knowledge of



THE EMBRYONIC HIMALAYA (EOCENE PERIOD)

Lec. I] [Fig. 2

certain tracts of Himalayas. The Assam section, however, is geographically still largely a *terra incognita*.

The Himalayas are not a single continuous chain or range of mountains, but a series of several more or less parallel or converging ranges, intersected by enormous valleys and extensive plateaus. The individual ranges generally present a steep slope towards the plains of India and a more gently inclined slope towards Tibet. The northern slopes are again clothed with a thick dense growth of forest vegetation surmounted higher up by the never-ending snows, while the southern slopes are generally too precipitous and bare either to accumulate the snows or support, except in the valley basins, any but thin jungles. The connecting link between the Himalayas and the other ranges of Central Asia–the Hindukush, the Karakoram, the Kuen Lun, the Tien Shan and the Trans-Alai ranges–is the great mass of the Pamir, "the roof of the world". The Pamirs (Persian *Pa-i-Mir*, Foot of the eminences) are a series of broad alluvium-filled valleys, over twelve thousand feet high, separated by linear mountain ranges, rising to seventeen thousand feet. From the Pamirs to the south-east, the Himalayas extend as an unbroken wall of snow-covered mountains, pierced by passes, few of which are less than seventeen thousand feet in altitude. The eastern Himalayas of Nepal-Sikkim rise very abruptly from the plains of Bengal and Oudh, and suddenly attain their great elevation above the snowline, within a strikingly short distance from the foot of the mountains. Thus, the peaks of Kanchenjunga and Everest are only a few miles from the plains and are visible to their inhabitants. But the western Himalayas of Punjab and Kumaon rise gradually from the plains by the intervention of many ranges of lesser altitude, and their snow-peaks, such as Nanga Parbat, Badri Nath or Nanda Devi are more than a hundred miles distant, hidden from view by the mid-Himalaya ranges to the inhabitants of the plains.

To the north of the Himalayas is the block of High Asia, the biggest and the most elevated land-mass on the earth's surface. Directly to the north is the plateau of Tibet, fourteen thousand feet mean altitude, traversed by the "Trans-Himalaya" and the Aling Kangri ranges; farther north are the Kuen Lun and Altyn Tagh ranges and, separated from them by the great desert basin of Tarim, the Tien Shan range.

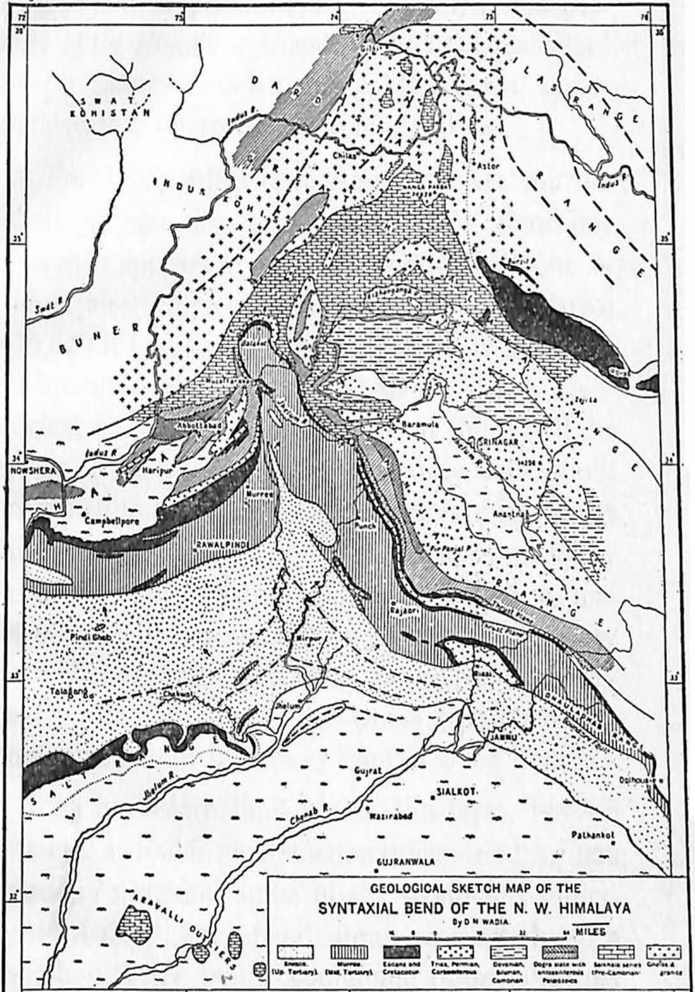
With regard to the meteorological influence of the Himalayas, this mighty range of mountains exercises as dominating an influence over the meteorological conditions of India as over its physical geography, vitally affecting both its air and water circulation. The high snowy ranges have a moderating influence on the temperature and humidity of northern India. By reason of its altitude and its situation directly in the path of the monsoons, it is most favourably conditioned for the preciptation of much of their contained moisture either as rain or snow. Glaciers of enormous magnitude are nourished on the higher ranges by this precipitation, which, together with the abundant rainfall of the lower ranges, feed a number of perennial rivers, which course down to the plains in hundreds of fertilizing streams. The Himalayas thus protect India from the continental desiccation which is gradually invading Central Asia. But for their good offices, the Rajputana desert would have extended far eastwards and northwards. Standing in the path of the prevalent equitorial wind-currents one can easily imagine what dominating influence this chain must have exerted on the climate and geography of middle Asia and, through these, on the distribution of life on the continent. To mention only the most significant instance of this effect: the vast desert tract of Tibet and of the Takla Makan basin (Tarim) to its north, the latter occupying an area as large as the Deccan peninsula and in its geomorphology comparable to our Gangetic basin, are some of the most desolate regions of the world today. It is a well known principle of geology that deserts are evancent features in a continent; most of the existing deserts are of recent origin, in the case of the Tarim depression, of late historic growth. These once fertile and well-forested regions have been fighting against adverse climatic conditions since the end of the Glacial period. They succeeded in preserving the remnants of their forests and cultivation even to such late age as the early centuries of the Christian Era, but have since then steadily succumbed. The increasing desiccation of this area, generally admitted to be in a material way connected with the interposition of the lofty mountains on the south, has had its full toll on the river systems. These rivers, once extensive and well-developed, have decayed and withered to such an extent that the few existing streams lose themselves entirely in the growing sands and surface debris, which they are wholly powerless to sweep away. The Kuen Lun Glaciers which fed these rivers have steadily dwindled and the small amount of water that penetrates the Himalayas through its gorges and defiles and reaches southern Tibet, is turned back to India by the trans-Himalayan affluents of the Indus, Sutlej, Ganges and the Brahmaputra. They swell the floods perennially flowing down these noble streams through the plains of northern India. In this manner the Himalayas have protected northrn India from the gradual desiccation that has over-spread Central Asia from Arabia and Syria, Khorasan and the Aralo-Caspian region, across Baluchistan, Afghanistan and Chinese Turkistan to Mongolia, since early historic times, and the desert conditions that inevitably follow desiccation in the heart of an old continent.

A significant fact with regard to the place of the Himalayas in the geography and structure of Asia is the definition of their eastern and western limits and the trend-lines within these limits. On these points there has been no consensus of opinion among the geographers and geologists and till lately the subject remained controversial.

Geographically, the Himalayas are generally considered to terminate to the north-west at the great bend of the Indus, where it cuts through the

Kashmir Himalayas, while the south-west extremity is defined by the similar bend of the Brahamaputra in upper Assam. At these points also there is a well-marked bending of the strike of the mountains from the general NW–SE, to approximately north and south direction. Geologists have refused to accept this limitation of the Himalayan mountain system, because according to them it ignores the essential physical and structural unity of the hill ranges beyond the Indus and the Brahamaputra with the Himalayas. They would extend the term ' Himalaya ' to all those ranges to the west and east, viz., of Hazra and the ranges of Burma, which originated in the same great system of Himalayan upheavels.

The present speaker's views on this subject were published in a paper " Syntaxis of the North-Western Himalayas " in Vol. LXV of the *Records of the Geological Survey of India* in 1931. These views were based on my ten years' work on the stratigraphic and structural geology of the Siwalik, Pir Panjal and Zanskar ranges of the Kashmir Himalayas. In 1934 the Royal Geographical Society of London accepted my conclusions on the acute bending of the axis of the Himalayas near the peak of Nanga Parbat; earlier the Survey of


GEOLOGICAL SKETCH MAP OF THE
SYNTAXIAL BEND OF THE N. W. HIMALAYA
By D N WADIA
MILES
Murree (Mid. Tertiary).
Eocene and Cretaceous
Trias, Permian, Carboniferous
Devonian, Silurian, Cambrian
Dogra slate with unfossiliferous Palaeozoics
Gneiss & granite
SWAT KOHISTAN
INDUS KOHISTAN
BUNER
DARDISTAN
KAILAS RANGE
Chilas
Astor
Indus R.
Swat R.
NOWSHERA
Campbellpore
Haripur
Abbottabad
Muzaffarabad
Murree
RAWALPINDI
Baramula
SRINAGAR
Anantnag
Punch
Rajaori
Mirpur
Jhelum
Chakwal
Talagang
Pindi Gheb
SALT RANGE
Jhelum R.
Chenab R.
Gujrat
SIALKOT
Wazirabad
JAMMU
Pathankot
Dalhousie
GUJRANWALA
ARAVALLI OUTLIERS

India, in their publication—" *Geography and Geology of the Himalaya Mountains* " (1932, Calcutta) by Sir Sidney Burrard and A. M. Heron, incorporated this interpretation in the treatise.

For 1,500 miles from Assam to Kashmir the chain follows one persistent SE–NW trend-line and then appears to terminate suddenly at one of the greatest eminences on its axis, Nanga Parbat (26,620 ft.), just where the Indus has cut an extraordinarily deep gorge right across the chain. Geological studies have shown that at this point the strike of the mountains bends sharply to the south and then to the south-west, passing through Chilas and Hazara, instead of pursuing its north-westernly course through Chitral. All the geological formations here take a sharp hair-pin bend, as if they were bent round a pivotal point. This extraordinary inflexion affects the whole breadth of the mountains from Jhelum in Punjab to the Pamirs.

At the eastern limit of the Himalayas, beyond Assam, a similar phenomenon is witnessed, as here also the structural strike of the mountains undergoes a deep knee–bend from an easterly to a south–westerly trend, continuing through Burma in the Arakan Yomas, instead of pursuing its trend-line and crossing into China.

For geographical purpose the Himalayas are classified into three parallel longitudinal zones :—

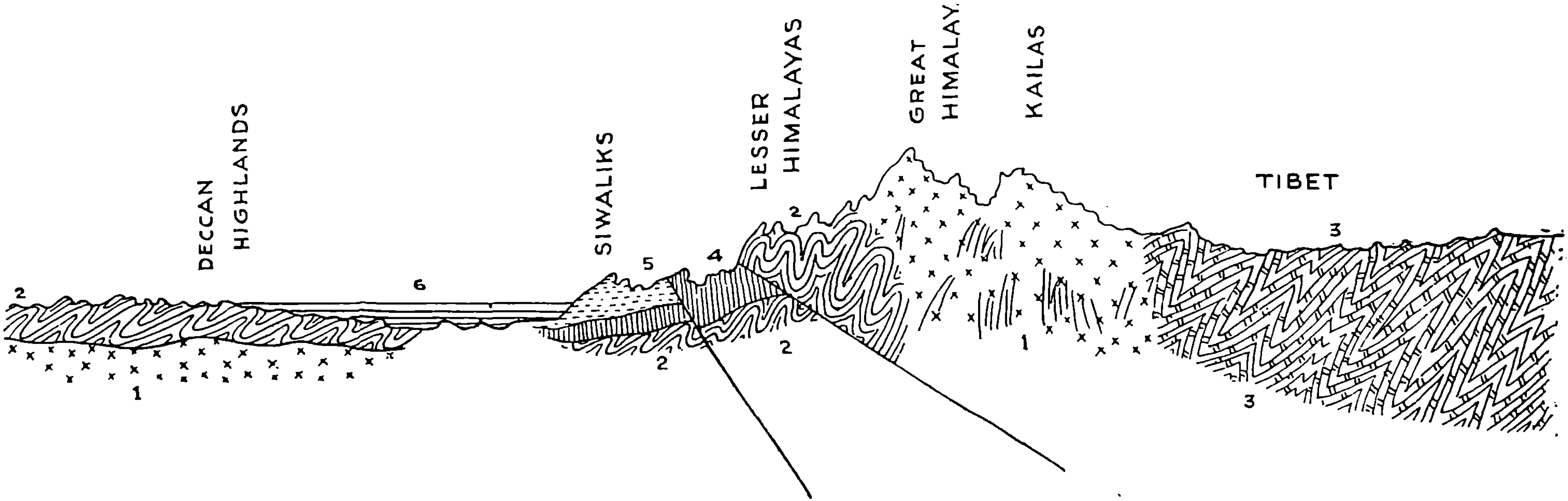
(1) The GREAT HIMALAYA, the innermost line of high ranges rising above 20,000 ft. On it are situated the peaks Everest, K^2, Kanchenjunga, Dhaulagiri, Nanga Parbat, etc., which are amongst the highest points on the earth's circumference.

(2) The LESSER or MIDDLE HIMALAYAS, a series of ranges of lesser elevation, seldom rising above 12,000–15,000 feet. Their average width is 50 miles.

(3) The OUTER HIMALAYAS or SIWALIK ranges, these form the zone of foothills with an average height of 3 000–4,000 feet and their width varies from 5–30 miles.

ECONOMICS: A subject about which there is much popular misconception, is the mineral wealth contained in the Himalayas. In over emphasizing mineral resources there is a tendency among even the educated public towards giving less importance to other natural economic resources contained in this vast elevated terraine, 1,600 miles long and 100–250 miles wide. We might conclude by saying a few words about these.

Economic resources of Himalayas fall under



RELATION OF THE HIMALAYAS TO THE PLAINS OF INDIA AND THE TIBETAN PLATEAU

1 Crystalline Rocks
2 Purana Rocks
3 Palaeo-Mesozoic
4 Older Tertiary & Mesozoic
5 Newer Tertiary
6 Indo-Gangetic Alluvium

forests, water and snow of annual and periodical rainfall and snowfalls, and the mineral and metal deposits contained in the rocks. The magnificient forests clothings the Himalayan slopes below the snowline are the glory of these mountains. They yield valuable economic resources, timber and other forest products, besides conserving ground water and protecting the soil from erosion. The uppermost forests of the Himalayas from 9,000-12,000 ft., consist of pines, cedars, *rhododendrons*, birch and *juniper* which give place higher up to wide pastures and grasslands with beautiful alpine flowers, supporting the itinerant Gujjars' flocks of sheep and cattle.

The Himalayan rivers are fed by the summer and winter rain and the everlasting snow-fields, situated above 15,000-16,000 feet. Millions of cusecs of water is discharged by the hundreds of streams descending the mountains, which, if properly harnessed, can be a source of agricultural wealth and abundant electric power to the Indian plains. Unharnessed and untrained rivers do annually a great deal of damage by their unrestrained floods uselessly flowing down into the sea. The mineral resources of the Himalayas are yet largely unexplored except for some areas in

Kashmir and Nepal. Workable deposits of coal, iron, aluminium and occurrences of copper, lead, zinc with the much-prized gem, sapphire, recorded in Kashmir, and some hitherto unsurveyed occurrences of nickel, cobalt, coal in Nepal and of copper in Sikkim are among the more notable mineral occurrences. They cannot be called resources, as very little exploratory work of a detailed nature is done to prove their extent or their workability on a commercial scale. They remain unutilized today for the most part. The known mineral deposits, however, are not large or numerous, and the Himalayas so far known cannot be considered as a region of active or extensive mineralization. Probably these mountains are too young and Nature has had not enough time to concentrate into workable deposits metals and minerals from depth into productive veins or lodes.

MINERALS AND WAR

The Strategic Minerals Position in India.

Man's progress, from the savage state to civilization, is due largely to his mastry over minerals and metals, all the stages of his progress being marked by his use of some particular mineral or metal. We have only to look back on the main epochs of this history – the *stone* age, *bronze* age, *iron* age, the *coal* and *oil* age and the new *uranium* age that is emerging on the horizon, which will place him in command of atomic energy. But this advance has caused most serious inroads on the world's stock of minerals and especially of metals. During the century and a quarter since the Napoleonic wars, the consumption of minerals has been more than a hundred fold of that consumed during the entire history of man on earth, and so far as metals are concerned, man has used up, between 1914 and today, especially during the two World Wars, more metals than during any previous periods of history. This has caused most serious depletion in the world's underground store of minerals. Metals, such as tin, have almost reached depletion stage and silver is made to stand substitute for tin in emergencies, while readily accessible and extractable stocks of platinum silver, nickel, lead and zinc, left for future needs of the world, within manageable depth are known to be meagre. The consumption of fuels, petroleum natural gas and coal has been at a far more serious rate, so serious that the world's known reserves of mineral oil at the present rate of production, will be exhausted within a few decades if new and spectacular discoveries of oil–fields, (such as those in Saudi Arabia and the Middle East during the last 20 years), but which are becoming very scarce, are not made. The total world coal reserves are larger; but they will last only a few decades longer if the present accellerated production and consumption of coal and its use in the ever lengthening catalogue of byproducts continues in the future at the same rate. So far no checks have been devised against this alarming depletion of the world's underground wealth and this robbing of the earth by the present generation at the expense of future generations. Metals and minerals are a rapidly wasting asset of a country for which there is no renewal or replacement. Agricultural and forest resources of the land can be rejuvenated by suitable manures and improved agricultural practices; but no fertilizer can revive an exhausted mine, for, geological processes are exceedingly slow, requiring hundreds of thousands of years to form a bed of coal or a vein of metal.

The species of distinct minerals known to man are roughly about 1,500 and of these less than 200 at the most, find applications in commerce and industry; these economic minerals are further classified into strategic minerals, critical minerals and key minerals, although the distinction between these is not material and is fast disappearing. Among these, again there is a rapidly mounting list of metals and minerals which are of vital use in the manufacture of modern munitions of war, e.g., the new atomic warfare weapons, jet-propelled engines, electronic appliances and other highly specialised commodities of strategic use. In the defence programme of a nation under the present day conditions of totalitarian war, metallurgical industries and their ancillary mining of minerals yielding the various ferrous and non-ferrous alloy metals,fluxes, refractories and accessory minerals, are assuming essential importance. At the present day it can be said that the world's mineral resources especially of the western world countries surrounding the North Atlantic coasts, are fairly well known and mobilized. From this knowledge it is appreciated by geologists that the stock will not last many generations if it is made to feed the wastage of recurring wars on the scale of magnitude that the modern world today apprehends. It was reported by the Commission of the XVIII International Geological Congress held in London in 1948, that the known recoverable reserves of lead and zinc ores will last only about 20 years at the present rate of consumption. The international mineral situation thus presents a picture of a depleted world, especially in respect of many base and strategic metals. To the extent that the countries of the Eastern hemisphere, especially the so-called industrially undeveloped or underdeveloped countries, have not actively engaged in world wars, their mineral resources are in a measure preserved. At this stage we may ask, what is the position of mineral economics in India and what is India's place in the world's mineral map ?

An overall picture of India's mineral resources *vis-a-vis* the world, its surpluses, sufficiencies and deficits is presented in the following table which gives a bird's eye view of India's position on the world's mineral map :—

Table I

I Minerals of India which are of world importance :

Iron ore	Titanium-ore
Mica	Thorium-ore

II Minerals in exportable surpluses and which are available for export under reciprocal agreements :

Bauxite	Monumental granite
Corundum	Natural abrasives
Magnesite	Sillimanite and kyanite
Manganese-ore	Silica
Monazite	Steatite

III Minerals in which India may be considered self-sufficient for present needs and for those of the immediate future :

Alum	Industrial clays
Aluminium-ore	Limestone, dolomite

Antimony	Marbles
Arsenic	Mineral pigments
Barytes	Nitrates
Building stones	Phosphates
Cement raw-materials	Precious and semi-precious stones
Chrome ore	
Coal	Rare earths & metals
Felspars	Sodium salts and alkalis
Glass sand	Vanadium
Gold	Zircon

IV Minerals which are absent or in short supply in India and for which she has to depend on foreign imports to-day :

Asphalt	Nickel and cobalt
Bismuth	Petroleum
Cadmium	Platinum
Copper	Potash
Fluorides	Silver
Graphite	Sulphur
Lead	Tin
Mercury	Tungsten
Molybdenum	Zinc

The more important mineral products mined in India are about 30 in number, including several which although comparatively unimportant in quantity to-day, are capable of material development in the future with expansion of her nascent industries.

From this picture we see that while India has assets of world importance in iron, manganese, aluminium, titanium, thorium and mica, the catalogue of her deficits is also impressive and in some respects serious; the deficits especially in petroleum, sulphur and the non-ferrous metals–(copper, tin, lead, zinc, nickel), and substances like potash, are of a grave nature. In the former, India occupies a commanding, if not a controlling position while in her resources of ferro-alloy metals, flux minerals, refractories, abrasives, bauxite and industrial clays she occupies a satisfactory position. In times of international peace this disequilibrium in the country's mineral economy – enormous assets in some categories and serious gaps and dificiencies in others – may not be harmful, but in the event of war, lack of sufficient reserves of the chief deficit minerals, even though relatively unimportant in themselves, may imply grave hazards to the country's security, even in the face of abundance of strategic and key minerals. The lack of critical minerals like petroleum, sulphur, base non-ferrous metals, etc., is a source of double danger to national security, since imports of these essential commodities may be jeoperdized and at the same time the off-take of the normal credit-earning exports may be stopped. A healthy economy, both for peace and war, can be achieved on the pattern evolved by the present U. S. A. Administration : (1) by balancing, as far as possible, surplusses against deficits by a system of exchange or barter with the industrially more advanced countries; (2) through building up a strong and diversified civilian peace-time industrial power; (3) production of synthetics and substitutes for some deficient and submarginal commodities; and (4) stockpiling of some 10 essential minerals and raw products by large-scale imports from friendly countries. The Democratic Government of the U. S. A., faced with some of the world's most pressing problems for future mineral supplies, has laid down a mineral policy and programme for the coming 23 years on these lines, though on a far more ambitious and comprehensive plan. For preserving intact her economy in peace as well as in the event of any future war, the Defence Minerals Procurement Administration and similar

Government - sponsored bodies are building up a stockpile to be drawn upon only in a future national emergency, backed by a high - powered civilian production programme that can be switched on at short notice to munitions - producing potentials. The recently published report of the President's Materials Policy Commission, known as the "Paley Report", is a highly valuable and informing document from which Indian industrialists can benefit much. This report forecasts that by 1975 there will be nearly a 100% rise in the demand for strategic and industrial minerals in the U. S. A. and in Europe, mostly on account of military defence and it advises and lays down policies and programmes for meeting this increased demand.

In the coming age, atomic minerals and the development and application of the forces of nuclear energy from them, will gain rapid prominence. More and more use of atomic energy by the leading Powers is confidently predicated as a source of power for activating air - craft, naval and submarine armaments. The world's uranium resources, though not scanty, are by no means plentiful and to what extent they will meet the increasing demands made on this metal by the

U. S. A. and European countries, is hard to predict. It is possible that within a few years the use of atomic energy, as at present, solely for the manufacture of implements of warfare, will cease or recede into the background. Scientific research will ultimately be victorious in diverting the use of atomic energy increasingly towards civilian needs of Man by providing him a cheap and ubiquitous source of power replacing the existing energy sources, coal, petroleum and electricity. It is refreshing to know that the work of the Indian Atomic Energy Commission is diverted primarily towards this aspect.

The experience of the last 3 years of the second World War, in the production of a wide range of non-military commodities, heavy engineering goods and munitions, has given satisfactory proof of the country's adequacy in basic metals and minerals. Subsequent events since the termination of War have strengthened her foundations in this respect and our industries to-day are in some measure able, with the mineral and metal resources that the country commands, to cope with the steadily rising demands of civil and defence requirements. In the coming decade or so, minerals will enter increasingly in the field of general trade and manufacturing industries which are an indispensible pre-requisite for any country's Defence set-up. Though still unequipped in a number of essentials, India can manufacture a fairly good range of specialized steels, machine tools, parts of air-craft, high explosives, diesel, automobile and locomotive engines, sea-going ships, etc., though not yet on a scale commensurate with her rising internal requirements.

We have seen above that minerals place in the hands of man a powerful weapon for waging war and that their unequal distribution may be a potent cause for it. Fully half the later wars of the last century have been directly or indirectly motivated through the desire of gaining access to stores of strategic minerals, ores, oil, alloy-metals, etc. If the supply and free movement of petroleum, a few ferro-alloys and some strategic minerals for non-industrial uses can be controlled by a central World Organization, totalitarian wars can be banished, or shorn of the insane waste involved in military as well as non-military devastations. The modern world being unable to set up a body of such competence, only the adoption of a wise and justly planned international mineral policy, framed and carefully implemented by an International Organization, can preserve peace and goodwill amongst countries unequally endowed by nature with mineral resources. No country in the world, however, well supplied it be, is self-sufficient in its requirements of minerals; nor is any country so situated that it can regard its mineral resources as purely domestic or national. Unequal geographical distribution of minerals being an unalterable fact beyond the control of man, planned international economy alone can devise means to eliminate this cause of inter-countries friction and make for increased inter-dependence of the countries of the world on each other for their vital industrial needs. Thus we can make minerals a rallying point for international peace co-operation and goodwill. By such practice India can make good her deficiency in several respects, e. g., the deficiency in tin, tungsten, lead, zinc, nickel, graphite and petroleum can be met by products of her neighbours, in return for supply from her great assets of iron, manganese, aluminium, magnesium rare-earths, coal etc. Our neighbour Burma has abundant stocks of the munition metals of which India is in defect, while her oil resonrces if systematically developed, can in a material measure supply the needs of India. Ceylon has reserves of the world's finest graphite, a mineral indispensible in metallurgy, which occurs there in deposits sufficient to last a long period.

Mineral exploration on a systematic plan and with the use of modern geophysical and other techniques has so far made but little progress in India. Under the new development and reconstruction programme the country has set before itself, these techniques have assumed supreme importance and a Central Geophysical. Institute is being planned by Government. With geophysics to aid in mineral and geological exploration and the increasing availability of trained technical and mining personnel that is foreshadowed in the expansion of University research facilities, the official Geological Survey and the Bureau of Mines, this disability is being overcome. We can confidently look forward to an increase not only in the country's total output of metals and minerals but their utilization for the manufacture of commodities which add to the country's wealth in times of peace and provide her with materials for defence in the event of an international struggle.

Germany and Japan may be cited as examples of countries who fought two great wars on hoarded munitions and other war materials. These countries are comparatively barren in economic minerals and are unprovided with almost all the basic raw materials needed for modern war-fare, and yet they maintained fierce, and at times victorious, war operations for 2–3 years. This was possible because of their command over mines and minerals of conquered or occupied countries and the long lead they had in pre-war years in preparing stock piles of important raw materials.

I shall end by presenting Table II which shows in conspectus the strategic mineral position of India as it exists at present.

Table II

I Minerals and Metals most vital in War :

1. Aluminium
2. Antimony
3. Coal
4. Chromium
5. Columbium
6. Copper
7. Iron
8. Lead
9. Maganese
10. Mercury
11. Molybdenum
12. Mica
13. Nickel
14. Petroleum
15. Platinum
16. Potash
17. Sulphur
18. Titanium
19. Tin
20. Tungsten
21. Uranium and atomic minerals.
22. Vanadium
23. Zinc

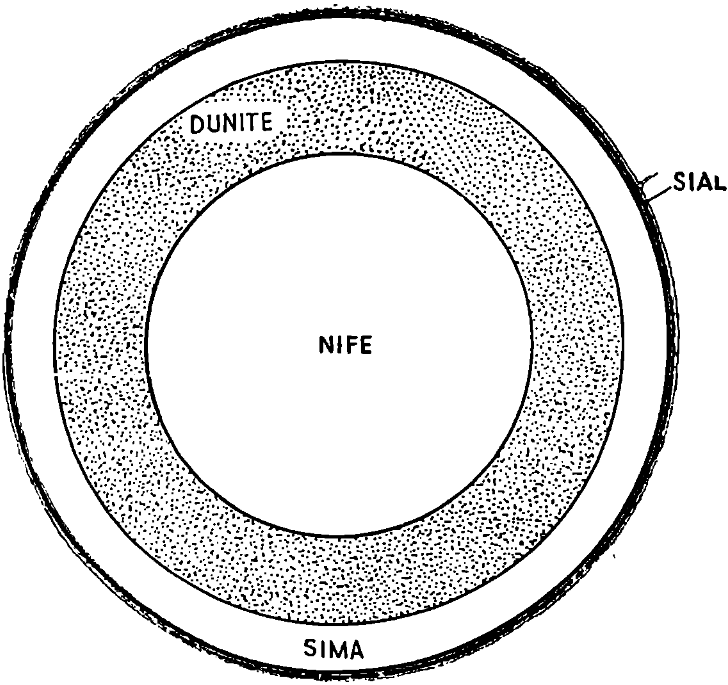
II Deficit strategic minerals of India :

1. Sulphur
2. Petroleum
3. Potash
4. Mercury
5. Nickel
6. Tin
7. Lead
8. Zinc
9. Molybdenum
10. Platinum
11. Copper
12. Graphite
13. Ferro-tungsten

MODERN CONCEPTS ABOUT THE EARTH'S INTERIOR

The origin of our planet Earth as a member of the solar system, either from condensation of an original primitive nebula or from accretion of large numbers of meteoric bodies (*planetesimals*), remains as yet an interesting speculation. From whatever source the planets originated, the members of the solar system have pursued different phases of planetary evolutions during their subsequent history. Both the hypotheses explain how our Earth in course of its evolution obtained its envelopes, the atmosphere and hydrosphere, covering the solid lithosphere. It is with the lithosphere the main body of the planet that we are concerned today. It consists of the outer *crust*, a solid shell of rock, enclosing the vast body of the Earth's *interior*, little less than 8000 miles in diameter, whether liquid or gaseous or solid, constituting what is called the barysphere or pyrosphere.

Fig. I EARTH'S INTERIOR



NIFE CORE — 2500 MILES APPROX. DUNITE SHELL – 1100 MILES
SIMA 300 MILES ,, SIAL, WITH MOUNTAINS, CONTINENTS, OCEANS 100 MILES

This was the older geologists' conception of the constitution of our Earth. In a large measure, it embodies also the essentials of the modern views regarding the composition and structure of the Earth's planetary body. The crust may be defined as the Earth's external solidified shell of variable thickness, 35 to 100 miles, according to different estimates. The crust is credited with great strength to support the weight of continents and mountains, and at the same time it must be weak enough to be buckled and crumpled to yield to pressures, both radial pressures, originating from the interior, as well as tangential pressures originating from the contraction of the Earth's circumference. The crust of the Earth by its buckling causes depressions which supports the great ocean basins covering 72% of its surface and elevations which form the continental landmasses with their plateaus and mountain – ranges, covering the remaining 28% of its surface. Between the highest points of the continental surface, (the peaks on the central axis of Himalaya mountains) and the lowest abysses of the ocean basins, there is a vertical difference of 11 miles. This fact illustrates the strength and rigidity of the Earth's crust, while the numerous convolutions, folds, and plications of its rock beds, which we see on the flanks of valleys and mountains, illustrate how the solid crust has yielded to tangential force to allow such complex plications of its beds. This apparent paradox is explained by the doctrine of *Isostasy* or the theory of "mountain compensation" which implies a certain amount of hydrostatic balance between the different segments of the earths crust and an adjustment between the surface topographic relief and the arrangement of density in the sub-crust, so that above each regaion of less density there will be a bulge, while over tracts of greater density there will be a hollow - the former will be the continents, plateaus and mountains, the latter the ocean-basins. The excess of material over portions of the earth above the sea level will thus be compensated for by a defect of density in the underlying material, the continents and mountains being floated, so to say, because they are composed of relatively light material. Similarly the floor of the oceans is depressed because it is underlain by unusually dense rocky substratum.

The density of the outer crust is 2.5 - 2.8. It is the theatre of the great geographical and geological revolutions that have taken place again and again on the face of the Earth since the beginning of geological time, submerging continents under ocean basins and uplifting the sea bed to form mountain – ranges, during different periods of geological history. The surface of the crust is partly composed of stratified sedimentary layers, whose aggregate thickness is highly variable but which, as can be seen from sections laid bare in the Himalayas and Alps, may be 10–11 miles thick. The bedded sediments are thickest underneath the continents, but the thickness decreases and may be entirely non-existent underneath the ocean basins. Beneath the cover of sedimentary stratified rocks there is a universal layer of crystalline rocks of granitic composition (the *Sial*) covering the lithosphere. This again is of variable thickness. It is of minimum thickness underneath the ocean basins—or the hydrosphere and, according to some authorities it may be practically non-existent in the great hollow of the Pacific Ocean. But underneath the continents it attains a maximum thickness of 50-60 miles, especially where the continents support the rocks and cores of mountain ranges of the height and body of the Himalayas, the Andes, the Alps, etc. Underneath the plains of continental land-masses, the thickness of the Sial diminishes to about 25–30 miles, this is especially so at the boundaries of the continents where they pass into the oceanic deeps.

Our main subject for consideration today is, however, the Interior of the Earth, the barysphere or the pyrosphere, lying underneath this 60–70 miles thickness of the external circumferential shell, known as the crust. Our knowledge about this deep-hidden core of the earth is derived from a few well-established facts. The best known fact is the great heat of the interior. The second is the great pressure existing even at comparatively small depth of the interior, and the third well-established fact is the high density of the core of the Earth, which is known to possess a specific gravity of 7–8, a density higher than that of steel. Let us examine the facts regarding the prevalence of great heat in the body of the Earth. The steepness of the heat gradient, as we descend mines, tunnels and deep-borings, is the earliest fact about mining known to man. On an average, in all parts of the world, the heat increase is at the rate of 1° F. for every 60 feet of depth. The second well known fact is the existence of thousands of hot springs, solfataras and over 500 living and active volcanoes on the face of the Earth, together with many times that number, of extinct volcanoes, which have spent their fire and are no longer active. The living volcanoes are discharging enormous quantities of gaseous, liquid and solid matter from depth to the surface. Hundreds of thousands of square miles of the Earth's surface today is covered under solidified lava masses discharged from these volcanoes. 200,000 square miles of our Deccan Platau, from Bombay to Nagpur and from Indore to Dharwar, is mantled under such lava flows discharged during one period of geology At places this blanket of lava is 3000-6000 feet deep composed of hundreds of sheets or beds of lava and ash-beds. This Deccan lava is a sample of the basic, potentially liquid, rock matter (magma) lying at depth of thousands of feet in the sub-crust—the *sima*—erupted to the surface during a period of volcanic activity. Such transfers of large volumes of rocks from the interior to the surface of the earth during volcanic eruptions is met with in many parts of the world. Another example of the action of igneous forces arising from the Earth's heat, is the intrusion of masses of acid liquid magma into the body of the crust in the form of large granitic bosses and lenses. These do not come to the surface but solidify under great pressure within the crust.

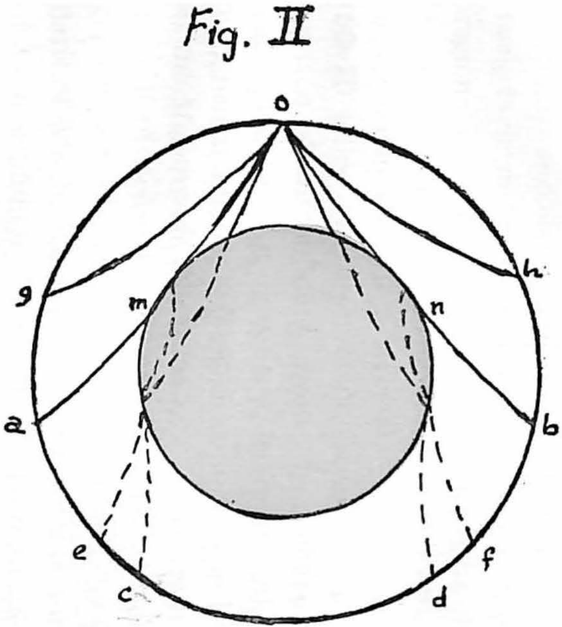
Thousands of square miles of such solidified magmatic plutonic matter, introduced from great depths of the Earth's interior to within some thousand to a few hundred feet of the surface, are to be met with in India and many regions of the world.

One can fully realize the immenstity of subterranean pressure even at comparatively small depths. It can easily be imagined under what pressures rocks of the Earth's crust must be lying at depth of many miles or underneath continents and mountains. This pressure is manifested in the chemical as well as mechanical changes witnessed in deep-seated rocks, causing new chemical and mineral combinations and imparting plastic flow structures in them. The rigidity, elasticity and internal friction of rock-masses at various depths have been the subject of elaborate laboratory experiments. The high density of the Core of the Earth, estimated at 10–12 times that of water, is also a measure of the great pressure existing there. With the increase of heat with depth, conditions prevailing at the sub-crust must be such that no matter can exist in the solid form, or even in the liquid state at 10–20 miles, but must turn to gaseous form. Deeper down the prevailing pressures, however, would counteract the effect of heat so as to condense the gaseous rock magma into a virtual solid, impart to it a specific gravity of 7–8 and make it behave for all intents and purposes as a body with the rigidity and internal friction of steel. While the density of the Earth as a planet is 5. 5, determined from gravity and astronomical measurements, the density of the central core is found to be as high as 8. This may be compared to the density of the average rocks of the Earth's surface crust, which ranges from 2. 5 to 3.

To understand the underground relations of the subcrustal layers of the Earth we must turn to recent research on the Earth's interior, its structure and composition. Much fresh light is thrown on this question by American scientists through geophysical studies, especially studies on the passage of earth-quake waves. Modern science has revolutionised our idea about the source of the Earth's internal heat also. According to old concepts, the heat is the residual heat preserved from the primitive nebula. On this concept there must be gradual cooling with the passage of each geological age and a time may come when the Earth may become a dead body with the total loss of its heat. Modern ideas have ascribed a totally different source of plutonic heat–as we shall see a little later. The old concept of the Earth was a body with a hot, virtually liquid, sphere of great density, occupying nearly 7/8 part of the diameter and surrounded by a thin cool rocky crust or shell. On this view the formation of mountain ranges on the Earth's surface was simply explained; the hot interior by continual loss of heat gradually contracted and as the circumference of the globe had to accommodate itself to a constantly decreasing diameter, it was thrown into folds and wrinkles. This was the origin of mountains.

These ideas of a liquid interior surrounded by a relatively thin solid shell held ground for many years, but modern geologists have repudiated the idea of a homogenous liquid or plastic interior. From the behaviour of our Earth as a planetary body, especially its response in respect of tides and its gravitational response to the rest of the solar system, the Earth is now believed to be entirely solid to the core, functioning as if it had the regidity of glass or steel.

We may now consider the physical constitution or structure of the Earth's interior. In this respect there is a consensus of opinion that the interior is composed of a series of more or less concentric



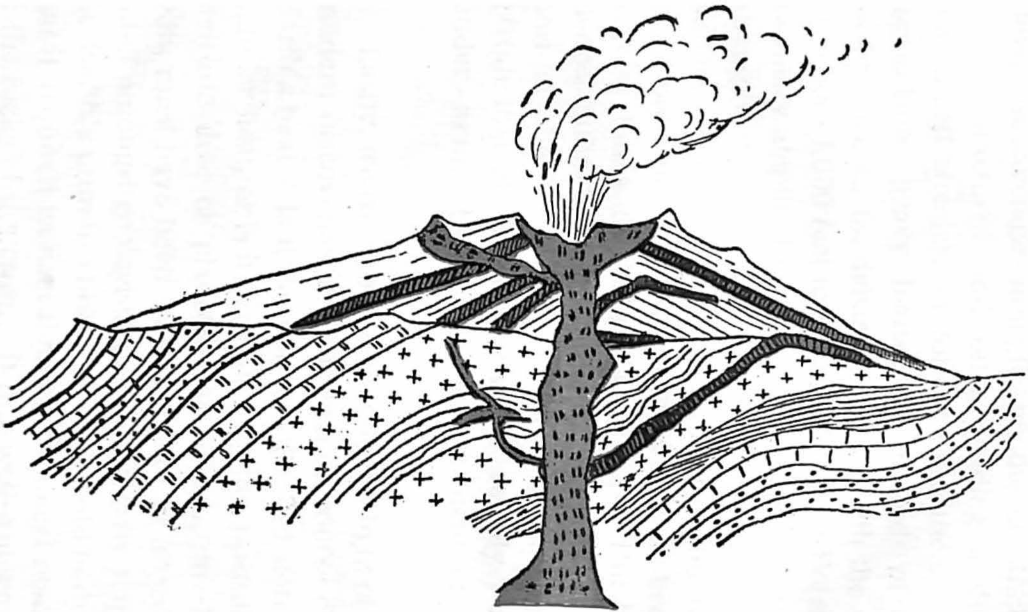
Lec. III] Behaviour of Earthquake waves as they cross different layers in the Earth's interior. [Fig. 2

shells of increasingly basic composition ending with a central core predominantly composed of iron and nickel. According to this view, underneath the Sial shell there is a layer of progressively basic composition (the *Sima*) which possesses greater rigidity and strength than the Sial. The thickness and elastic properties of this intermediate basic layer under the Sial differ notably in different regions of the Earth. It is thicker underneath the oceans than under the continents in general. The lower boundary of this layer at a depth of about 60-70 miles on the average, is known to be a surface of discontinuity from the behaviour of earthquake waves traversing it, in the different continental regions. This discontinuity is known as the *Mohorovicic Discontinuity*. Underneath it is a shell of dense basalt, or ultra-basic dunite, of great thickness of some 1700-2000 miles, the lower parts of which, according to some authors may be of the constitution of meteorites. Underneath this again are several more or less concentric shells of ultra-basic magma, separated by discontinuities of second or third order. This fact is indicated by the respective speeds of earthquake waves passing through them, their reflections and refractions. The central core or nucleus of the Earth on this view, some 2,000 miles in radius, is believed to be a virtually fluid mass composed of iron-nickel, but behaving as a solid with high internal friction because of the tremendous pressure of the litho-sphere on it. The preponderance of iron and nickel in the interior explains the phenomenon of our Earth's magnetism. The Earth behaves as a magnet with its north and south pole situated a considerable distance away from the North and South Pole of ths Earth's axis of rotation. The magnetic equator of the earth passes through the region of Travancore, S. India. The fact that the Magnetic Equater passes through Indian territory-gives India a great potential advantage in the conduct of such fields of research as Cosmic ray research.

Intensive research on earthquake waves and underground gravity observations of the last 30 years in the different regions of the world, support the conception of structure and the composition of the earth's interior as outlined above. They have completely changed our ideas about the constitution of our globe and have built up the new concept of its structure. In the continental layers the velo-city of propagation of earth-quake waves, as observ-ed in seismograph records of hundreds of earthquakes, is $5\frac{1}{2}$ kilometers per second. Below the above-named Discontinuity the velocity increases to about 8 kilometer per second; in the still deeper ultrabasic zone, separated by secondary discontinuities, the speed of the seismic wave, the primary or longitudinal wave, is found to increase with depth. Below this, however, the rate of increase is observed to be much lower as the consequence of the transition from the crystalline magma of the upper layers to the amorphous or glassy magma of the deeper layers. Underndath this comes the iron-nickel core of the earth of much higher density but of greatly reduced rigidity and elasticity. Its outer boundary is tolerably defined by the changes and reflections the earthquake waves undergo as they graze its surface, or are refracted through its mass. It transmits the longitudinal waves through it with much less velocity than the overlaying layers, because of its non-elastic state, while the secondary or transverse waves are not transmitted at all through the central core of the earth. These facts are illustrated by the diagram (Fig. 2).

The Earth's outer crustal shell, taken as a whole, has considerable flexibility and has well-defined belts of mechanical weakness. Nevertheless, the average strength of the crust, though greatly fractured and often yielding under long continued stresses, as for example, the foot of the mountains, heavy loads of thousands of feet of sediments, as in deltas, or underneath the weight of 3,000–4,000 feet ice-sheets as at the Poles is at ordinary depth distinctly more than the crushing strength of many dense and compact rocks at the surface. The strength of the rocks of the lithosphere probably increases downwards till it becomes several times that of surface rocks. But in the deeper Sima layers the strength begins to decrease and at the bottom of the Sima it may be only 1/10th that of the surface rocks, readily yielding under strains by plastic flow to areas of lesser pressures.

Lastly, we have to consider, in the light of these modern discoverias, the question of source of the Earth's heat. Is it the relic of the old stored up nebular heat, or is it generated by the pressure of meteoric dust or planetesimals which, to begin with, must have been cold ? There is a growing belief amongst geologists that in the early stages of the Earth's primitive history it was a cold body and that it acquired its heat through chemical reactions in the rocks of the crust. It is a well-known fact



Lec. III] Diagramatic Section across a Volcano. [Fig. 3

that most ordinary rocks contain a minute qnantity of uranium or radium. This widely disseminated radium content of the rocks of the crust through atomic disintegration, generate heat which is propagated both upwards and downwards. This is a cumulative process and, through its agency, the Earth has become progressively hotter with age. While radiation through the crust to outer space tends to keep the outer layers cool, there is no channel for the dissipation for heat conducted into the deeper layers underneath the Sima. The downward passage of this radiogenic heat and its accumulation at the intermdiate layers and at the centre is believed to be the source of all plutonic and volcanic heat.

SUB-RECENT AND RECENT CHANGES IN THE GEOGRAPHY OF INDIA

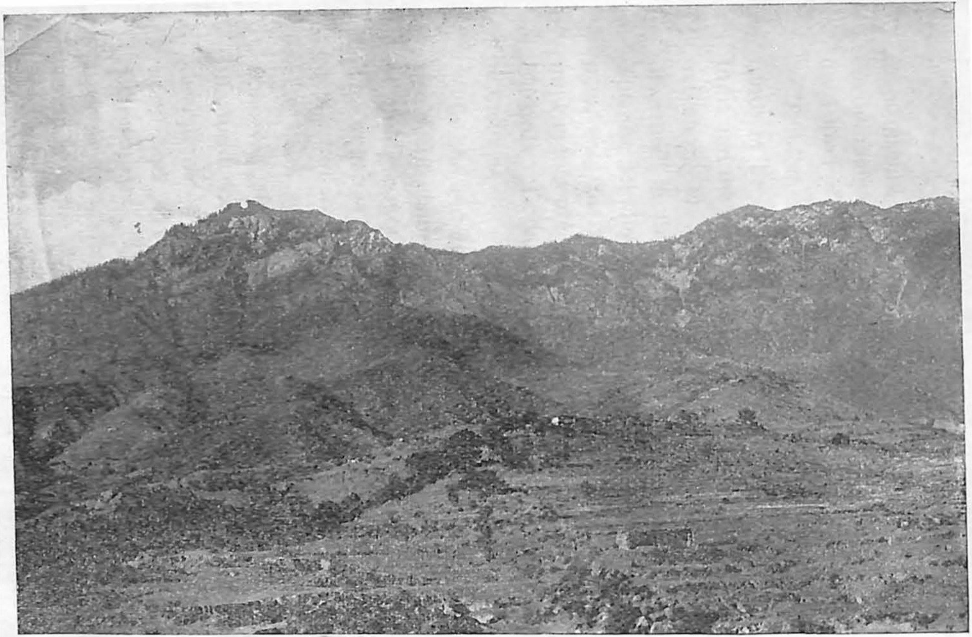
We often hear the expression *terra firma* as a symbol of the earth's stability and permanence. But the earth has no claim to be called *terra firma* as the earth's crust possesses no real stability. Under the weight of great mountains, the crust bends and even gives way in cracks and fractures and folds. Even sudden great changes in barometric pressure, heavy tides, etc., produce tremors, in the crust, which though feeble are measurable by the seismograph, while there are some 10,000 perceptible earthquake shocks felt every year all over the globe. "As old as the hills", again, is an expression which though poetically acceptable, is scientifically inaccurate. The greatest and most imposing ranges of mountains like the Himalayas, the Andes, the Rockies, the Alps, etc., are geologically speaking, of only yesterday. They are very young compared with the sorely eroded and worn out ranges such as the Aravallis of Rajputana, the remnants of a once mighty chain, which in past geological ages stretched across the length of North India and probably extended into the Arabian sea. The surface features of the earth's crust, the distribution of sea and land, continents, mountains, rivers, lakes are subject to constant and ceaseless change and every geological age comes to possess its own geographical features. This is the first and most important lesson of geology; new land-masses and mountain-chains arise and are worn down to the sea-level by various meteoric and atmospheric agents; from their debris, carried away by rivers and discharged as sediments into the sea, is built the material for new land on the floor of the oceans while the bottom of the sea is periodically elevated to form, out of these, new mountain chains.

The changes that have taken place in India since the last geological age, the Pleistocene, have been of great magnitude and importance. We might consider them separately as changes on the land surface, the changes caused by the rise and growth of mountains, changes in the river-systems of north and south India, changes in India's animal population, great climatic changes, etc. At the end of the Pliocene period, that is to say at the end of the fifteenth out of the sixteen geological periods which make up the earth's history, even at this late date in the long vista of time, the sub-continent of India had acquired only a part of its present geography. North India by that date had acquired its mountain systems, the Himalaya the youngest mountain-range of the earth, had completed its major uplift, though they had not yet risen to their present elevation. Peninsular India the Deccan, had acquired its triangular outline with more or less well-defined coast-lines along the Arabian sea and the Bay of Bengal, and its mountains had very hearly their present features. In North India, there was a longitudinal trough, a great depression in the crust, stretching from Sind to Assam, of considerable depth, partly filled by the sea, a remnant of the Himalayan sea, which yet persisted after the main sea was driven out by the rise of the mountains. This sunken-basin is believed to have been created as a complementary depression to the elevation of the Himalaya. There were gulfs stretching inland far to the north along the present valleys of the Indus and the Ganges, the gulfs of Sind and

Assam. There were no plains covering the region from Punjab to Bangal, no desert of Rajputana and no deltas. The great plains of North India have originated by filling up of this trough by the sediments poured into it by the rivers descending the Himalayas.

Climatically, India underwent a momentous revolution during the Pleistocene epoch, that is, the last of the sixteen periods of geological history, the age which continues into the sub-Recent and historic age. It experienced a great refrigeration of climate which was an echo of the *Ice Age* of the northern world, during which North Eurasia and North America. down to the latitude of 40° in the latter and 49° in the former were buried under sheets of ice. The Himalayas experienced the same fate and gigantic tongues of ice descended far to the south of their present limits, almost touching the Sub-Himalayan foot-hills. The rest of India did not experience an Ice Age in the strict sense ; though its ground was not covered under ice, it passed through an epoch of great cold and heavy precipitation of rains, caused by the cyclonic storms induced by the ice-covered regions to the north. This is known as the *Pluvial Age* of Deccan, the effect of which, both physical and biological, are traceable in several parts of South India and Ceylon.

As a consequence of the great lowering of the former tropical and sub-tropical temperature, it is believed that northern India experienced a widespread extinction of its higher life then existing, viz., its large mammal population. It is a well documented fact that during the Miocene and Pliocene epochs (the Siwalik age of Indian geology) northern India had an influx of mammals from Central Asia and even North America possessing a wonderful diversity of species, genera and families. There were scores of species of bovine, equine and carnivoran animals; there were rich and varied assemblages of pigs, elephants, giraffes, hyppopotami, antelopes, rhinoceroses and monkeys, including the higher anthropoid apes. Compared to this wealth of animals the present population is quite impoverished both in individuals as well as in species. The sudden and widespread reduction by extinction of the Siwalik mammals is a highly significant event for the geologist as well as the biologist. It is ascribed to the effect of intense cold of the glacial age, the more highly organised and specialised families of mammals being less fitted



Lec. IV] Glaciated mountains & moraine-filled Valley in Kashmir Himalaya. [Fig. 1

to withstand a sudden change in its physical environments than the less specialised and generalised species.

The other great event of geogrphical significance in the Pleistocene is the advent of Man in India and the world. No indubitable trace of his existence, or relics left by him are to be discerned in the previous age (Pliocene), but with the Middle and Upper-Pleistocene, relics of man, viz., his stone (*palaeolithic* and *neolithic*) implements preserved in the gravels of the rivers Narbada, Godavari and the Soan become numerous.

In the purely geographical sense the most significant change of the time was the filling up of the sub-mountane trough referred to above. This trough is believed to be 6,000–10,000 feet in depth and its filling up by the sediments, silt, clay, sand, gravel, brought down from the newly upheaved Himalayas should be considered the most notable event of sub-recent times. Its disappearance gave rise to the great plains of the north and to the early Ganges, Indus and Brahmaputra. The disappearance of the Sind and Assam gulfs took place by the southward advance of the deltas of the Indus and Ganges-

Brahmaputra. The present Ganges is believed to be a descendent of a great pre-historic northwest flowing river, the successor of the lagoons and lakes surviving the sub-montane basin. As this basin gradually shrank and receded it was replaced by the estuary of a mighty river. This river subsequently became the Ganges. Few changes in the physical geography of India during these times have been so well proved as changes in the river systems of North India. The number, volume and even the direction of some of the units of this drainage bear evidence to this fact. This is particularly true of the Punjab rivers. The river Jumna, the reputed Saraswati of Hindu scriptures, in Vedic times flcwed to the sea through Western Punjab and Rajputana by a channel that is now occupied by an insignificant stream which loses itself in the sands of Bikaner desert (the Ghaggar). In the course of time the Saraswati took a more and more easterly course and ultimately merged into the Ganges at Prayag. It then received the name Jumna. Similarly, most of the great Punjab rivers have shifted their channels. The Chenab, Jhelum, Beas and Sutlej have frequently deserted their beds and altered their course many scores of miles. The records of the 3rd century B. C. shew that the Indus flowed more than 80 miles to east of its present course, through the now practically dry bed of a deserted channel (the Eastern Nara), to the Rann of Cutch which was then a gulf of the Arabian sea. The famous cities of Mohenjodaro, situated on the Indus in Sind and Harappa, on one of its afluents in Southern Punjab, were abandoned through the vagaries of the shifting Punjab rivers.

Compared to this juvenile hydrography of north India, the drainage pattern of peninsular India is of very high antiquity and has persisted more or less unchanged since early geological time. The Deccan plateau is one of the oldest and stablest blocks on the earth's surface as compared with the Himalayas, which represent a weak and flexible area of the earth's circumference. Although no revolutionary changes have occurred in the Deccan plateau since very early geological time, Tertiary Deccan had a drainage system different from the present one. Ordinarily we should find the drainage in a land of such antiquity to be more or less equally divided on the two sides of a central dividing highland, but in the Deccan we find all the rivers flowing east from the Western Ghats, which are situated close to the Arabian sea-board. The rivers Tapi and Narbada are the only exceptions and they are found flowing not in valleys excavated by themselves, but in valleys mechanically produced along lines of dislocation and subsidence (rift-valleys). It is probable that the Deccan plateau extended in the Mesozoic age, much further to the west, and the Western Ghats then formed the water-shed of that land, being situated somewhere in its middle. The land-mass west of the Ghats has subsided under the sea and forms a part of the Arabian sea-bed. The researches on the sub-marine topography of the Arabian sea, conducted by the Murray Expedition of 1934, throw valuable light on this. Evidence of extensive faulting causing this subsidence is observed in the steep scarped face which the Western Ghats of Konkan and Malabar present towards the sea, and in the remarkably smooth coast-line of the whole Malabar Coast from Mekran to Cape Comorin.

The next sub-recent change we have to notice in the geography of India is the conversion of a large tract of Rajputana into a desert, an event which can be considered as almost of historic date, i.e., happening within about 3,000 years. The origin of Rajputana desert (Thar) is attributed to long continued aridity of the region, combined with the sand drifting action of the southwest monsoon winds which sweep through Rajputana for several months of the year without precepitating any part of the contained moisture. The annual rainfall in Western Rajputana – the mean fall is not much above 5″ – gives rise to no rivers or streams there and consequently there is no river action to carry off the growing volume of sands to the sea, which have hence gone on accumulating year after year. The origin of Rajputana desert is a part of a widespread subrecent phenomenon which has affected many millions of square miles of Central Asia. The growing aridity and desiccation of Central Asia is today witnessed in a wide desert or semi-desert belt stretching from the Sahara through Syria, Arabia, the Aralo-Caspian depression, through Khorasan, Chinese Turkistan, the Tarim and Takla Makan, to the Gobi desert of Mongolia. A telling evidence about the deterioration of climate in the Rajputana area within the last 2,300 years is furnished by well authenticated accounts of Alexander the Great's return march from Punjab through Rajputana and Sind to Persia. Within the area of western Rajputana proper, there were large forests and it is recorded that Alexander crossed the Indus in a flotilla constructed of timber derived from these forests. This region now is a howling waste of sand, studded with saline tracts, ruins of deserted towns and river beds.

The Kashmir valley provides another example of geographical change in the Himalayan region within sub-recent times. Geologists have discovered the remains of deposits of a lake which filled the whole of the Kashmir valley-basin between the Pir Panjal range to the south and Zanskar range to the north. This lake must have filled the Kashmir basin to a height of several thousand feet, the deposits of which are now found in isolated mounds and broken up alluvial terraces on the flanks of the Pir Panjal (the *Karewas*). This lake is believed to have been drained in proto-historic times by a breach in the mountains near Baramula.

The most striking evidence of recent geographical change in the Himalayan region is furnished by these alluvial mounds, (Karewas) the uneroded remnants of which dot the Kashmir Valley from end to end, especially on its south-west flank.

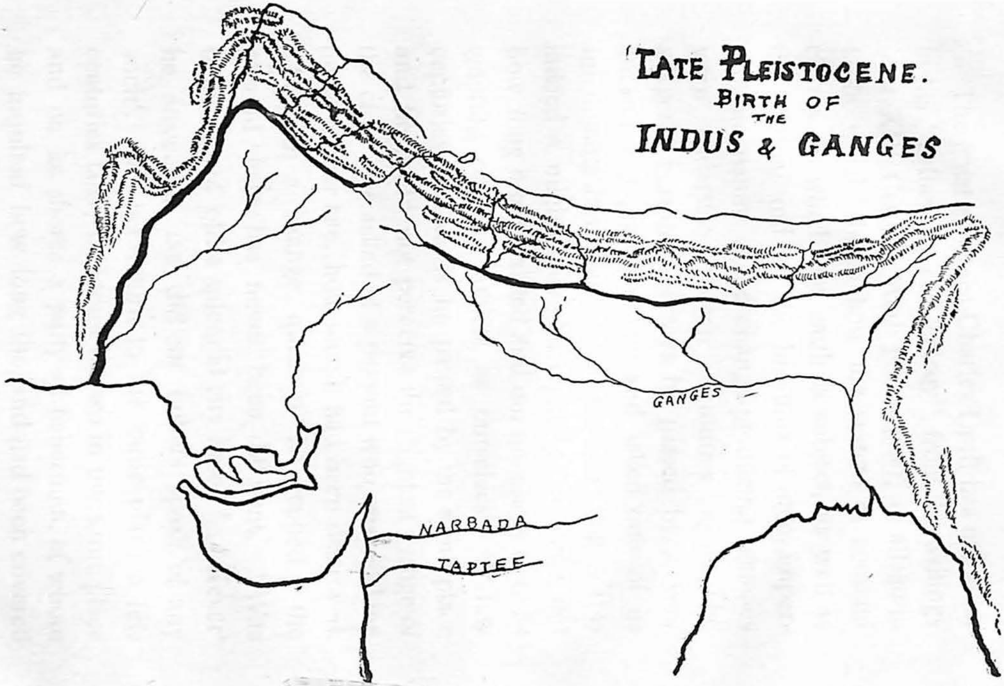
The Karewas are some thousand feet in depth and contain many fossil remains of semi-tropical plants and animals. Benches and terraces of the Karewas, folded and elevated are found 7,000 feet above the present bed of the Jhelum. This is due to the uplift the Kashmir Himalayas have undergone since the time of formation of the Karewas, Pliocene to Late Pleistocene.

The deep dissection of post-Tertiary deposits by Himalayan rivers in other parts of these mountains affords yet another evidence to the same effect. Most Himalayan rivers have a system of terraces or benches which range upto 3,000 feet above the present level of their valley-beds. The river-terraces of the Sutlej in its upper reaches, in the province of Hundes in Central Himalayas, covering several hundreds of square-miles, offers a signal example. These deposits are being deeply trenched by the Sutlej, at places to a depth of 3,000 feet. At several localities the terraces contain suites of recognisable mammalian fossils of Pleistocene age; this fact indicates that since the deposition of the terraces in the Pleistocene, parts of the Central Himalayas have been uplifted several thousand feet.

The next series of changes are comparatively minor uplifts in the Deccan and in the Chota Nagpur region of Bihar, creation or accentuation of rifts and block-faults, a few minor warps or oscillations, the silting up of the Rann of Cutch, differential movements caused by great earthquakes, upheavels along the Malabar coast and depression of the delta tracts.

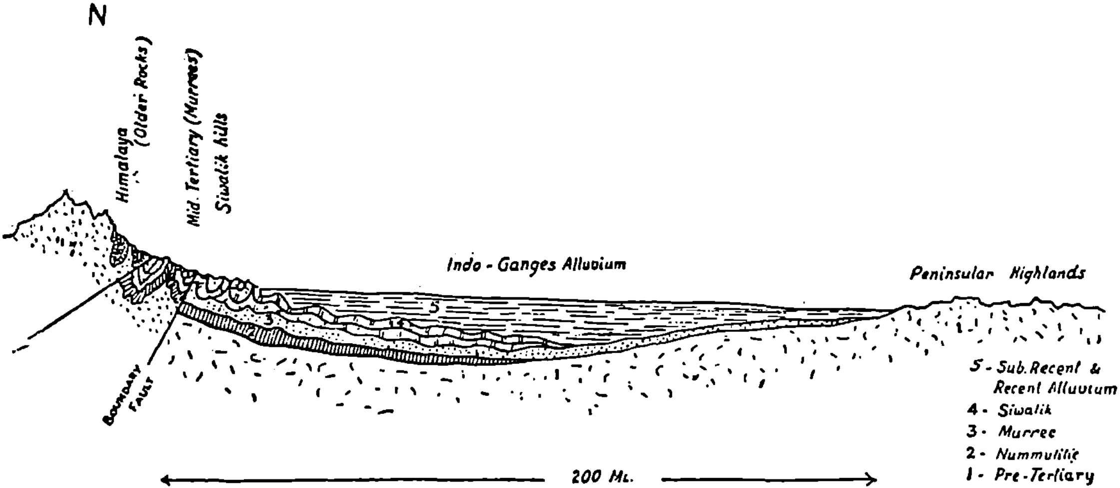
Large tracts of south-east Gangetic plains were made fit for human habitation, by draining and desiccation, only late in the Upper Pleistocene. Bengal became a habitable land at a much later date than western India, as the sea of the Assam gulf persisted upto the Rajmahal hills so late as 5,000–10.000 years ago. The Sind gulf was pushed back by the southward progress of the Indus delta at an earlier period.

From the above account of the geographical revolutions that have taken place in one geological epoch–the last and briefest one in the sequence of geologic Time–we find that the Earth is subject to a regular cycle of change. Earth-features come into being, they grow, they decay and are planed down to sea-level. Out of their debris washed into the sea are made new lands, with new system of geographic features.



Lec. IV] Diagram showing hypothetic Origin of North Indian rivers. [Fig. 2

The great geologist Charles Lyell has narrated, in his "Principles of Geology", from the writings of a XIII Century Arab philosopher, an allegoric fable which shows how the system of constant change to which our earth is subject, as well as the gradual and for the life-time of men, imperceptible, nature of the change-producing agencies were understood seven centuries ago. The allegoric person here says he passed by a very ancient and populous city and asked one of its inhabitants how long it had been existing. 'It is indeed a mighty city' he replied; 'we know not how long it has existed and our ancestors were as ignorant on this subject as ourselves'. A few centuries afterwards he passed by the same place and he could not perceive the slightest vestige of the city. He asked of a peasant who was working on its former site, how long it had been destroyed. 'In sooth a strange question' he replied; the ground here has never been different.' 'Was there not of old a splendid city here?' 'Never' he answered, nor did our fathers speak of any such'. On his return to the same place a few centuries later, he found the *sea* in the same place and on its shores a party of fishermen, of whom he inquired how long the land had been covered by the waters. ‘What a question ? this spot has always been what it is now.’ The person again returned a few hundred years afterwards and the sea had disappeared; on his inquiring how long ago this change had taken place, he got the same answer as he had got before. Lastly, on his coming back after another lapse of centuries, he found there a flourishing city more beautiful and prosperous than the old one, and concerning its origin the inhabitants answered him, ‘Its origin is lost in antiquity; we are ignorant how long it has existed, and our fathers were on this subject as ignorant as ourselves’.



SECTION ACROSS THE INDO-GANGETIC SYNCLINORIUM (Diagrammatic)
(Vertical Scale exaggerated)

Lec. IV] [Fig. 3

MINERAL WEALTH OF INDIA

—the Role of Minerals in National Reconstruction.

We shall consider the subject of this evenings lecture under six heads. This will enable us to examine this hitherto somewhat neglected subject in its major bearings on India's present economy and future industrial reconstruction plans. Firstly we shall take up the interesting question (1) the mineral position of India in the world, then (2) its sufficiences; insufficiences, and deficits in minerals; (3) the chief mineral assets of world importance; (4) the past neglect of systematic mineral exploration and lack of indigenous utilisation of resources; (5) a planned program of mineral development; and lastly (6). suggestions regarding a mineral policy and program so that both the individual autonomous States who own the unequally distributed mineral deposits, as well as the Nation as a whole, may derive maximum benefit, from these resources. An over-all picture of India's position in respect of strategic and defence minerals was given in the second lecture, and in some sense the present lecture may be considered an extension of the previous one.

Minerals and metals form the basis of the world's industrial civilization. The work of the world is done by tools which are made directly or indirectly out of minerals and ores. Modern defence armaments and munitions depend more or less entirely on the products of mines, and it is on this account that in the last three centuries since the commencement of the industrial era, there have been such inroads on the world's stock of minerals that several vital metals and minerals have almost reached depletion mark. Geologists have sounded a warning note that the world's known stock of petroleum, tin, lead, zinc, within mining access, will not last more than a couple of decades. To the extent, therefore, that India has remained backward in the world's industrial race and has not participated actively in the wars of the last half century, her mineral wealth has not been drawn upon so wastefully. With systematic mining, conservation and scientific utilization, India's mineral resources will go a long way towards building up of the country's economy and create a strong industrial potential. In the present address I shall review briefly the mineral position in India and its chief natural assets and deficits; their planned development and utilization for building a healthy, diversified mining and mineral industry that is commensurate with the natural resources with which nature has endowed this country.

THE PRESENT MINERAL POSITION IN INDIA.

Deposits of useful minerals and rocks have been worked in India for many centuries, though generally in a small way. In the medieval ages, India had a fairly developed metallurgical industry that used to produce its own metals, both ferrous and non-ferrous, and satisfy most of its indigenous needs. The immense quantities of slags of iron and steel and metals like copper, zinc, lead and gold, and to a smaller extent silver and cobalt, in parts of Rajputana and Bihar and several centres in the Deccan, bear testimony to the occurrence of a vigorous and flourishing metal industry in the past. In certain of these districts, the slag dumps cover furlongs of the countryside and, in one instance, the crucibles used for smelting zinc and lead are spread over a hill-side and build a village. This fact indicates that profitable mining operations must have been carried out for many centuries in various parts of the country. The famous iron pillars forged of remarkably pure rustless iron, manufactured in the early centuries of Christian era, (one such, that of Delhi, is 23 feet long), and the celebrated *wootz*, the steel used for Damascus swords, are well known examples of the art of ancient Indian metallurgy. Of course, the ancients were content to exploit only large, easily accessible deposits, without any particular reference to their grade or richness. Minerals like coal, oil, chrome-ore, manganese, mica, ilmenite, etc., were altogether untouched till amost the end of the 18th century, when the wonderful industrial development of the western world brought these minerals to the notice of European capitalists, who started large scale operations for mining these minerals for the purpose of foreign export. In most cases the existence of old workings has guided modern exploration and development. The 23 more important products mined in India to-day are :—

1. Coal	34 million tons.
2. Iron–ore	3.7 million tons.

3. Manganese-ore	1.1 million tons.
4. Mica	16,000 tons.
5. Salt	2.5 million tons.
6. Building materials	17 million tons.
7. Gold	227,000 Ozs.
8. Petroleum	65 million gallons.
9. Copper	7,000 tons.
10. Ilmenite	300,000 tons.
11. Industrial clays	500 000 tons.
12. Saltpetre	2,000 tons.
13. Lead-zinc ores	18,000 tons.
14. Chromite	20,000 tons.
15. Kyanite and Sillimanite	30,000 tons.
16. Magnesite	116,000 tons.
17. Steatite	60,000 tons.
18. Gypsum	200,000 tons.
19. Monazite*	
20. Beryl*	
21. Diamonds	3,000 carats.
22. Fuller's earth	1,000 tons.
23. Rutile	1,000 tons.

Less important mineral products today, but which are capable of material development in future expansion of industries, with application of technical knowledge, skill and enterprise are :—

*Figures withheld.

24. Agates 25. Antimony 26. Apatite 27. Asbestos 28. Barytes 29. Bauxite 30. Borax 31. Corundum 32. Felspar 33. Graphite 34. Mineral paints 35. Salts & Alkalies 36. Silver 37. Tungsten-ore 38. Zircon	Production variable and generally small.

The above two tables show in conspectus the mineral output position as it exists in India to-day. The annual production, in terms of rupees, varies from year to year but an average year's production, as given above, is valued at Rs. 75–82 crores. This figure is rather low, as, in many cases, only the pit-head value of raw undressed minerals is calculated.

2. PAST NEGLECT OF SYSTEMATIC MINERAL EXPLORATION IN INDIA.

Until very recent times, exploration of ores and minerals for industrial utilization on a consistent national plan had received no attention. The bulk of mining was done with European capital and technical skill, but for the solitary exception of a Tata, whose vision and enterprise brought into existence Jamshedpur, and an iron and steel industry on a scale somewhat commensurate with its vast ore reserves. This fact remained true upto the last war. As a result of this, an unhealthy and uncontrolled traffic in India's minerals grew up. Excepting coal, oil and iron ore, the bulk of minerals was raised only for purposes of export entirely in the raw condition, e. g., the whole output of manganese ore, mica, ilmenite, chromite, referactories and the major part of the remaining 6 or 7 minerals raised in India.

India's coal resources have been a subject of long examination and considerable debate. Although about 60,000 million tons are known to be present in Indian rocks, the extractable quantity within 2000 feet depth from the surface, has been variously estimated between 20,000 million and 40,000 million tons The reserves of superior grade, coking and metallurgical coal, however, are believed to be not more than 2,000 million tons. This superior grade coal, again, has in the past been indiscriminately drawn upon for railway and factory uses, a fact which has given rise to serious misgivings about the future of metallurgical industries in India, especially iron and steel, the ore reserves for which are of a vast magnitude. Till lately Indian coal was the cheapest in the world and its very cheapness at the pitheads led to the wasteful employment of the better grades and to the adoption of crude, cheap methods of mining. In raising the annual quota of 25 to 27 million tons of coal for India's local consumption in the pre-war years, it has been estimated that at least an equal quantity was lost, or rendered useless underground, through fires, roof collapses, subsidances and unscientific mining methods. Luckily energetic steps are being taken now to control these wasteful practices.

In the absence of organized scientific research Indian mineral industry kept on stagnating upto the beginning of the second World War. Upto then the Geological Survey of India directed its energies chiefly to academic problems and geological mapping, because of the very limited personnel on its staff. Systematic mineral exploration was confined to manganese and aluminium-ore (bauxite) and occasional sporadic drilling campaigns to prove suspected coal or ore-bearing areas. Since 1944, however, this gloomy picture began to change. The creation of a Department of Planning and Development at the Central Government, the establishment of the Board of Scientific and Industrial Research, a programme of four-fold expansion of the Geological Survey, the formulation of a National Mineral Policy and the organization of a Bureau of Mines promised a new era for mining and mineral industries on modern and progressive lines.

The plans for the future provide for detailed and intensive exploration of resources as well as their conservation and utilization for indigenous manufactures and fabrication. Geophysical exploration, practically unknown in India, other than for oil, carried out by the Oil companies, promises attractive dividends from certain Indian terraines. The fact is now recognized that the 3000 miles long border of the great alluvial plains overlapping the crystalline rocks all around it and other large areas buried under deltas, deserts and ancient lava-flows, need systematic geophysical sounding. It is a reasonable speculation that some of these formations mask extensions of ore-bearing rocks in Dharwar, Rajputana, Karnatak; coal bearing rocks in the upper Godavari and Mahanadi valleys; or oil-bearing older Tertiary rocks in the Punjab, Rajputana and Assam. These blanketed areas of India which aggregate over half a million square miles, are beyond the reach of ordinary geological prospecting. Gravimetric, magnetic and seismic reflection and refraction surveys are likely to locate deep-lying ore-masses, oil pools, coal-fields, water reservoirs and some hitherto unsuspected mineral occurrences.

3. THE CHIEF MINERAL ASSETS OF INDIA.

(i) The following products of Indian mines may be classed as of world importance :—*Iron ore and manganese ore*, ores of aluminium, magnesium and *titanium*, high-grade refractories, rare earths, mica, thorium and other atomic elements of strategic importance. These provide workable basis for well-regionalised mineral, metallurgical and heavy engineering industries. Reserves of iron (some current estimates put them at such high figure as 20,000 million tons), manganese–, aluminium-and magnesium–ores are such as to make India the leading metal manufacturing country of the East, if not of the world in the near future. Iron and steel production can be increased to many times its present output of barely 1·6 million tons. Abundant local resources exist for large-scale manufacture of ferro-manganese as well as silicon–, chrome–, vanadium–, titanium–, and other alloy steels, with a wide range of light metal alloys, especially Al–Mg alloys, for which there is a great future. The outstanding problems that confront the metal manufacturer in India is, however, not so much the paucity of ore reserves, as ready access to coal supplies which are confined to a narrow sector in east India. Low-cost electric power is thus the decisive factor in the regionalisation of heavy and light metal industry in parts of India remote from the Bihar Coal-fields.

(ii) *Ferro–Manganese and Ferro–Alloys.* Being the world's largest supplier of high-grade manganese ores, with an annual output approaching a million tons, it should be possible in India to manufacture 200–300 thousand tons of ferro-manganese per year and export that commodity rather than raw manganese ores. Low-phosphorous ores and low phosphorous coke are available at a few localities for making this alloy.

(iii) *Light Metals and Alloys.* Large reserves of the light metals aluminium and magnesium, which are yet scarcely touched, exist in suitable concentrations in south India. Good grade beryllium ore occurs in fair amount and an immense source of titanium, "the metal of the future," exists in ilmenite. Prospects for the manufacture of light metal alloys, which are now in increasing demand for a surprisingly wide range or engineering requirements, are particularly bright and should have the foremost place in a programme of reconstruction. These metals can largely replace the world's growing deficiency in copper, zinc and lead. Electro-metallurgy, the chief mode of production of these metals, uptill now has not made much headway, but with the installation of hydel plants in connection with the 5 great River Projects, one big handicap in the cheap supply of thermal energy will disappear.

A stable metal industry demands easy access to fluxes, refractories and subsidiary minerals. Reserves of most of these are ample and well distributed.

(iv) *Rare Earth Minerals.* Reserves of ilmenite (titanium ore) are computed at nearly 300 million tons. Though the reserves are large, they are by no means inexhaustible at the rate of depletion that was going on in pre-war years. The Travancore State has now rightly taken steps to prohibit unlimited ilmenite exports and to start manufacture of titanium paints locally. This is only a small begining and more energetic and persistent efforts are needed to develop this great national resource of the country. Titanium is going to be a most important metal of the future as it possesses some superlative properties for use in industry, commerce and defence purposes.

The rare earth minerals – monazite and zircon, source of a host of rare elements of high industrial potential, occur associated with ilmenite sands of Travancore. The Travancore monazite is an important ore of thorium, containing 8 to 10% Tho_2 besides a small fraction of uranium. Since harnessing of the atomic energy of uranium, monazite has sprung into importance. The reserves of Travancore monazite are computed at ever a million tons. Steps are taken by Government to conserve this valuable potential source of atomic fuel of the future.

There are large reserves of zircon in Travancore yielding the rare metal zirconium, which with its oxide and the associated element hafnium, is capable of playing several specialized roles in modern technology.

(v) *Mica.* Mica forms another important mineral asset; it is the only Indian mineral whose exports have brought a fair monetary return, because India has demanded and obtained almost monopolistic prices in the world market. The whole output is exported which supplies 80% of the world's demand of superior grade mica. In preparing this quantity of mica by cutting and grading to standard specifications of foreign buyers an enormous amount of waste mica is produced and a profitable outlet for the utilization of the enormous dumps of this waste mica may be found in the making of paints boards, moulded insulators, micanite, extraction of potash, etc.

4. MINERAL DEFICITS OF INDIA.

(i) *Non-Ferrous Metals.* In contrast with the sufficiency of ferrous metals, the position in India with respect to tin, lead, zinc, nickel, silver and mercury and to a lesser extent copper, is distinctly unfavourable. An extended and detailed geological prospecting of the mining areas which are known to have supplied the by no means insignificant demand for copper, zinc and lead in the years before the 19th century, however, is necessary before we can finally accept these deficits. Medieval India supported, copper, zinc, and lead mining and smelting industries in Rajputana, Bihar and in some Deccan centres. The Darjeeling-Gangtok copper deposits need more extensive exploration and drilling tests; so also the Khetri copper and the Zawar lead-zinc deposits of Rajputana. At these centres geophysical prospecting and deep drilling tests may prove some deposits that may be worth working on the modern scale.

(ii) *Petroleum.* India's hitherto known oil deposits are of very limited extent and we have no data for even a rough forecast of possible reserves. Oil bearing rocks in India are confined to the strip of Tertiary rocks bordering the extra-Peninsula. This strip joins up the Iranian oil arc with the Burma-Java arc, two prolific oil belts of the Old World. But the energetic prospecting of this Tertiary belt in the last 60 years has yielded discouraging results. Three potential petroliferous regions which can be regarded as promising for intensive prospecting by modern methods are :—

(1) Southern Assam and parts of Bengal hidden under the alluvium.

(2) The shallow submarine tract of the Cambay

Gulf, Cutch and southern Rajputana buried under the desert sand.

(3) Certain tracts in the outer Himalayas of Jammu and Kangra.

Against a consumption of over 1000 million gallons yearly, the present annual production of petroleum in India fluctuates between 60 and 80 million gallons, produced by the Assam Oil Company, from their Digboi field. Future progress of oil development in India can only be looked for from the application of the new highly perfected technique of depth exploration, by seismic and gravi-metric methods, in zones with promising geological formation and structures. The only alternative to ever-increasing oil imports for meeting the vital need for oil fuel is synthetic manufacture of petroleum from low-grade, high-ash coal which occurs in abundance in the Damodar valley coal-fields.

(iii) *Non-Metallic Minerals* like sulphur, graphite, potash, fluorides. For these minerals India has at present to depend wholly or largely on foreign imports. Their production by chemical means, e. g., sulphur from gypsum and potash from waste mica, has yet to be attempted on industrial scale.

5. PLANNED PROGRAMME OF MINERAL DEVELOPMENT.

A planned programme of mineral developments somewhat on the above lines and in conformity with modern trends of world mineral economics may radically alter India's mineral position. The schedules of minerals given on page 65 hereof may undergo a complete change both as regards the minerals named and the financial returns shown against them. For instance, the production of alluminium from bauxite; aluminium, magnesium, titanium, beryllium-alloys, if carried out on a scale commensurate with the magnitude of these resources; production of ferro-manganese; titanium paints; processing of the high grade refractories kyanite, sillimanite, zircon; manufacture of industrial products from the rare minerals, are the big possibilities of the future. Production statistics then may come to bear no relation at all to the present meagre returns from these minerals.

Three main trends of mineral planning and national mineral policy must underly such a programme :—

(1) Domestic treatment and processing of raw minerals instead of their export.

(2) Maximum utilization of our resources in iron, aluminium, magnesium, titanium, thorium, beryllium, vanadium.

(3) Intensive programme of geophysical investigation.

In an assessment of the mineral wealth of India, must be included the reservoir of underground water and the noble rivers flowing from the snows of the Himalayas, and still more the soils covering the vast alluvial plain of the North. These form natural assets of the highest value in India and are in various ways ancillary to its mineral development. The 300,000 square miles of fertile soil of the Great Plains possess agricultural and underground water resources, the full potential of which is not yet realized. The water of the rivers fed by the Himalayas and Western Ghats are profoundly important low-cost sources of power and energy which can serve regions not supplied with coal.

6. MINERAL POLICY – THE ROLE OF THE CENTRE AND THE STATES.

The Government of India has been taking steps to establish adequate and efficient organization to implement a central policy for mines and minerals. A constructive mineral policy, however, is difficult to frame, much more to implement, so long as the regulation of mines and the subject of mineral utilization and development remain predominently in the hands of different States and Provincial Governments. Minerals are a rapidly depleting asset and the question of ensuring their maximum utility and minimum waste affects the country as a whole and should be a Central responsibility and not of individual, provincial or vested interests. It is important, therefore, that the respective roles of the Centre and the States in mines and mine products should be precisely indicated. While the States should undoubtedly have a right to the income from their own mineral deposits and be paid full compensation for any mineral properties taken over by the Federal Government for purposes of ensuring co-ordinated development in the national interests, the nation's interest in particular minerals when public interest so demands must be given paramount consideration. From this point of view, coal, petroleum, iron-ore, gold, mica, manganese, salt, ilmenite and such other minerals as uranium-ore and atomic minerals as may from time to time become of key or strategic importance, have to be brought under Central control. This Central control should imply at the same time effective measures for improvement in unsystematic and wasteful mining, a practice which still persists in our mica and coal mines, and introduction of mining research modern technique, adequate training of personnel for mineral industries, etc. With the transfer of strategic minerals to the Centre there will still be left a number of valuable metal-ores, industrial minerals, salts, ornamental and precious stones, etc., under the executive control of the States.