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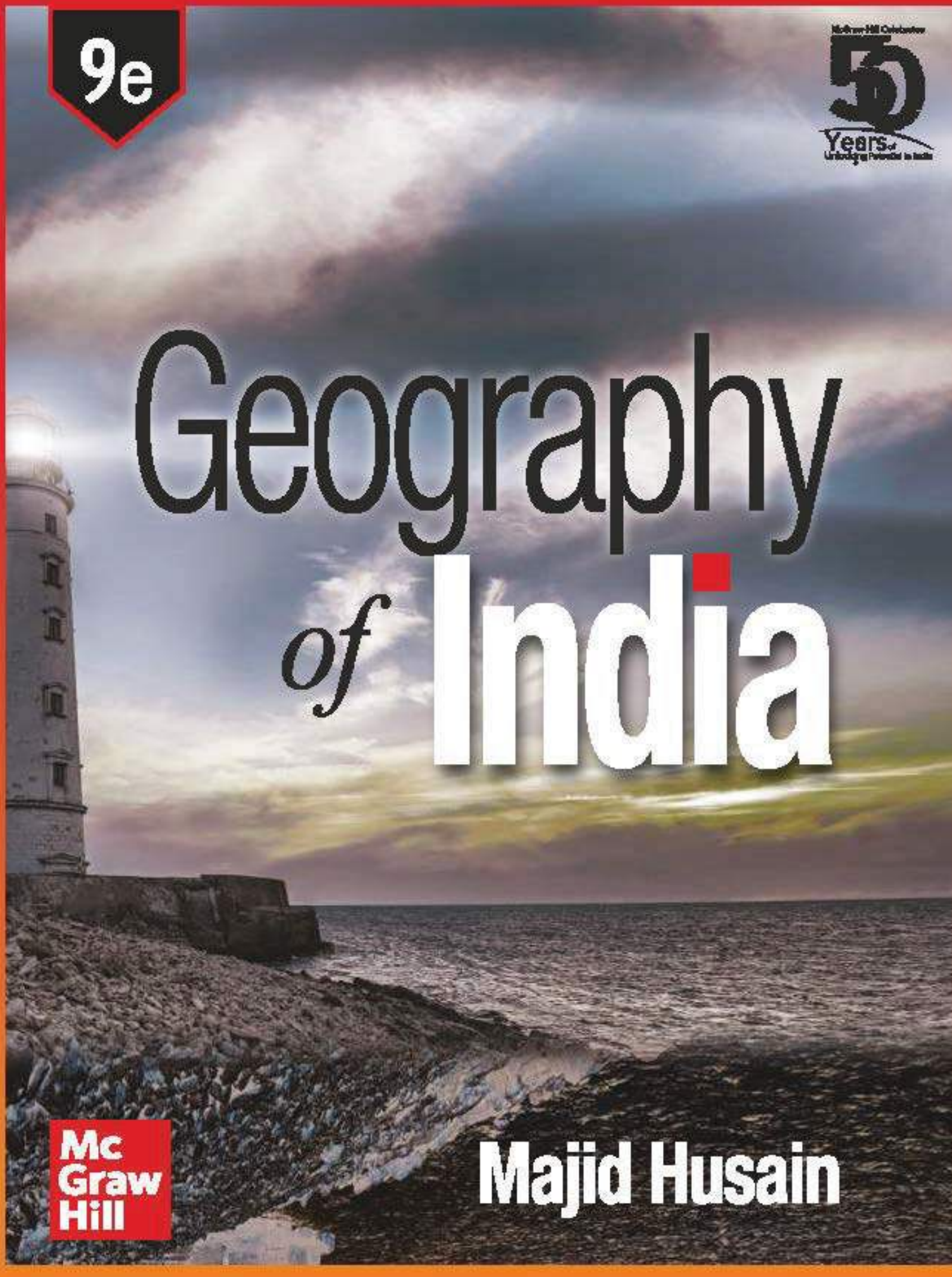

Geography of India

Majid Husain

Mc Graw Hill

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Geography *of* **India**

Majid Husain

About the Author

Born on July 2, 1938, in the village Banhera Tanda (Haridwar district) Prof. Majid Husain completed his early education from Nehru Inter College Manglaur. He had obtained his M.A. (Gold Medalist), LL.B. and Ph.D. from Swansea University, Aligarh, and pursued his higher education in Swansea (Wales) and School of Oriental and African Studies, London.

Prof. Husain had retired in 2003 as Professor and Head, Department of Geography, Jamia Millia Islamia, New Delhi. Having an excellent capability to simplify the difficult concepts in Geography in lucid and cogent style, he had authored and edited over four dozen of books. Majid Husain was an Indian Geographer of International fame, and was well known for his immense contribution to Geography through numerous publications, research works and teaching in many universities.

His unique teaching style helped students to assimilate even the most convoluted topics. He taught complete module of Geography for optional, Geography for Prelims, Environment and Ecology and mentored his students for personality test as well. Many students taught by him are working as IAS, IPS, IFS and in other elite services. His accolades were not just limited to research and teaching, he had numerous publications and useful books for UPSC and other competitive examinations to his credit.

Books written by him are also taught as textbook in University of Pennsylvania. Some of the bestselling books he has authored books

include Geography of India, World Geography, Fundamentals of Physical Geography, Geography : 3000 Terms and Concepts, Indian and World Geography, Environment and Ecology - Biodiversity, Climate Change and Disaster Management, Human Geography, Evolution of Geographical Thought, Population Geography (Perspectives in Human Geography), Models in Geography, Systematic Agricultural Geography, Bio-geography (Perspectives in Physical Geography).

The places he served include Jamia Milia Islamia, New Delhi; North East Hill University, Shillong; and University of Kashmir, Srinagar. In his 43 years long in-service experience he also served as Ex-President-Indian National Cartographic Association, Ex-Vice President-International Association of Landscape Ecology with two terms. Prof. Majid Husain was one of the most senior faculties of Geography in India, who had been honored with several awards and distinctions for his invaluable research in the field of Geography.

He was bestowed with “Man of the Year“ award by American Biographical Society, US-1997,

Delhi Govt. Award for the “Best Geography Teacher” in 1997 and “Bhugol Bhushan Award” in 2008 by Deccan Geographical Society India, “Shiksha Ratna Award” in 2011.

Prof. Majid Husain will always be remembered as an iconic academician of India.

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Majid Husain

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To
My students and grandchildren,
My hope for the future

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Preface to the Ninth Edition

Published first in 2008, the book Geography of India, written mainly for the candidates who prepare for competitive examinations and has become increasingly popular with each revised edition. In fact, it has become a must for the aspirants of the Indian Administrative Services and the National Education Test (NET). The book has achieved the status of the 'flag-ship' title of the McGraw-Hill as one of their best sellers. It covers all the prescribed topics of the IAS Geography optional paper II (Geography of India). It is equally helpful for the compulsory General Study Paper II (Geography of the World), and helps to solve the Geography and Ecology questions of the Preliminary Examination of the UPSC. Moreover, it also covers topics of the General Studies Paper IV like, resources of India, different types of irrigation, cropping patterns of India, transport, and public distribution system and food security. It is a text book for the Post-Graduate and Under-Graduate students in almost all the

universities in India and in many of the developing countries where Geography is taught through English medium.

The author received a number of constructive suggestions from the serious and committed students and teachers of Geography to revise the previous editions. It is in this background that the book has been thoroughly revised and updated in information and data.

The book is updated with latest change in status of Jammu & Kashmir and Ladhak. All updates are inserted in the form of Maps, Data and statistics. Updated current events, especially to mention the Amphan Cyclone, COVID- 19 situation in India along with NRC, CAA, Vizag gas leak, Indo-China Issues, Locust menace and much more forms a part of this edition. Varied topics covered are Resources of India, different types of irrigation, cropping patterns of India, transport and public distribution system and food security, disasters and Government initiatives.

The salient features of the revised edition are:

- Coverage on COVID-19, locust invasion, Vizag gas leak, Amphan cyclone and CAA & NRC
- Based on UPSC syllabus, strong in theoretical concepts, supplemented with original maps and diagrams
- Topic on geodiveristy, geotourism, fossil parks and geological heritage sites/national geological monuments
- Cratonisation and detailed heading on Indian deserts has been included
- Analysis on soil degradation in India along with the schemes and projects by the government to control land degradation and soil improvement have been included
- National New Mineral Policy 2019 and government policies in dairy enhancement added
- Governmental initiatives in renewable energy and oil industry, power sector, updates on crude oil production
- India–General land use updated, wastelands and degraded lands updated, agricultural policy, land reforms updated, government schemes in agriculture added, innovations in

agriculture, production share of various horticulture crops in India updated

- Governmental initiatives for textile development, National Steel Policy 2017, updates on fertilizer industry and drugs.
- Agreements and projects on roadways, ship recycling, aviation, traffic accidents
- Integrated Watershed Management Programme (IWMP) and updates on Metro extensions in Project Phase III
- Addition has been made on Urban Disasters, Social Media and Cyber crime
- More tables have been created and charts and pie charts provide an insight to the data

Dispute, Kolkata Kunming Corridor, the Pakistan-China Economic Corridor, and the New Silk Route - One Belt One Road (OBOR) have been incorporated in the present volume.

In addition to the above, the cartography of many of the maps have been improved and new maps have been added. The new maps in the present volume are: (i) the Panch Prayag (Five Confluences), Uttarakhand, (ii) the Kaveri Catchment Area, (iii) the Kolkata-Kunming Corridor, (iv) the China-Pakistan Economic Corridor, (v) the New Silk Route-One Belt One Road (OBOR).

Written in a simple and lucid style, it is hoped that the thorough revision of this book will be
of immense help to those interested in the subject and will also encourage them to search further
and learn more. Suggestions and constructive criticism are gratefully invited for further improvement of the book.

Majid Husain

Preface to the First Edition

Geography of India is a compulsory paper at the postgraduate and undergraduate levels of geography in all the Indian universities and autonomous colleges. In the geography optional paper of the civil services examination of the UPSC, it carries 50% weightage, equivalent to 300 marks. A sound performance followed by a high score in the General Studies Paper of the preliminary and main examinations is, therefore, significantly dependent on a clear understanding of the subject of geography, especially geography of India. In order to get high scores in the exam, a comprehensive book written in a simple and informative style supported by maps, figures, tables, etc., is a must. The book must also cover all topics and sub-topics of the syllabi prescribed as course structure by the UPSC and universities.

There are a number of books available on the subject of Indian geography by foreign authors and many Indian authors as well. While some of them contain data that is not up-to-date, others do not fully cover the syllabi of universities.

It is based on the above observations and my decades of teaching and research in geography that this book has been conceived. My goal is to provide the students of geography with a strong foundational book on Indian geography that would equip them to deal with any type of questions both in their graduate and postgraduate courses and also for the civil services examinations.

A unique feature of this book is that it has included all the topics and sub-topics prescribed by the UPSC in the new syllabus (Revised in December 2007) of Geography of India.

The following is the list of new topics as per the newly announced syllabus which has been adequately covered and documented in this book:

- Rainfall patterns.
- Forest and wildlife resources and their conservation.
- Land holdings, land tenure, and land reforms.
- Aqua-culture, sericulture, apiculture, and poultry.
- Agro-ecological regions, agrobased and aluminium industries, industrial houses and
  complexes including public sector undertakings, multinationals and liberalisation, Special Economic Zones, and Tourism including Eco-Tourism.
- Growing importance of ports on national and foreign trade, trade balance, trade policy, export processing zones.
- Indian Space Programme.
- Historical perspective of Indian Society, linguistic and ethnic diversities, religious minorities, cultural regions.
- Population problems and policies, Health Indicators, Urbanisation and remedies.
- Problems of Indian urbanisation and remedies.
- Regional Planning and Development of Island Territories.
- Cross-border terrorism, India’s role in world affairs, Geopolitics of South Asia.
- Tsunamis, Environmental awareness, Linkage of Rivers, Globalisation and Indian Economy.

Moreover there is inclusion of important entries on mountains, peaks, series, passes, rivers, lakes, national parks, tiger reserves, mining and industrial centres, places of tourist interest, and sea beaches on the map of India with a 40-word geographical write-up on each of the entries. This unique feature, I am sure would enable candidates in successfully attempting the compulsory question on the map of India in the UPSC examination.

Divided into seventeen chapters, and supported by neatly drawn maps and diagrams, the organisation of chapters and topics covered is as follows:

Chapters 1–6 discusses the physical personality of India while explaining the spatial aspect of physical elements and processes that make up the environment. This portion of the book also deals with the structure, physiography, landforms, climate, energy, natural vegetation, soils, energy, and biotic and abiotic resources of India.

Chapters 7–12 analyses the spatial distribution of agriculture and allied activities, agroclimatic and agro-ecological regions, industries, transport and communication and services and their impact on landscape.

The cultural milieu including the historical perspective of Indian Society, racial and ethnic diversity of India, major tribes, role of language, religion and traditions in the formation of cultural regions, the demographic attributes of Indian population, its problems and policies and health indicators have been examined in the thirteenth chapter.

The fourteenth chapter gives an evocative account of the rural and urban settlements while a discussion on planning and regional development constitutes the fifteenth chapter.

The spatial analysis of political aspects of India, including the geographical basis of Indian federalism, states reorganisation, regionalism, and national integration, boundary disputes, disputes on water sharing, cross border terrorism, India’s role in world affairs, Geopolitics of South Asia and Indian Ocean have been dealt with in chapter sixteen.

The last chapter presents a brief account of contemporary issues like environment hazards, earthquakes, tsunamis, landslides, population explosion and food security, epidemics, changes in land use, environmental impact assessment, environmental awareness, linkage of rivers, Globalisation and Indian economy and sustainable development.

It is hoped that the scholarly and comprehensive approach of the book will be of great help to the students and teachers alike and all those genuinely interested in knowing in detail about the geographical features and aspects of India.

Suggestions and comments for further improvement of the book are welcome and shall be gratefully considered.

—Majid Husain

Acknowledgements

My sincere thanks to all writers whose work I have referred in this book, and also to all those who have given permission for the reproduction of copyrighted material.

I am thankful to my teacher and supervisor, Prof. Mohammad Shafi, a doyen and a pioneer geographer in the field of land use studies, whose commitment to teaching and research inspired me constantly from my student days at the Aligarh Muslim University, Aligarh. I am indebted to Prof. S.M. Tahir Rizvi, Prof. S.M. Ali, Prof. Enayat Ahmad, Prof. Moonis Raza, Prof. Mohammad Anas, Prof. S.M. Rafiullah, Janab Mukhtar Ahmad sb., Prof. S. Manzoor Alam, Prof. C.D. Deshpande, Prof. G.S. Gosal, Prof. Fakhruddin Ahmad, Prof. Nasiruddin Ahmad, Prof. Niaz.A. Siddiqui, Prof. Mehdi Raza, Prof. A. Aziz Tonki, Prof. Z.U. Alvi, Prof. Qazi Mohd. Ahmad, Prof. Aijazuddin Ahmad, Prof. R.C. Sharma, Prof. M. Farooq Siddiqui, and Prof. K.Z. Amani, for their encouragement in my academic pursuits.

The plan of the book was conceived about thirty years back when I started teaching post-graduate classes at the North Eastern Hill University, Shillong in 1977. The writing of the manuscript was,

however, in pieces and patches. It was at the persuasion of Dr. Ramesh Singh, Director, Civils India, Delhi that the dream changed into reality. I am thankful to him and the staff members of Civils India, who assisted me in more than one way in the preparation and revision of this book.

I am indebted to McGraw-Hill especially Ms. Shukti Mukherjee (Senior Manager, Portfolio), Ms. Jyoti Nagpal (Product Developer), Ms. Shreya Soni (Content Developer) and Mr. Gagan Gusai (Project Manager, Production Services) for their dedication and commitment to produce the book meticulously a short period of time.

For her sufferings and forebearance, I thank my wife who remained a perennial source of strength. Thanks are due to my daughter Dr. Shagufta Bano Husain, my sons Javed Alam and Mansoor Majid, my son-in-law Abdul Rahman Mehdi Asad, my daughters-in-law Shahida Naz and Saifi Zaka, and my grand-children (Majid Abdul Rahman, Madeeha Javed, Jibraan Mansoor, Rashad Abdul Rahman, Fareeha Javed, Areeb Mansoor, Hiba Abdul Rahman and Uzair Alam) who provided a happy environment for writing of the book. May God bless them all.

Thanks are due to Dr. Krishnanand from Shaheed Bhagat Singh College, University of Delhi for providing valuable reviews that helped in further updating the book. Dr. Shehnaz, Dr. Haseena Hashia, Dr. Mary Tahir, Dr. Tasawwur, Mr Saini from Jamia Millia Islamia, also supported the author at all times during the revision of the book while he was ailing.

—Majid Husain

About the Civil Services Examination

The Civil Services examination comprises two successive stages:

(i) Civil Services (Preliminary) Examination (Objective Type) for the selection of candidates for Main Examination; and

(ii) Civil Services (Main) Examination (Written and Interview) for the selection of candidates for the various services and posts.

Scheme and subjects for the Preliminary and Main Examination.

A. Preliminary Examination

The Examination shall comprise two compulsory Papers of 200 marks each.

Note:

(i) Both the question papers will be of the objective type (multiple choice questions).

(ii) The question papers will be set both in Hindi and English. However, questions relating to English Language

Comprehension Skills of Class X level will be tested through passages from English language only without providing Hindi translation thereof in the question paper.

B. Main Examination

The written examination will consist of the following papers:

Qualifying Papers:

Paper A: (One of the Indian Language to be selected by the candidate from the Languages included in the Eighth Schedule to the Constitution). 300 Marks

Paper B: English

300 Marks

The papers on Indian Languages and English (Paper A and Paper B) will be of Matriculation or equivalent standard and will be of qualifying nature. The marks obtained in these papers will not be counted for ranking.

Papers to be counted for merit

Paper I: Essay	200 Marks
Paper II: General Studies–I (Indian Heritage and Culture, History and Geography of the World and Society)	200 Marks
Paper III: General Studies –II (Governance, Constitution, Polity, Social Justice and International Relations)	250 Marks
Paper IV: General Studies –III (Technology, Economic Development, Bio-diversity, Environment, Security and Disaster Management)	250 Marks
Paper V: General Studies –IV (Ethics, Integrity and Aptitude)	250 Marks
Paper VI: Optional Subject – Paper 1	250 Marks
Paper VII: Optional Subject – Paper 2	250 Marks
Sub Total (Written test):	1750 Marks
Personality Test:	275 Marks
Grand Total:	2025 Marks

Candidates may choose any one of the optional subjects from amongst the list of subjects given below:

List of optional subjects for Main Examination:

(i) Agriculture
(ii) Animal Husbandry and Veterinary Science
(iii) Anthropology
(iv) Botany
(v) Chemistry
(vi) Civil Engineering
(vii) Commerce and Accountancy
(viii) Economics
(ix) Electrical Engineering
(x) Geography
(xi) Geology
(xii) History
(xiii) Law
(xiv) Management
(xv) Mathematics
(xvi) Mechanical Engineering
(xvii) Medical Science
(xviii) Philosophy
(xix) Physics
(xx) Political Science and International Relations
(xxi) Psychology
(xxii) Public Administration
(xxiii) Sociology
(xxiv) Statistics
(xxv) Zoology
(xxvi) Literature of any one of the following

Assamese, Bengali, Bodo, Dogri, Gujarati, Hindi, Kannada, Kashmiri, Konkani, Maithili, Malayalam, Manipuri, Marathi, Nepali,

Oriya, Punjabi, Sanskrit, Santhali, Sindhi, Tamil, Telugu, Urdu and English.

Geography Syllabus for Main Examination

Paper-I
Principles of Geography
Physical Geography

(i) *Geomorphology:* Factors controlling landform development; endogenetic and exogenetic forces; Origin and evolution of the earth's crust; Fundamentals of geomagnetism; Physical conditions of the earth's interior; Geosynclines; Continental drift; Isostasy; Plate tectonics; Recent views on mountain building; Vulcanicity; Earthquakes and Tsunamis; Concepts of geomorphic cycles and Landscape development; Denudation chronology; Channel morphology; Erosion surfaces; Slope development ; Applied Geomorphology: Geohydrology, economic geology and environment

(ii) *Climatology:* Temperature and pressure belts of the world; Heat budget of the earth; Atmospheric circulation; atmospheric stability and instability. Planetary and local winds; Monsoons and jet streams; Air masses and fronto

genesis, Temperate and tropical cyclones; Types and distribution of precipitation; Weather and Climate; Koppen's, Thornthwaite's and Trewartha's classification of world climates; Hydrological cycle; Global climatic change and role and response of man in climatic changes, Applied climatology and Urban climate.

(iii) *Oceanography:* Bottom topography of the Atlantic, Indian and Pacific Oceans; Temperature and salinity of the oceans; Heat and salt budgets, Ocean deposits; Waves, currents and tides; Marine resources: biotic, mineral and energy resources; Coral reefs, coral bleaching; sealevel changes; law of the sea and marine pollution.

(iv) *Biogeography:* Genesis of soils; Classification and distribution of soils; Soil profile; Soil erosion, Degradation and conservation; Factors influencing world distribution of plants and animals; Problems of deforestation and conservation measures; Social forestry; agro-forestry; Wild life; Major gene pool centres.

(v) *Environmental Geography:* Principle of ecology; Human ecological adaptations; Influence of man on ecology and environment; Global and regional ecological changes and imbalances; Ecosystem their management and conservation; Environmental degradat ion, management and conservation; Biodiversity and sustainable development; Environmental policy; Environmental hazards and remedial measures; Environmental education and legislation.

Human Geography

(i) *Perspectives in Human Geography:* Areal differentiation; regional synthesis; Dichotomy and dualism; Environmentalism; Quantitative revolution and locational analysis; radical, behavioural, human and welfare approaches; Languages, religions and secularisation; Cultural regions of the world; Human development index.

(ii) *Economic Geography:* World economic development: measurement and problems; World resources and their

distribution; Energy crisis; the limits to growth; World agriculture: typology of agricultural regions; agricultural inputs and productivity; Food and nutrition problems; Food security; famine: causes, effects and remedies; World industries: locational patterns and problems; patterns of world trade.

(iii) *Population and Settlement Geography:* Growth and distribution of world population; demographic attributes; Causes and consequences of migration; concepts of over - under-and optimum population; Population theories, world population problems and policies, Social well-being and quality of life; Population as social capital. Types and patterns of rural settlements; Environmental issues in rural settlements; Hierarchy of urban settlements; Urban morphology: Concepts of primate city and rank-size rule; Functional classification of towns; Sphere of urban influence; Rural - urban fringe; Satellite towns; Problems and remedies of urbanization; Sustainable development of cities.

(iv) *Regional Planning:* Concept of a region; types of regions and methods of regionalisation; growth centres and growth poles; regional imbalances; environmental issues in regional planning; planning for sustainable development.

(v) *Models, Theories and Laws in Human Geography:* System analysis in Human Geography; Malthusian, Marxian and Demographic Transition models; Central Place theories of Christaller and Losch; Von Thunen's model of agricultural location; Weber's model of industrial location; Rostov's model of stages of growth. Heart-land and Rimland theories; laws of international boundaries and frontiers.

PART II

Geography of India

1. *Physical Setting:* Space relationship of India with neighboring countries; Structure and relief; Drainage system and watersheds; Physiographic regions; Mechanism of Indian monsoons and rainfall patterns, Tropical cyclones and western

distur - bances; Floods and droughts; Climatic regions; Natural vegetation; Soil types and their distributions.

2. *Resources:* Land, surface and ground water, energy, minerals, biotic and marine resources; Forest and wild life resources and their conservation; Energy crisis.
3. *Agriculture:* Infrastructure: irrigation, seeds, fertilizers, power; Institutional factors: land holdings, land tenure and land reforms; Cropping pattern, agricultural productivity, agricultural intensity, crop combination, land capability; Agro and socialforestry; Green revolution and its socioeconomic and ecological implications; Significance of dry farming; Livestock resources and white revolution; aqua - culture; sericulture, apiculture and poultry; agricultural regional isation; agro-climatic zones; agro-ecological regions.
4. *Industry:* Evolution of industries; Locational factors of cotton, jute, textile, iron and steel, aluminium, fertilizer, paper, chemical and pharmaceutical, automobile, cottage and agro-based industries; Industrial houses and complexes including public sector undertakings; Industrial regionalisation; New industrial policies; Multinationals and liberalization; Special Economic Zones; Tourism including eco-tourism.
5. *Transport, Communication and Trade:* Road, railway, waterway, airway and pipeline networks and their complementary roles in regional development; Growing importance of ports on national and foreign trade; Trade balance; Trade Policy; Export processing zones; Developments in communication and information technology and their impacts on economy and society; Indian space programme.
6. *Cultural Setting:* Historical Perspective of Indian Society; Racial, linguistic and ethnic diversities; religious minorities; major tribes, tribal areas and their problems; cultural regions; Growth, distribution and density of population; Demographic attributes:
   sex-ratio, age structure, literacy rate, work-force, dependency ratio, longevity; migration (inter-regional, intra-regional and

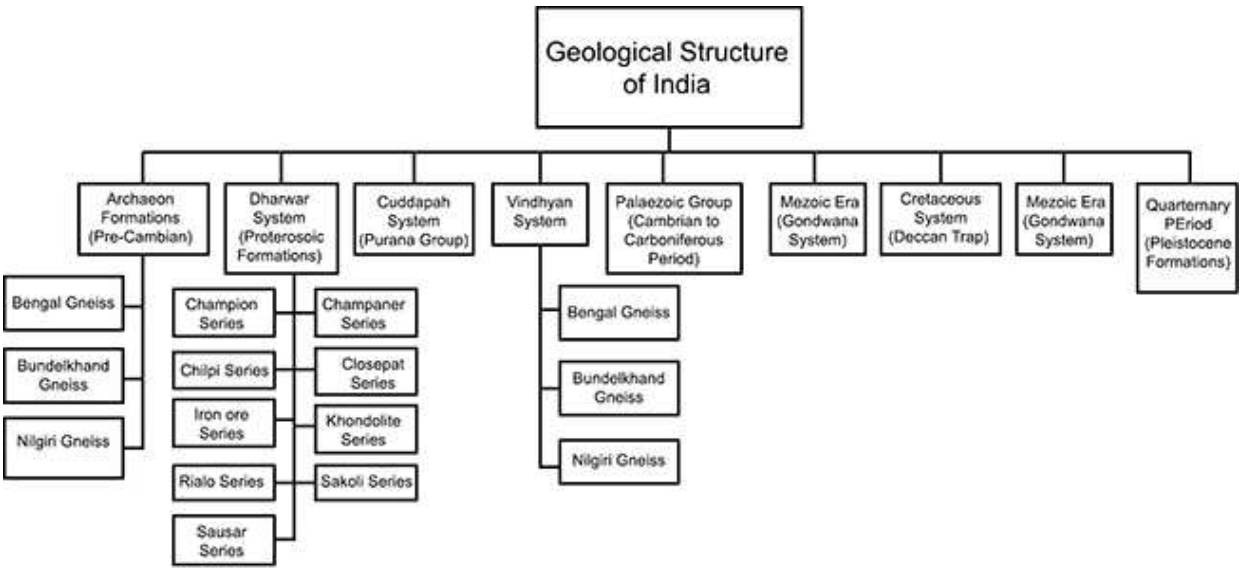
international) and associated problems; Population problems and policies; Health indicators.

7. *Settlements:* Types, patterns and morphology of rural settlements; Urban developments; Morphology of Indian cities; Functional cla ssification of Indian cities; Conurbations and metropolitan regions; urban sprawl; Slums and associated problems; town planning; Problems of urbanization and remedies.
8. *Regional Development and Planning:* Experience of regional planning in India; Five Year Plans; Integrated rural development programmes; Panchayati Raj and decentralised planning; Command area development; Watershed management; Planning for backward area,desert, drought prone, hill, tribal area development; multi-level planning; Regional planning and development of island territories.
9. *Political Aspects:* Geographical basis of Indian federalism; State reorganisation; Emergence of new states; Regional consciousness and inter state issues; international boundary of India and related issues; Cross border terrorism; India's role in world affairs; Geopolitics of South Asia and Indian Ocean realm.
10. *Contemporary Issues: Ecological issues:* Environmental hazards: landslides earth quakes, Tsunamis, floods and droughts, epidemics; Issues relating to environmental pollution; Changes in patterns of land use; Principles of environmental impact assessment and environmental management; Population explosion and food security; Environmental degradation; Deforestation, desertification and soil erosion; Problems of agrarian and industrial unrest; Regional disparities in economic development; Concept of sustainable growth and development; Environmental awareness; Linkage of rivers; Globalisation and Indian economy.

Note: Candidates will be required to answer one compulsory map question pertinent to subjects covered by this paper.

1

Geological Structure and formation of India



INTRODUCTION

The geological structure and formations of a region helps in understanding the types and character of rocks and slopes, the physical and chemical properties of soils, the availability of minerals, and the surface and underground water resources. All these resources have a direct impact on the socio-economic development of the people of a country, or region.

Geological Time Scale

The time scale is used by the earth scientists, geologists and researchers to date certain events of history on the earth.

The age of the earth as estimated by radiometric dating is approximately 4.6 billion years. Earth's past is split into sections based on the events that occurred during this time. The geologic time units are based on *stratigraphy* (correlation and classification of the rocks) and classified as *Eon* (Period greater than half a billion years); *Eras* (sub division of an Eon and they last for millions of years); *Periods* and *Epochs* **(Fig. 1.1)**

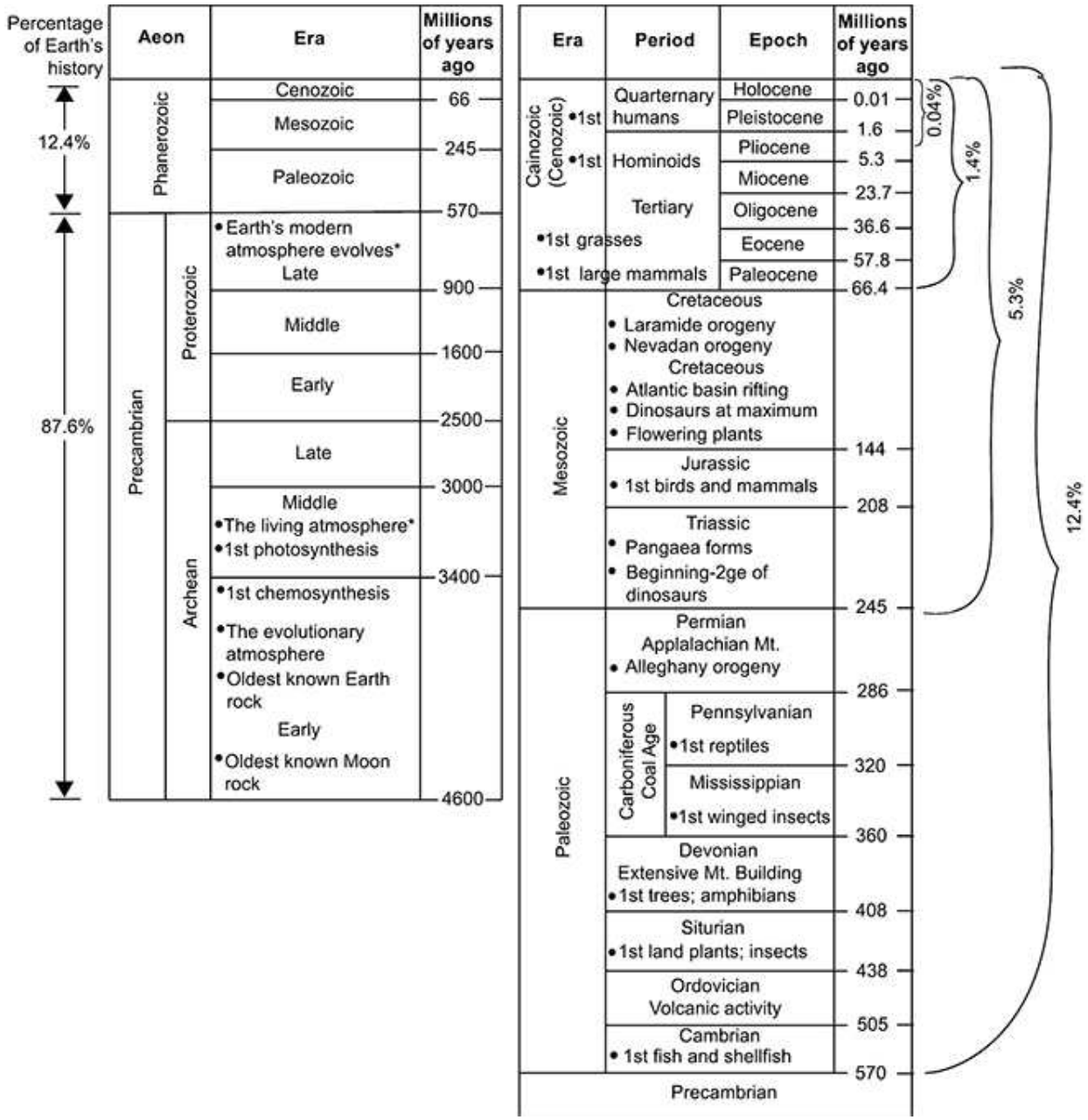


Fig. 1.1 The geological time scale is organised using absolute and relative dating methods. Absolute dates are determined through modern technological means, especially radioactive dating. In the column at left note that 87.6% of geologic time occured during the Precambrian. Data from 1983 Geologic Time Scale, Geological Society of America (after Robert W. Christopherson)

Geologically, about 200 million years ago the subcontinent of India was a part of the Gondwanaland (the Southern Continent). The geological history of India is unique, as Peninsular India was a part of the old landmass since the formation of the Earth's crust, which grew in complexity as a succession of Alpine-orogeny resulting in the upheaval of the Himalayas in the Tertiary Period and the aggradational formation of the Indo-Gangetic plain during the Pleistocene Period. The latter continues till today, through sedimentation in the flood plains of the rivers and the lower part of the Gangetic plain, namely the *Hugli basin*. The geological history of India is complex as well as varied. It begins with the first formation of the Earth's crust, first deposited sedimentary rocks, first orogeny, and extends up to the recent laying down of alluvial deposits. Many of these rock formations occur in superimposed positions and have been subjected to intense folding and faulting. The geological structure of India has been described briefly in the following sections**.**

THE ARCHAEAN FORMATIONS (PRE-CAMBRIAN)

The Archaean Era is also known as the Precambrian Period. This is the division of geologic time scale from the formation of the Earth (about 4.6 billion years ago) to the beginning of the Cambrian Period of the Paleozoic Era (about 570 million years ago).

The Precambrian time constitutes about 86.7% of the Earth's history**.** The term "Archaean", introduced by J.D. Dana in 1782, refers to the oldest plutonic rocks of the Earth's crust. The oldest known rocks of the Earth, the evolutionary atmosphere, the first chemosynthesis, the first photosynthesis, the life-supporting atmosphere and the Earth's modern atmosphere, were developed during the Precambrian Era (Archaean and Protozoic). Rocks of the Archaean system are devoid of any form of life. In other words, the Archaean rocks are all azoic or unfossiliferous. They are thoroughly crystalline, extremely contorted, faulted, and practically devoid of any sediment. They are largely intruded by plutonic intrusions and generally have a well-defined foliated structure. These rocks are

known as the basement complex **or** fundamental gneisses. Thus, all over the world, the Archaean rocks are the foundation of all the great ancient plateaus, and they form the core of all the great folded mountain ranges of the world.

In the Indian Geological Time Scale, advocated by T.S. Holland, the Precambrian Era is known as the *Purana*. The Archean system includes the Aravalli, Dharwar, Cuddapah, Vindhyan, Meghalaya Plateau, and Mikir Hills. These are also called the Archean gneiss. The mineral composition of Archaen gneiss varies from granite to gabbro. The constituent minerals are: orthoclase, oligoclase, quartz, muscovite, biotite, and hornblends. The Archaen rocks cover two-thirds of Peninsular India. They also occur in the roots of the mountain peaks all along the Greater Himalayas from the western most part of Kashmir to the eastern-most part of Arunachal Pradesh as well as in the Trans-Himalayan ranges of Zaskar (Zanskar), Ladakh, and the Karakoram **(Fig. 1.2 and Fig. 1.3).**

The Archaean rocks cover two-thirds of Peninsular India. In the Peninsular region, the Archaean rocks are known to be of three well-defined types:

(i) The Bengal Gneiss

- *The Bengal gneiss* is highly foliated, which is distributed in the Eastern Ghats, Odisha (known as Khodolites after Khond tribes in Koraput and Bolangir districts), stretching over Manbhum and Hazaribagh districts of Jharkhand, Nellore district of Andhra Pradesh, and Salem district of Tamil Nadu.
- They also occur in the Son Valley, Meghalaya Plateau and Mikir Hills.These formations are very thinly foliated. These rocks were identified for the first time in the Midnapur district of West Bengal.

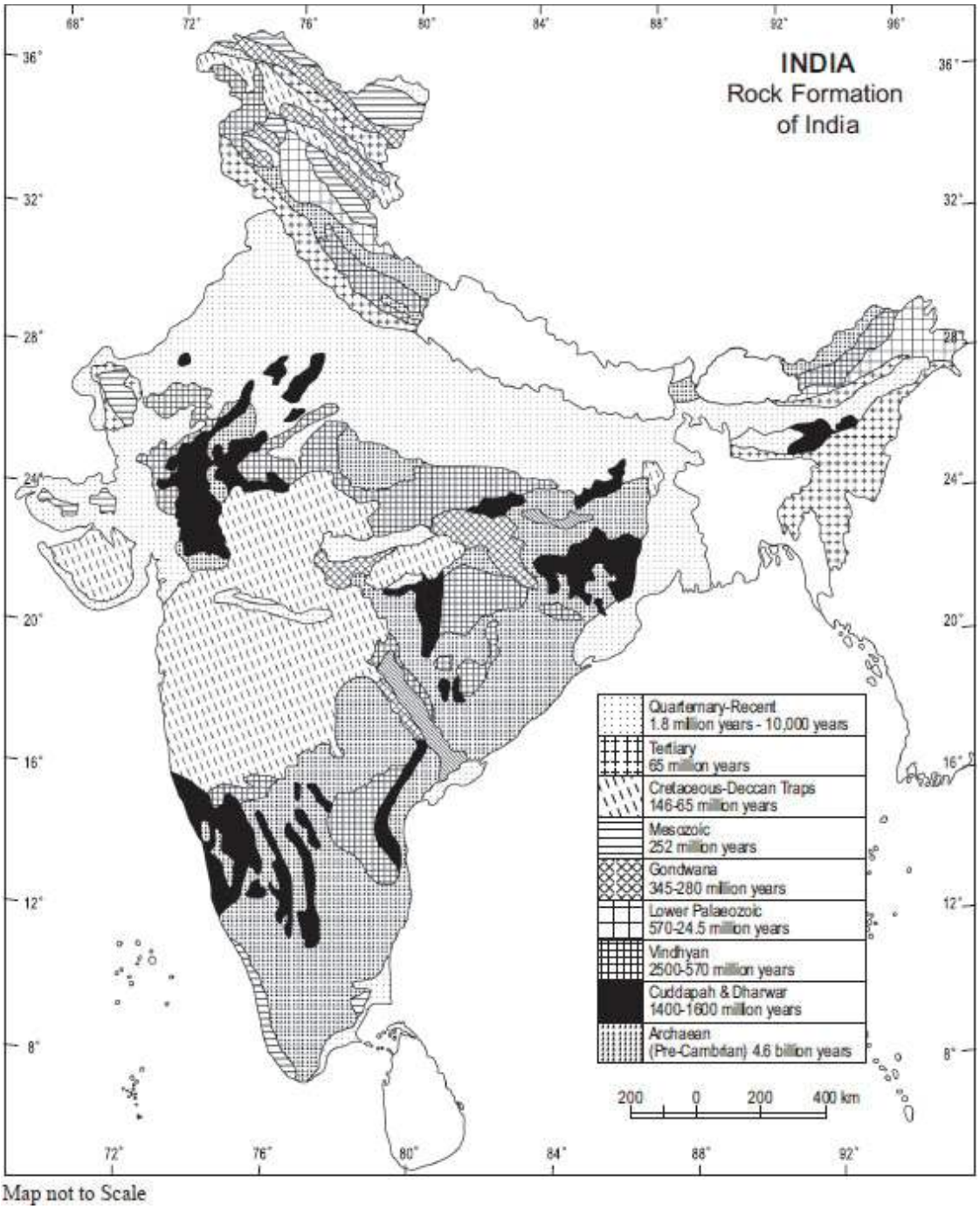


Fig. 1.2 Geological Systems

(ii) The Bundelkhand Gneiss

- *The Bundelkhand* gneiss are massive granitoid which form the second group of fundamental gneiss of the Archaean age.
- It is geographically distributed in Bundelkhand (UP),

Baghelkhand (MP), Maharashtra, Rajasthan, Andhra Pradesh, and Tamil Nadu.

- It is a coarse grained gneiss which looks like granite.
- The Bundelkhand gneiss is conspicuously criss-crossed and characterised by quartz veins.

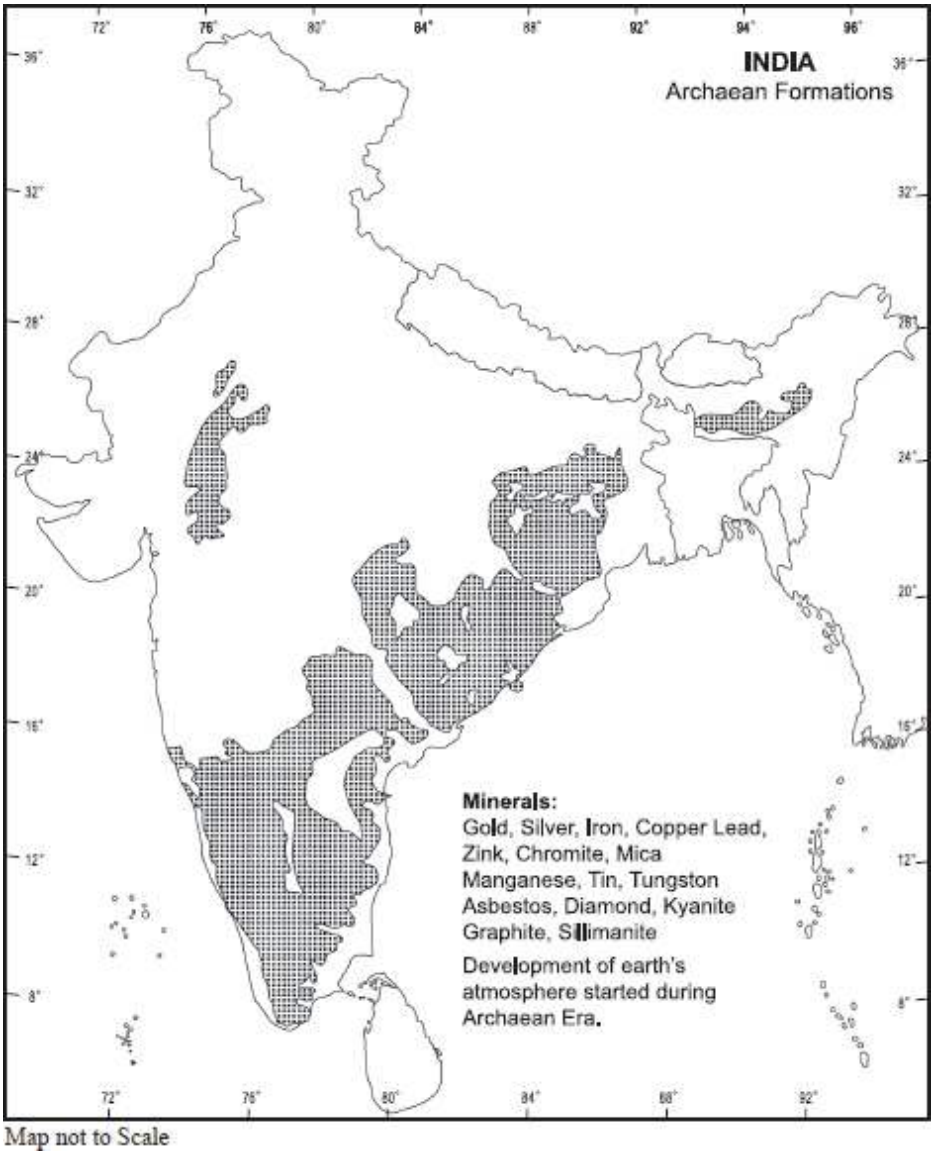


Fig. 1.3 Archaean Formations (Pre–2500 Million Years)

(iii) The Nilgiri Gneiss

- These are massive, eruptive dark-coloured gneiss. The name

being given in honour of *Job Charnock* whose tombstone in Kolkata was made of this rock.

- The Nilgiri gneiss is bluish-grey to dark coloured rock, medium to coarse grained in texture.
- This is plutonic gneiss intrudes into the other Archaean rock masses.
- Nilgiri gneiss is popularly recognised as belonging to the Charnockite series.
- It is widely found in South Arcot, Palni Hills, Shevaroy Hills and Nilgiri in Tamil Nadu, Nellore in Andhra Pradesh, Balasore in Odisha, Karnataka, Kerala, Malabar, Jharkhand, Chhattisgarh and Aravallis (Rajasthan).
- The Archaean rocks are the repositories of the mineral wealth of India. These rocks are rich in ferrous and non-ferrous minerals like iron ore, copper, manganese, mica, dolomite, lead, zinc, silver and gold.

DHARWAR SYSTEM (PROTEROZOIC FORMATIONS)

This geologic time extends from 2500 million years ago to 1800 million years ago**.** These are the first metamorphosed sedimentary rock systems known as the Dharwar System in the Indian Geological Time Scale, as they were studied for the first time in the Dharwar district of Karnataka. They are composed largely of igneous debris, schists and gneisses. The Dharwar rocks occur in scattered patches in (i) Dharwar and Bellary districts of Karnataka and extend up to the Nilgiris and Madurai districts of Tamil Nadu, (ii) Central and eastern parts of the Chotanagpur Plateau, Meghalaya Plateau and Mikir Hills, and (iii) the Aravallis, Rialo (Delhi series), from Delhi to the south of Alwar and the Himalayan region **(Fig. 1.4).**

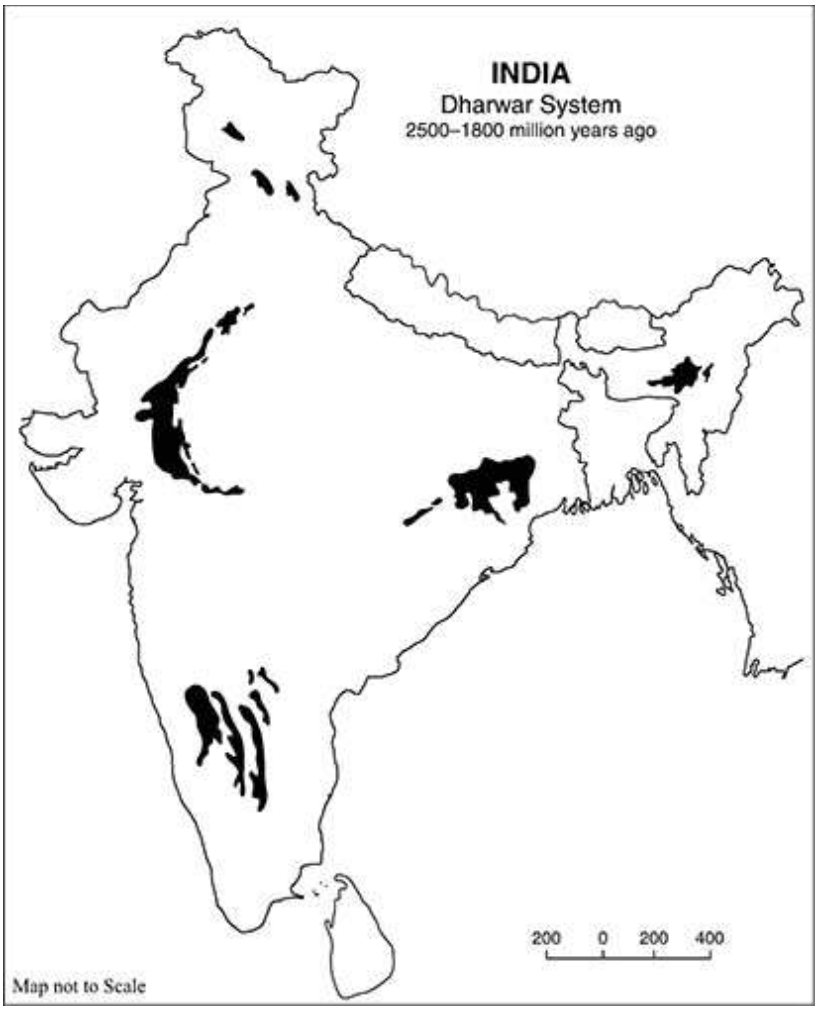


Fig. 1.4 Dharwar System (2500–1800 million years ago)

The Dharwar rocks are rich in minerals like iron ore, manganese, lead, zinc, gold, silver, dolomite, mica, copper, tungsten, nickel, precious stones and building materials.

Some of the important series of the Dharwar System are:

Name of the series of Dharwar System	Distribution in India	Significant features

Name of the series of Dharwar System	Distribution in India	Significant features
Champion Series	• North east of Mysore city to the east of Bangalore • It stretches in Kolar and Raichur districts of Karnataka	• One of the deepest gold mines in the world • Depth more than 3.5 km • Gold content is 5.5 per tonne of the ore • Headquarters of National Institute of Miner's Health is located here
Champaner Series	Lies in the outlier of Aravalli system in the vicinity of Vadodara	• Quartzites, conglomerates, phyllites, slates, limestones and marbles • Popular for green variety of marble
Chilpi Series	Occupies parts of Balaghat, Jabalpur and Chhindwara districts of Madhya Pradesh	• Minerals found: grit, phyllite, quartzites, green stones, magniferous rocks

Name of the series of Dharwar System	Distribution in India	Significant features
Closepet Series	Distributed in Balaghat and Chhindwara districts of Madhya Pradesh	• It is a Dharwarian formation • Minerals found: quartzite, copper pyrite, magniferous rocks • Ore supplied to the Malanjkhand Copper plant
Iron Ore Series	Distributed in Singhbhum, Bonai, Mayurbhanj, Keonjhar in the form of a range	• It is about 65 km in lengthIt has reserves of about 3000 million tonnes of iron ore • Iron ore is supplied to Jamshedpur, Durgapur, Rourkela and Bokaro Steel plants
Khondolite Series	Occupies large area in Eastern Ghats from the Northern extremity to Krishna Valley	• Principal rock types: khondolites, kodurites, charnockites, gneisses

Name of the series of Dharwar System	Distribution in India	Significant features
Rialo Series (Delhi Series)	Extends from Delhi (*Majnu Ka Tila*) to Alwar (Rajasthan in Northeast to Southwest direction)	• Rich in limestone and Makrana marbles • Makrana and Bhagwanpur are known for their high quality of marbles
Sakoli Series	Stretches over Jabalpur and Rewa districts	• Series belongs to the Dharwarian formation • Rich in mica, dolomite, schist and marble • (*Superiormost quality*)
Sausar Series	Series spreads over Nagpur and Bhandara districts of Maharashtra and Chhindwara district of Madhya Pradesh	It belongs to Dharwarian GroupMinerals found: mica schist, quartzite, marble and magniferous rocks

THE CUDDAPAH SYSTEM (THE PURANA GROUP)

The Cuddapah system is made of shales, slates, limestone and quartzite. The rocks are generally without fossils because there was no origin of species during their formation. The Cuddapah formations, named after the district of Cuddapah in Andhra Pradesh, are sedimentary-metamorphic formations. The Cuddapah system occurs in the (i) Cuddapah and Kurnool districts of Andhra Pradesh, (ii) Chhattisgarh, (iii) Rajasthan-Delhi to the south of Alwar, and (iv) the Lesser Himalayas in the extra-Peninsular region **(Fig. 1.5).**

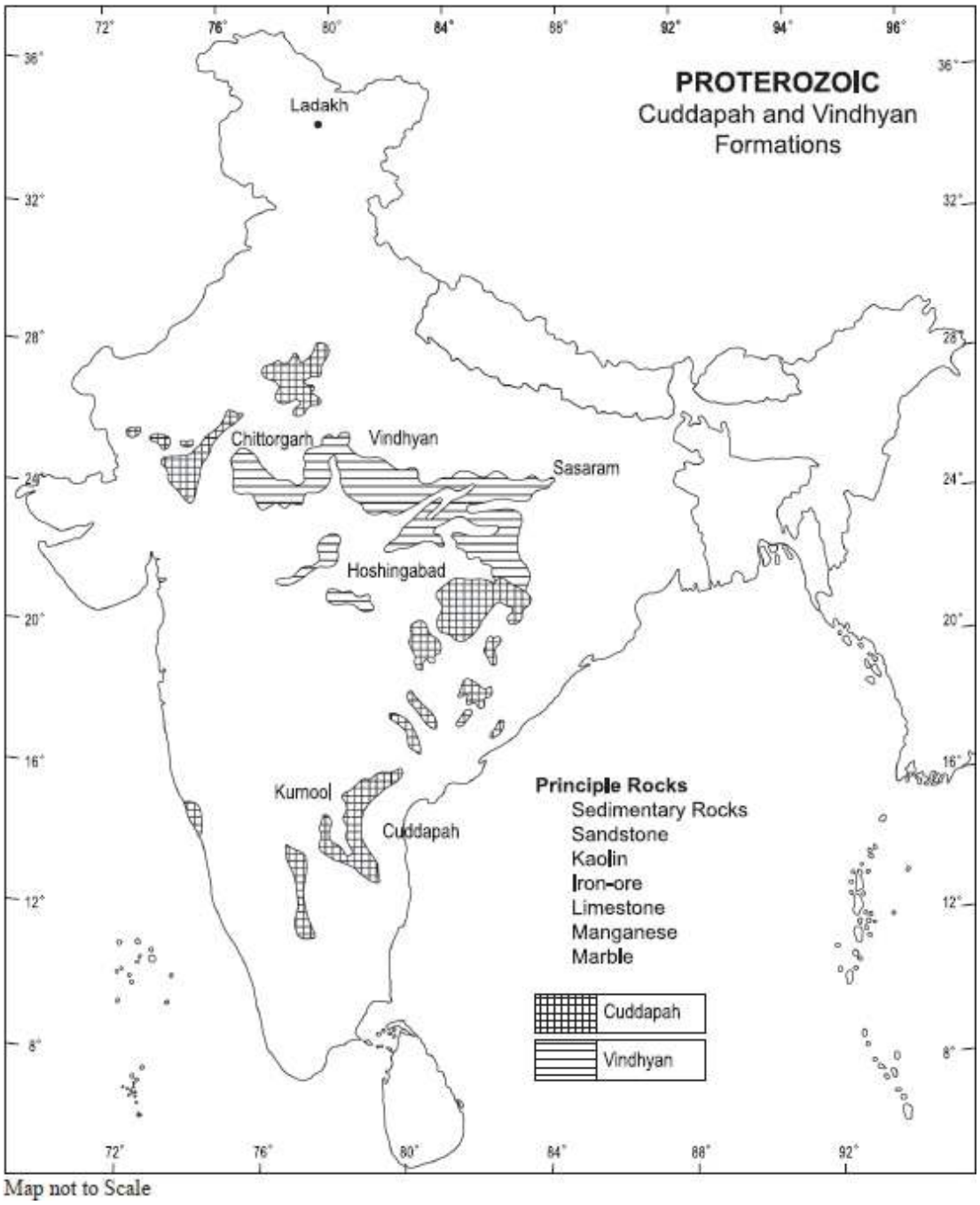


Fig. 1.5 Proterozoic Formations (2500–570 Million years ago)

At places the Cuddapah formations are 6,000 m in thickness. The enormous thickness of these rocks indicates the sinking of beds of the basin with growing sedimentation.

THE VINDHYAN SYSTEM

The Vindhyan system derives its name from the Vindhyan Mountain. This mountain forms a dividing line between the Ganga Plain and the Deccan Plateau. The system covers an extensive area of 103,600 sq km from Chittorgarh in Rajasthan to Sasaram in Bihar. It has enormous sedimentary deposits and at places their depth is more than 4000 m. In some tracts, the Vindhyan rocks are buried under Deccan lava. The Great Boundary Fault (GBF) separates the Vindhyan System from the Aravallis for a distance of about eight hundred km **(Fig. 1.5).**

The Vindhyan system is well known for red-sandstone, sandstone, building material, ornamental stone, conglomerates, diamondiferous and raw materials for cement, lime, glass and chemical industries. In certain places these rocks yield inferior quality of iron ore and manganese. The well known diamond mines of Panna and Golconda lie in the Vindhyan system. The historical buildings of Qutab Minar, Humayun's Tomb, Fatehpur Sikri, Agra Fort, Red Fort, Jama-Masjid, Birla Mandir, the Buddhist Stupa of Sanchi, etc., have been constructed from the red sandstone obtained from the Vindhyan Ranges. Coarser sandstones have been used as grindstones and millstones.

Name of the series of Vindhyan System	Distribution in India	Significant features
Bhander Series	Western parts of Vindhyan formation	• Main Rocks: Sandstones, shales, limestone • It provides good building material

Name of the series of Vindhyan System	Distribution in India	Significant features
Bijwar Series	Stretches over districts of Chhatarpur and Panna in Madhya Pradesh	• Main Rocks: Sandstone, red sandstone, quartzite • Basaltic intrusions found whose dykes are rich in diamonds
Kaimur Series	Stretches over Bundelkhand (UP), Baghelkhand (MP)	• Main Rocks: sandstone, conglomerate, shale • Red sandstone is used was used in historical monuments like Red fort, Hawa Mahal, Qutub Minar, Humayun's Tomb

The principle rocks of the Cuddapah system are sandstones, shales, limestone, quartzites slates, inferior quality of iron-ore, manganese ore, asbestos, copper, nickel, cobalt (Delhi System), marble, jasper, building material and stones for interior decoration. The metallic contents in the ores of Cuddapah rocks are, however, low and at places uneconomical for extraction.

Papaghani Series

The series has been named after the Papaghani river (Andhra Pradesh), in the valley of which these rocks have been exposed. It consists of quartzites, sandstones, shales, slates, limestones and marbles. The series is intruded by magma in the form of dykes and sills which have metamorphosed limestone into marble, talc, slate, and serpentine.

THE PALAEOZOIC GROUP (CAMBRIAN TO CARBONIFEROUS PERIOD)

The Palaeozoic Era includes the Ordovician, Silurian, Devonian, Carboniferous, and the Permian periods of the Standard Geological Time Scale. This is known as the *Dravidian Era* in the Indian Geological Time Scale.

The Palaeozoic Era extends from 570 million years ago to 24.5 million years ago. It marks the beginning of life on the Earth's surface. The formations of this period are almost absent in the Peninsular India except near Umaria in Rewa. These formations exist in the Salt Range, Pir-Panjal, Handwara, Lidder-Valley, Anantnag of Kashmir (Jammu & Kashmir), Spiti, Kangra, Shimla region (Himachal Pradesh), and Garhwal and Kumaun (Uttarakhand). It was during this period that the Pangaea was broken and the Tethys Sea came into existence. The Cambrian rocks include shales, sandstones, clays, quartzites slates, salts, marble, etc.

Palaeozoic System in the Indian Geologic Time Scale

The Gondwana formations are fluviatile and lacustrine in character. They were deposited in the river basins and lakes during the Upper Carboniferous Period. These basins later subsided along the trough faults amidst ancient rocks of the great southern continent called the Gondwanaland. These rocks were formed during the Upper Carboniferous and the Jurassic Periods (Mesozoic Era)**.**

THE MESOZOIC ERA (THE GONDWANA SYSTEM)

"Mesozoic" means middle life. The term is used for a period of geologic time in which the presence of fossil invertebrates dominated the rocks. The Mesozoic Era includes three periods: Triassic, Jurassic, and Cretaceous. In the Indian Geological Time Scale, these periods extend from the Upper Carboniferous up to the beginning of the Cenozoic Era or the *Aryan Era*.

The term 'Gondwana' was covred by H. B. Medicott in 1872. It was derived from the ancient tribe of Gonds that inhabits central provinces

of Madhya Pradesh.

The Gondwana group begins with the Permo-Carboniferous period which, in the Standard Geologic Time Scale, is known as a period of coal formation **(Fig. 1.6).** The Lower Gondwana rocks are found in the Talcher, Panchet and Damuda series. Most of the good quality coal deposits (bituminous and anthracite) of India are found in Gondwana formations. Moreover, iron ore occurs in the iron-stone shales of Raniganj coal fields. In addition to coal and iron, kaolin, fire-clay, sandstone and grits are also found in the Gondwana formations.

Talcher Series

It is the series of the Gondwana system named after Talcher in Dhankenal district of Odisha. It is rich in good quality coal used for smelting and in thermal power plants.

Talcher coalfield has the highest coal reserves in India of 38.65 billion tonnes. This coalfield is divided into five production areas namely Talcher, Jagannath, Kalinga, Lingaraj and Hingula.

The industries in Talcher are located along the river Brahmani which flows from north west to south east.

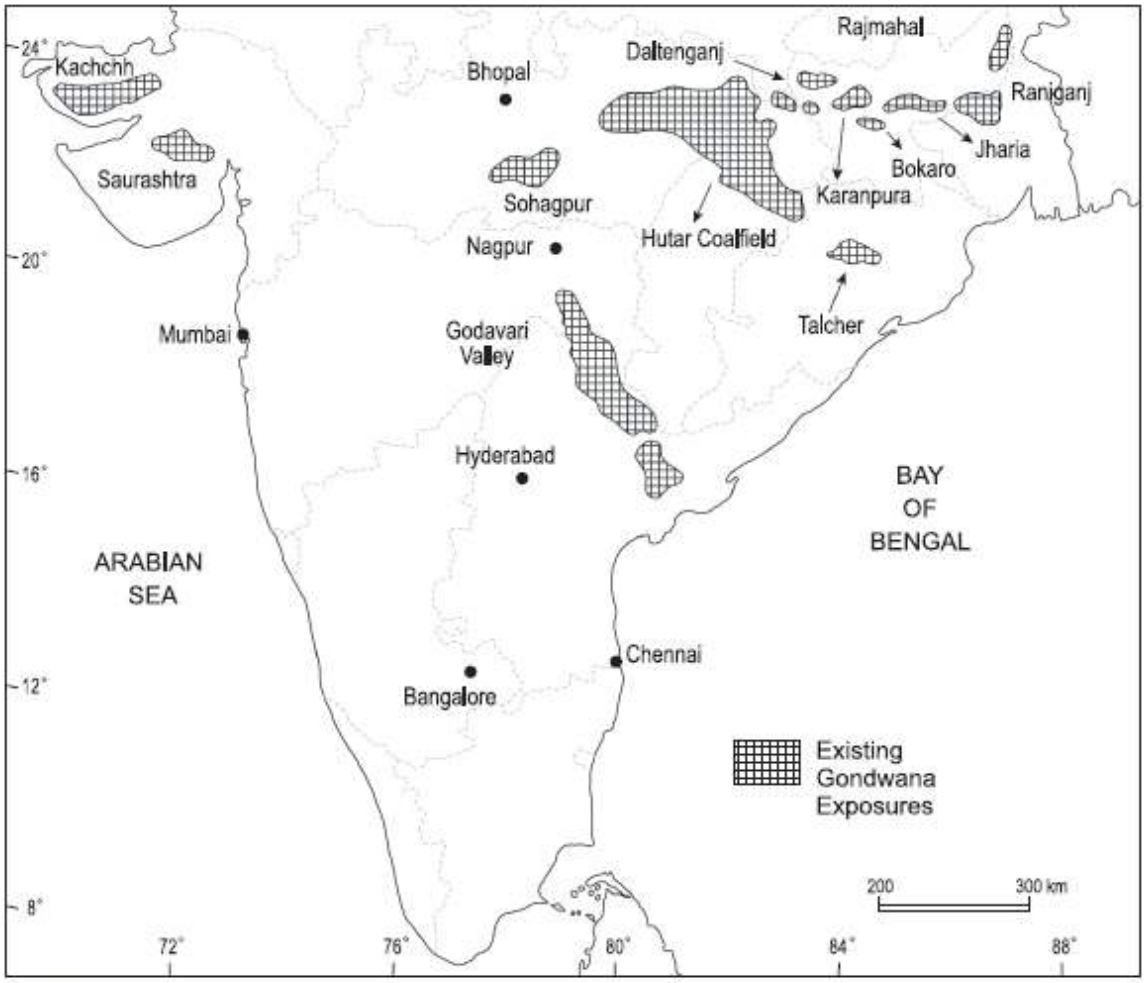


Fig. 1.6 Gondwana System (345–280 million years before present)

The Damuda Series

The Damuda series belongs to the Middle Gondwana Period which contains enormous deposits of coal seams.The coal seams are thicker and more elongated in the eastern coal fields than in the west. The important coal bearing areas of this period are Raniganj, Jharaia, Karanpura, and Bokaro of the Damodar basin, Singrauli, Korba, and Pench valley in Chhattigarh and Madhya Pradesh, Talcher in Mahanadi Basin in Odisha, and Singareni of Satpura Basin in Madhya Pradesh. The *Jhingurda Coal Seam* with a thickness of about 131 m is the thickest coal seam in India. The Gondwana rocks are also found in Himalayas from Kashmir to Arunachal Pradesh and

Poorvanchal. The coal seams of these areas are metamorphosed. They are also found in Saurashtra, Kachchh, western Rajasthan, Coromandal Coast, and Rajmahal Hills **(Fig. 1.6).**

Panchet Series

It is the youngest series of the Lower Gondwana System, which derives its name from the hill of that name, south of Raniganj. The series consists of greenish-sandstone and shales. It is, however, devoid of coal-seams.

The iron-ore shales of the Lower Gondwana System are particularly well developed in the Raniganj coalfield of West Bengal. However, they contain inferior quality iron ore, i.e., siderite and limonite. Being inferior in quality, they are generally not mined for iron. The Gondwana System of rocks provides over 95% of the coal of India. Moreover, it provides iron-ore, limestone, sandstone, and raw material for ceramic industry.

India's best and largest coal deposits are found in the Gondwana System—mainly in the Damodar Valley of West Bengal, Jharkhand, the Mahanadi valley of Odisha and Chhattisgarh, the Godavari valley of Andhra Pradesh, and the Satpura basin of Madhya Pradesh **(Fig. 1.6).**

As stated above, the beginning of the Upper Carboniferous Period is known as the Aryan period. The salient features of the Aryan formations are:

(i) During the Upper Carboniferous Period, the Himalayan region was occupied by a vast geosyncline which was connected to the Pacific Ocean in the east through China and the Atlantic Ocean in the west through Afghanistan, Iran, Asia Minor, and the present Mediterranean Sea. This was called the *Tethys Sea*.

(ii) The area of the Kashmir Himalayas (from Pir Panjal to Hazara in the north-west and Ladakh in the north-east) witnessed violent volcanic activity.

(iii) The upper continent of Gondwanaland developed fissures and its broken parts started drifting away from each other.

The Subcontinent of India drifted towards north and north-east to collide with the Asian land mass (Eurasian Plate).

(iv) There was large scale eruption of lava in the Deccan Trap.

(v) The development and expansion of the Arabian Sea and the Bay of Bengal.

(vi) The Tertiary mountain building gave birth to Himalayas.

(vii) The Subcontinent of India assumed its present shape.

(viii) The beginning of Ice Age, belonging to the Pleistocene Period, covering large parts of the earth under ice-sheet.

(ix) Evolution and spread of man in different parts of the world.

THE CRETACEOUS SYSTEM (THE DECCAN TRAP)

The Cretaceous Period extends from about 146 million years ago to 65 million years ago. The term “Cretaceous” has been obtained from the Latin *creta*, meaning “chalk”. This is a very widely distributed system in the country which has divergent facies of deposits in different parts of India. This period is marked by the transgression of the sea (Coromandal coast, Narmada valley) and outpouring of huge quantity of lava (basalt) so as to form the Deccan Trap and intrusion of plutonic rocks such as gabbro and granite.

Towards the end of the Cretaceous period the Peninsula was affected by intense volcanic activity. During this period, enormous quantity of basaltic lava was poured out to the surface assuming a great thickness of over 3,000 m. The Lava Plateau (the Deccan Trap) is the result of that lava eruption. The Deccan lava covers about 5 lakh sq km of area in Gujarat (Katch, Kathiawad), Maharashtra, Madhya Pradesh (Malwa Plateau), Chhattisgarh, Jharkhand, northern Andhra Pradesh and north-western Karnataka **(Fig. 1.7).**

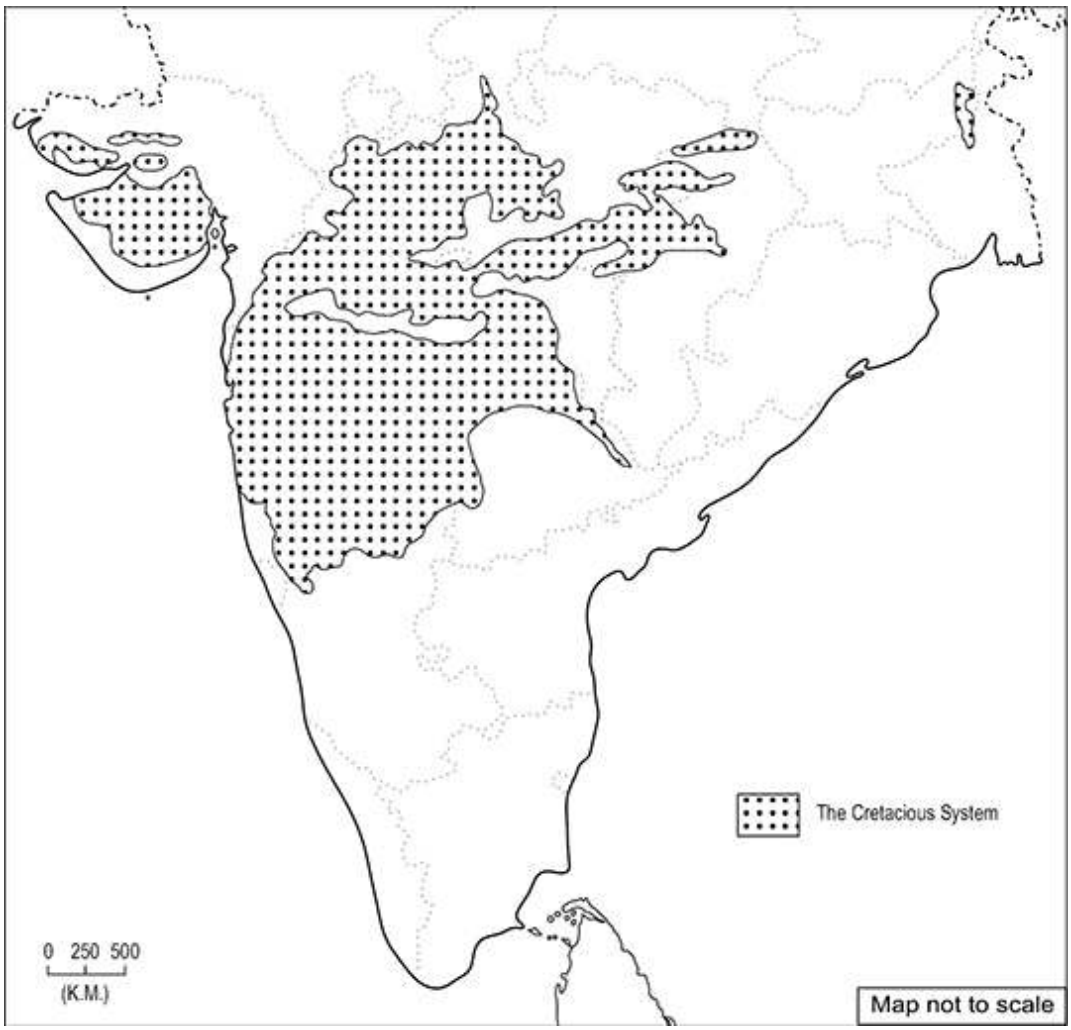


Fig. 1.7 The Cretaceous System (The Deccan Trap)—146–65 million years ago

The lava plateau of India (Deccan Trap) has a maximum thickness of about 3000 m along the coast of Mumbai from where it decreases towards south and east. It is about 800 m in Kachchh, 150 m at Amarkantak and 60 m at Belgaum (Karnataka). The individual lava flows, on an average, have a thickness of about 5 m to 29 m. Such flows have been identified in a boring near Bhusawal (Maharashtra). These are inter-bedded with sedimentary beds called “inter-trappean beds”.

The basalt of the Deccan Trap is used for the construction of roads and buildings. Moreover, quartz, bauxite, magnetite, agate, and semi-

precious stones are also found in the trap. It is also rich in magnesium, carbonate, potash, and phosphates.

THE TERTIARY SYSTEM (THE CENOZOIC ERA)

Cenozoic means recent life. The beginning of the Tertiary Period is about 66 million to 2.6 million years ago. Fossils in these rocks include many types, closely related to modern forms, including mammals, plants and invertebrates. The Cenozoic Era has two periods: The Tertiary and the Quaternary. The term ‘tertiary’ was used by Giovanni Arduino during the mid eighteenth century.

The two great events that occurred during the Tertiary Period include: (i) the final beaking-up of the old Gondwana continent, and (ii) the uplift of the Tethys geosyncline in the form of the Himalayas. During the early Tertiary Period, as the Indian plate collided with Eurasian plate, the sediments which had been accumulating in the Tethys basin had begun to rise by a slow rise of ocean bottom. The upheaval of the Himalayas altered the old topography of the subcontinent **(Fig. 1.8, 1.9).**

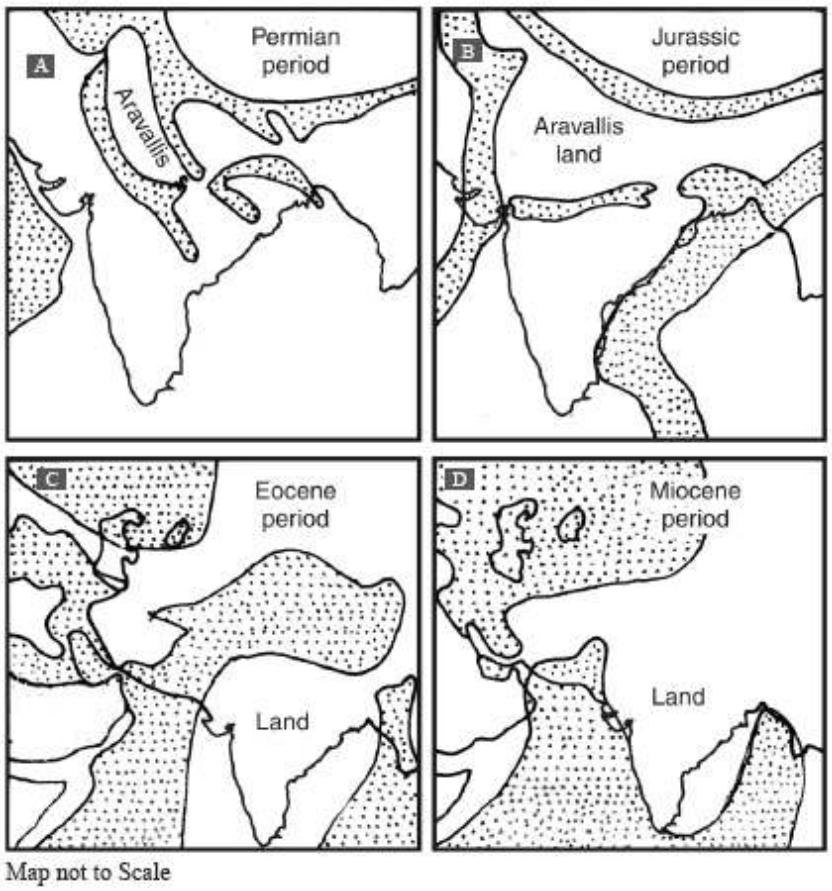


Fig. 1.8 Change in Topography of Subcontinent

Three phases of the upheaval of the Himalayas have been distinguished:

(i) During the first upheaval (Eocene—about 65 million years ago), which culminated in the Oligocene, and resulted in the upheaval of the Greater Himalayas.

(ii) It was followed by a more intense movement during the mid-Miocene period about 45 million years ago, which resulted in the folding of Lesser Himalayas.

(iii) The third upheaval took place during the Post-Pliocene period, about 1.4 million years ago which resulted in the folding of Shiwaliks or the Outer Himalayas**.** There is enough evidence to prove that the Himalayas are still rising**.**

In the Peninsular region, the Tertiary System occurred on the coast of Kachchh, Kathiawar, Konkan, Malabar, Nilgiris, and the Eastern Ghats.

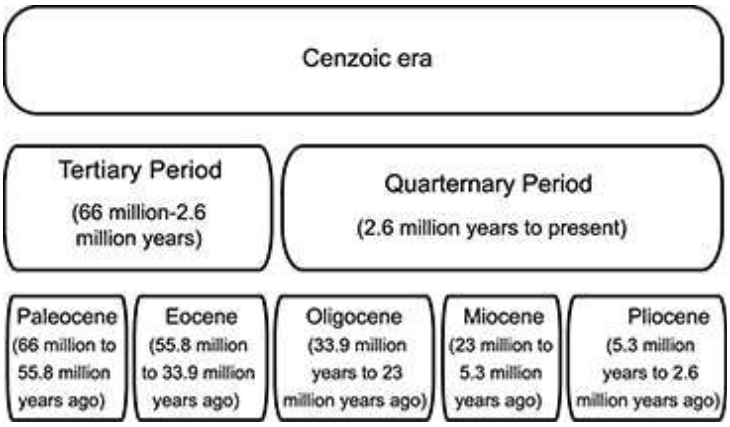


Fig. 1.9 Geological time scale of the Tertiary System

THE QUATERNARY PERIOD (THE PLEISTOCENE AND RECENT FORMATIONS)

Quaternary is the name proposed for very recent deposits, which contain fossils of species with living representatives. The northern plains of India came into existence during the Pleistocene Period **(Fig. 1.10).** During the Quaternary Period, the ice-sheets descended to as low as 1500 m in altitude. The third physical division of India which is the Great Indo-Gangetic-Brahmaputra Plain had not figured at all till the Quaternary Period. The bottom configuration of this plain occupies largely a synclinal basin, called foredeep, which is a downwarp of the Himalayan foreland of variable depth, formed concommitantly with the rise of the Himalayas to the north. The Pleistocene period is marked by Ice Age and glaciation on a large scale in the Northern Hemisphere. The moraine deposits and the Karewa formations of Kashmir Valley and the Bhadarwa (Doda District of Jammu Division) are of the Pleistocene period. It forms the terraces of the Jhelum, on the flanks of the Pir-Panjal. The thickness of the karewas at places is up to 1400 m. The river terraces of the

Narmada, Tapi, Godavari, Krishna, and Kaveri, etc., are also of the Pleistocene Period.

Karewas

The karewas are the lacustrine deposits of the Pleistocene period. They consist of sands, clays, loams, silt, and boulders. The karewas of Kashmir are generally found along the lower slopes of Pir-Panjal with a dip towards the Kashmir Valley. The Pampore and Pulwama karewas are well known for the cultivation of saffron, almond, and walnut.

GEODIVERSITY AND GEOTOURISM

The richness of diversity is determined by the development of biotic and abiotic resources. Geodiversity is defined as the variety of geological features like rocks, minerals, fossils, soils which are a part of the Earth's evolution. The geodiversity of the country is responsible for the wide range of geosites. The Geological Survey of India has enlisted certain areas in the subcontinent of India as National Geological Monuments. These monuments play an important role in providing an insight into the past–about its formation, the orogeny, the palaeo-environment and the exotic collection of the flora and the fauna

'*Geoconservation*' is the identification and preservation of sites that help us to understand the processes of formation of the earth.

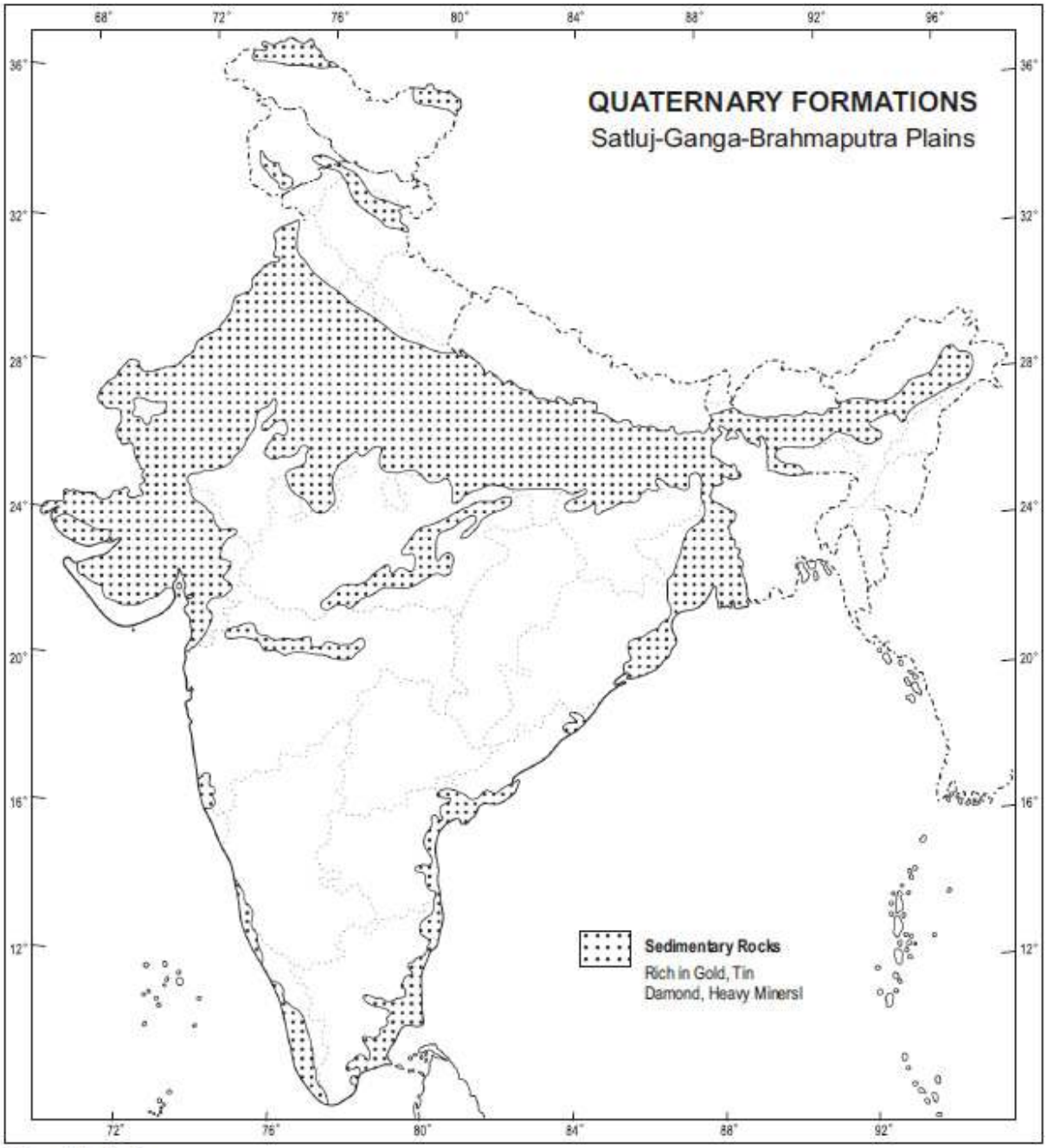


Fig. 1.10 Quaternary Formations (1.8 million years to 10,000 years ago)

'*Geotourism*' is defined as the tourism that sustains the geographical character of a place-its environment, heritage, aesthetics, culture and the wellbeing of its residents. India is a

country with diverse physical attributes, rich cultural heritage and ancient history full of events. Hence tourism is of importance in projecting the Indian heritage to the rest of the world.

A '*Geoheritage*' is concerned with the preservation of features like landforms, natural and artificial exposure of rocks and sites where these features can be studied and examined for their preservation puroposes.

A '*geosite*' is a locality that constitutes a part of geoheritage. A geopark has been described as a territory encompassing one or more sites of scientific importance by UNESCO in its Global Geoparks Network. A geopark is of importance in archaeological, ecological and cultural values. Some of the natural geosites have been described under :

1. Natural springs and glacier lakes

R.D. Oldham in the 19th century published the work of his father T.R.D. Oldham (1882) in the form of an inventory of 300 thermal springs in India. The Ministry of Power and Irrigation constituted a committee on "Hot Springs" in 1963 to study and explore the commercial utilization of the potential of the hot springs. There are about 340 hot springs. The Northwest Himalaya region of Jammu and Kashmir, Himachal Pradesh, Uttarakhand has about 340 hot springs. They are mostly concentrated along 30–50 km wide thermal band occurring along the river valleys. Naga-Lusai and West Coast provinces manifest a series of hot springs.

The thermal springs in India have classified as:

i) Himalayan Province-Territory Orogenic belt with territory magmatism
ii) Areas of Faulted blocks-Aravali belt
iii) Volcanic arc-Andaman and Nicobar arc
iv) Deep Sedimentary basin-Cambay Basin in Gujarat
v) Radioactive basin-Surajkund, Hazaribagh, Jharkhand
vi) Cratonic province-Peninsular India

The hot springs in the Peninsular region of India are related to faults in which meteoric water is in deep circulation .The circulating water acquires heat from the normal gradient of heat in the area (*Aravali range, Son-Narmada-Tapti region, Godavari and Mahanadi and South Cratonic Belts*) and emerges out at suitable localities.

Glacial lakes originate from the glaciers. They are formed when a glacier erodes the land and melts. It then fills the space created by its movement. There are about 2026 glacial lakes and water bodies in the Indian basin of the Himalayas out of which 503 are glacial lakes. The highest number of these lakes is found in the Brahmaputra basin.

A sudden burst of glacial lake produces violent flow of water and the associated debris is known as 'Glacial Lake Outburst flood (GLOF)'. A lake outburst and debris flow disaster occurred in Kedarnath, Uttarakhand in June 2013.

FOSSIL PARKS

Fossil Parks are important as they provide information about the diversity and the evolution of life through time. They help in preserving the fossils and spread awareness to the public about the values of fossils. The protected areas are maintained by the Geological Survey of India, in order to preserve the rocks, minerals, fossils and meteorites.

1. Shivalik Fossil Park (Saketi, Sirmaur district, Himachal Pradesh)

It has life size models of vertebrates that might have inhabitated Shivalik Hills, about 1.5 to 2.5 million years ago. It covers an area of about 1.5 km2 in the Markanda valley of Sirmaur. This park was built to put a check on the destruction of fossil bones. This site has been developed to a panorama of Plio-Pleistocene period (ca. 2.5 million years) through large afforestation.

2. Mandla Plant Fossils National Park (Dindori, Madhya Pradesh)

This national park preserves the fossil remains of primordial forest about 40–150 million years ago. The total area of the park is 0.27

km2 which is spread over in seven villages of Dindori district namely Ghuguwa, Umaria, Deorakhurd, Barbaspur, Chanti Hills, Chargaon and Deori Kohani.

3. Ghughua Fossil Park (Madhya Pradesh)

This national park has a trove of plant fossils belonging to 31 genera of 18 plant families. The fossils indicate to life in the area about 65 million years ago. It has a reservoir of woody plants, climbers, leaves, flowers and seeds. The dicotyledons and palm fossil woods are in abundance. Some fossils of shell bearing animals are also found indicating that the region was humid and received plenty of rainfall.

Fig: 1.11 The Ghughul National Park [*Source: Government of India*]

4. Marine Gondwana Fossil Park, Manendragarh, Sarguja district, Chattisgarh

It has fossiliferous marine Permian rocks of Talchir formation dated to 280–240 million years. It has a spread of 1 km on the right bank of Hasdeo river and Hashia nala

Some other Fossil parks managed by the Geological Survey of India include:

5. National Fossil Wood Park, Tiruvakkarai, Tamil Nadu

It has 200 fossil trees ranging in length from 3–15 m and upto 5 m in girth which are seen as lying horizontally embedded in Cuddalore Sandstone of the Mio-Pliocene age about 20 million years ago. It covers an area of 1 km2. The longest specimen measures 13.4 m×0.9 m. Scientists believe that these trees did not grow at that site but were transported there before they were petrified.

6. National Fossil Wood Park in Sathanur, Tamil Nadu

This wood park contains large trunks of petrified trees (conifers) of Upper Cretaceous age (100 million years ago). These trees were non-flowering and dominated the land vegetation. The fossilized tree trunk at Sathanur measures over 18 m in length.

7. Akal Wood Fossil Park, Jaisalmer district, Rajasthan

The fossils of the wood found in this park reflect the warm and humid climate cordering the sea some 180 million years ago. It is spread over an area of 21 hectares. It contains fossils of wooden logs (petrophyllum, ptyllophyllum, equisetitis species and dicotyledonous wood and gastropod shells of Lower Jurassic period) lying in random horizontal orientation.

8. Stromatolite Park, Bhojunda, Chittaurgarh district, Rajasthan

Stromalites are structures produced by blue green algae. They are stratiform ,columnar and nodular structures in carbonate rocks .They are the result of the combination of life activity and sediment trapping ability of algae and the preying bacteria. Their formation occurs in shallow water where the tides bring the floating sedimentary material and make it flow through carbonate particles. These are the impressions of the earliest life forms.

9. Stromatolite Park, Jharkhand, Udaipur district, Rajasthan

It is the largest and rich in the deposits of phosphorite. This site preserves and provide evidences of early life on the earth. They stretch over a length of 15 km in the rock phosphate within the Precambrian Aravalli Supergroup of rocks. The rock phosphate occurs in dolomite limestone associated with stromatolites which have bluish grey appearance.

Statewise details of the geological heritage sites /national geological monuments declared by the Geological Survey of India are given in the following table

State	Geological heritage sites/National geological monuments
Andhra Pradesh	Volcanogenic bedded barytes, Mangampeta, Cuddapah district
	Eparchaean Unconformity, Chittoor district

State	Geological heritage sites/National geological monuments
	National Geological Arch, Tirumala Hills, Chittoor district
	Erra Matti Dibbalu-Stable coastal red sediments, Vishakapatnam, Bheemunipatnam
Kerala	Laterite near Angadipuram, Malappuram district
	Varkala Cliff Section, Thiruvananthapuram district
Tamil Nadu	Fossil wood near Tiruvakkarai, South Arcot district
	National fossil wood park, Sathanur, Perambalur district
	Charnockite, St. Thomas Mount, Madras
	Badlands of Karai formation with cretaceous fossils along Karai, Perambalur district
Gujarat	Sedimentary structures–Eddy Markings, Kadam Dam, Panchmahal district
Rajasthan	Sendra Granite, Pali district
	Stromatolite Park, Bhojunda, Chittaurgarh district, Rajasthan
	Stromatolite Park, Jharkhand, Udaipur district, Rajasthan
	Akal Wood Fossil Park, Jaisalmer district
	Kishangarh Nepheline Syenite, Ajmer district
	Welded Tuff, Jodhpur district
	Malani Igneous Suite Contact, Jodhpur district
	Great Boundary Fault at Satur, Bundi district
Maharashtra	Lonar Lake, Buldhana district
Chattisgarh	Lower Permian Marine Bed, Manendragarh, Sarguja district
Karnataka	Columnar lava, St. Mary's Island, Udupi district
	Peninsular Gneiss, Lalbagh, Bangalore
	Pyroclastics and pillow lavas, Kolar Gold fields, Kolar district
Himachal Pradesh	Siwalik Fossil Park, Saketi, Sirmur
Odisha	Pillow lava in iron ore belt at Nomira, Keonjhar district
Jharkhand	Plant fossil bearing inter-trappean beds of Rajmahal Formation, upper Gondwana sequence around Mandro, Sahibganj district
Nagaland	Nagahill Ophiolite Site near Pungro

State	Geological heritage sites/National geological monuments
Sikkim	Stromatolite bearing Dolomite/Limestone of Buxa Formation at Mamley near Namchi, South district

Source: Ministry of Mines, Government of India, 2016.

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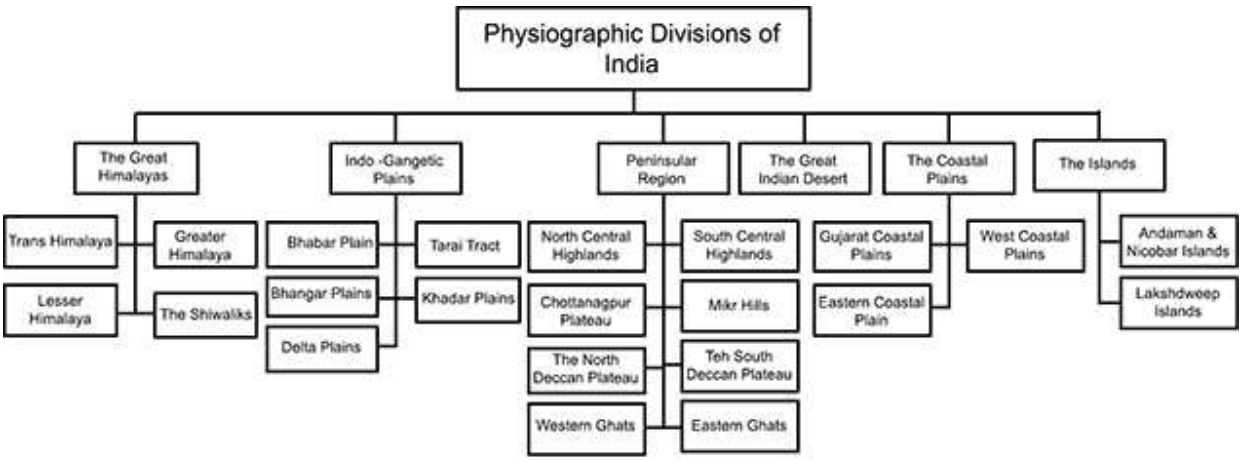
*Approximate stages in the development of earth's atmosphere

2

Physiography



PHYSIOGRAPHIC DIVISIONS OF INDIA

Physiography deals with the study of the surface features and landforms of the Earth. On the basis of tectonic history, stratigraphy, and physiography, India may be divided into the following four physiographic divisions as shown on the map **(Fig. 2.1)**:

1. The elevated Peninsular region;
2. The mighty Himalaya and their associated young folded mountains;
3. The Indo-Gangetic-Brahmaputra Plains;
4. The Deserts.
5. The Coastal Plains and Islands.

THE HIMALAYAN REGION

The Himalaya consist of four lithotectonic mountain ranges, namely (i) the Trans-Himalaya or the Tethys Himalaya, (ii) the Greater Himalaya, (iii) the Lesser Himalaya, and (iv) the Shiwalik or the Outer Himalaya. The Indian Himalaya extend from the eastern boundary of Pakistan to the border of Myanmar for about 2500 km with a varying width of about 500 km in the west and about 320 km in the east. They lies to the north of the Ganga-Brahmaputra Plains and are separated from the plains by the Himalayan Front Fault (HFF). They include parts of Jammu and Kashmir, Himachal Pradesh, Uttarakhand, Nepal, Sikkim, Bhutan and Arunachal Pradesh. Their offshoots run in a north-south direction along the India-Myanmar boundary through Nagaland, Manipur, and Mizoram.

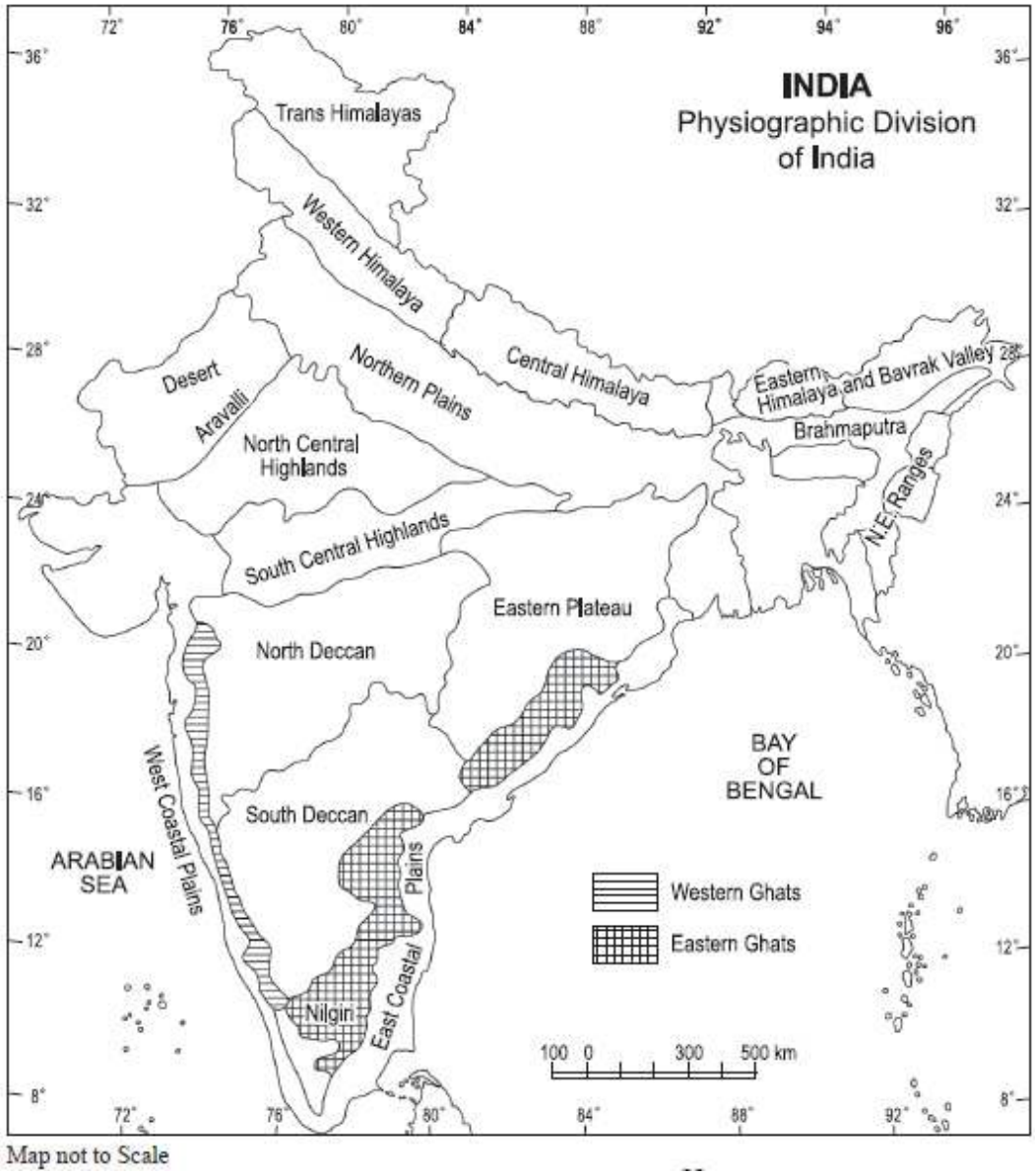


Fig. 2.1 Physiographic Divisions

Origin of the Himalaya

The origin of the Himalaya has been a point of contention among the geologists and geomorphologists. It is a complex mountain system having rocks from the Precambrian and Eocene periods. Mostly formed of sedimentary and metamorphic rocks, it has been subjected to intense folding and faulting. The main theories about the origin of the Himalays are as under: