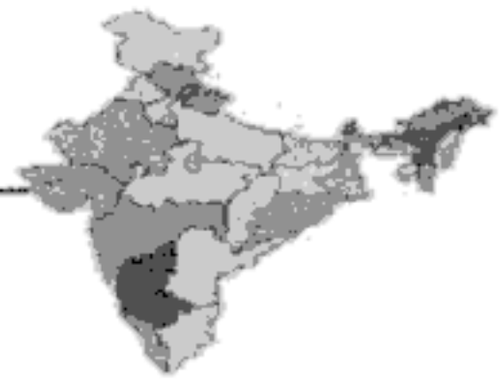
Chapter 1

STRUCTURE OF INDIA



INTRODUCTION

The geological structure of a country 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.

Geologically, 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 (**Fig. 1.1**).

1. 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 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

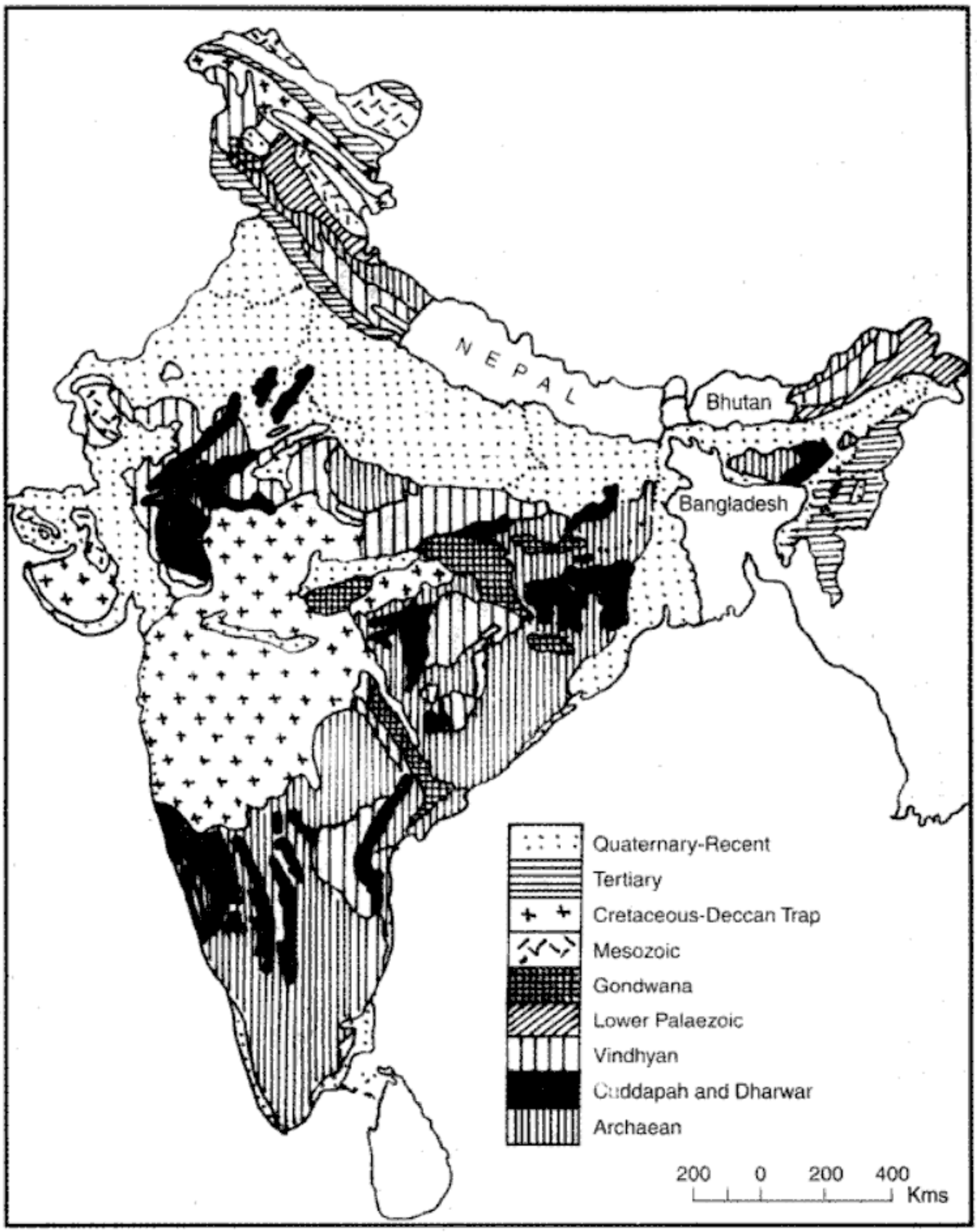


Fig. 1.1 Geological Systems

form of life. In other words, the Archaean rocks are all azoic or unfossiliferous. They are thoroughly crystalline, extremely contorted and 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 plateaux, 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 Pre-Cambrian 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 Archaean 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. 1.1 and Fig. 1.2).**

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 which occurs in the Eastern Ghats, Orissa (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. For the first time these rocks were identified in the Midnapur district of West Bengal.

(ii) The Bundelkhand Gneiss

The Bundelkhand Gneiss forms the second group of fundamental gneiss of the Archaean age. It occurs in Bundelkhand (U.P.), Baghelkhand (M.P.), 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.

(iii) The Nilgiri 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 intruding 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 Orissa, 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.

2. 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. In India, these rocks 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

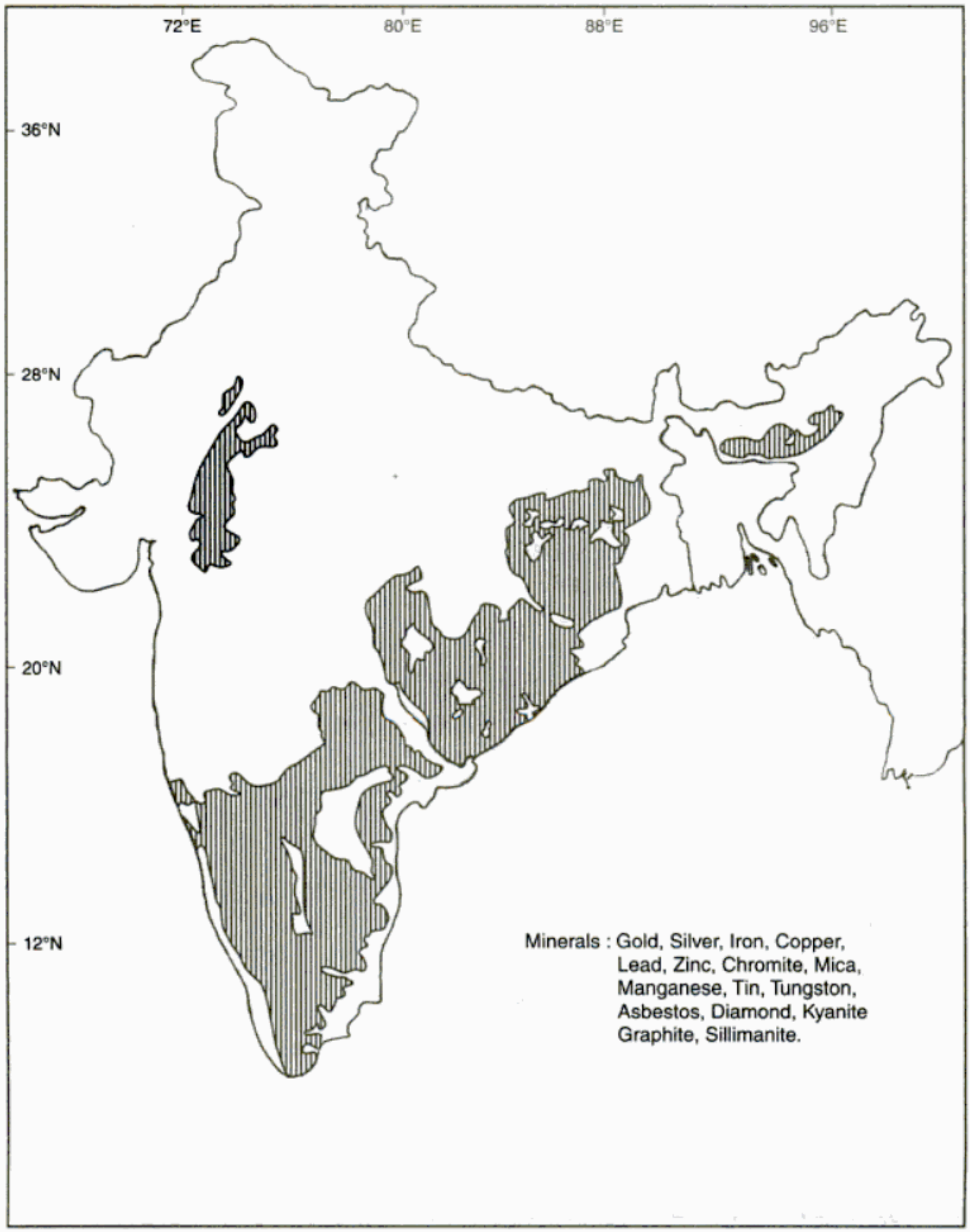


Fig. 1.2 Archaean Formations (Pre–2500 Million Years)

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. 1.3).**

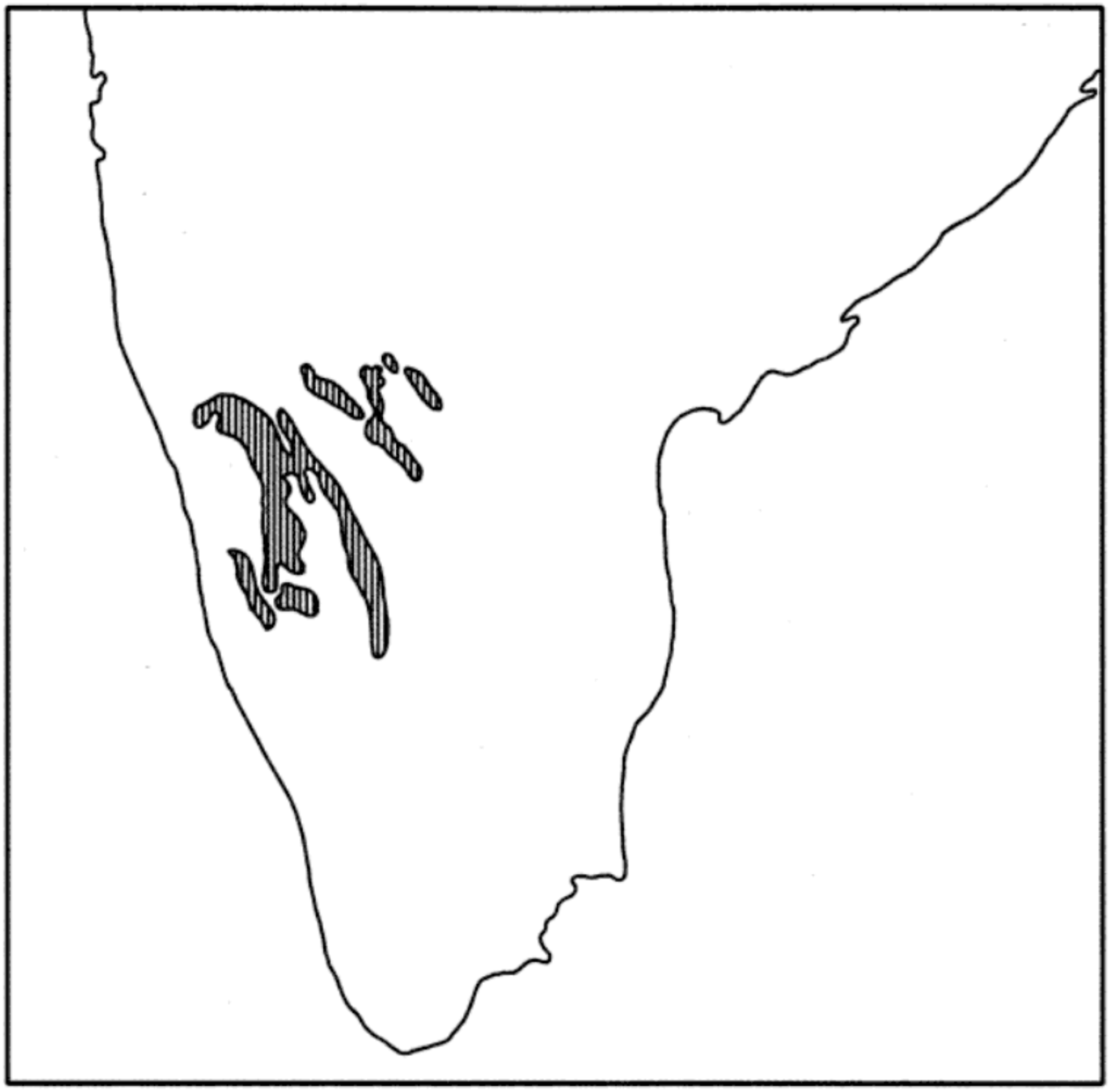


Fig. 1.3 Dharwar System

The Dharwar rocks are highly metalliferous. They are rich in 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:

(a) Champion Series

Belonging to the Dharwarian System, the series has been named after the Champion reef in the Kolar Gold fields. Lying to the north-east of Mysore City and to the east of Bangalore, this series stretches in the Kolar and Raichur districts of Karnataka. Its gold mines are one of the deepest in the world, being more than 3.5 km in depth. The gold content in this series is about 5.5 grams per tonne of ore.

(b) Champaner Series

It is an outlier of the Aravalli system in the vicinity of Vadodra. It consists of quartzites, conglomerates, phyllites, slates and marbles. An attractive green variety of marble is obtained from this series.

(c) Closepet Series

Stretching over the Balaghat and Chhindwara districts of Madhya Pradesh, it is a Dharwarian formation. The series consists of quartzite, copper pyrite, and magniferous rocks. The Malanjkhand Copper Plant gets its ore from the Closepet series.

(d) Chilpi Series

It occupies parts of Balaghat and Chhindwara districts of Madhya Pradesh. The series consists of grit, phyllite, quartzites, green stones and magniferous rocks.

(e) Iron-Ore Series

It occurs in Singhbhum, Bonai, Mayurbhanj and Keonjhar in the form of a range. The iron-ore series is about 65 kilometres in length and reserves about three thousand million tons of iron-ore.

(f) Khondolite Series

It occupies a large area in the Eastern Ghats from the northern extremity to the valley of Krishna. The principal rock types in this series are khondolites, kodurites, charnockites and gneisses.

(g) Rialo Series

Also known as the Delhi series, it extends from Delhi (Majnu-Ka-Tila) to Alwar, Rajasthan in a north-east to south-west direction. This series is rich in marbles. The Makrana, and Bhagwanpur known for high quality of marble belong to this series.

(h) Sakoli Series

Stretching over Jabalpur and Rewa districts, this series belongs to the Dharwarian formation. It is rich in mica, dolomite, schist and marble. The marble of this series is of superior quality.

(i) Sausar Series

This series spreads over Nagpur, Bhandara districts of Maharashtra, and Chindwara district of Madhya Pradesh. It belongs to the Dharwarian group and is rich in quartzite, mica chist, marble and magniferous rocks.

3. THE CUDDAPAH SYSTEM (THE PURANA GROUP)

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. 1.4**)

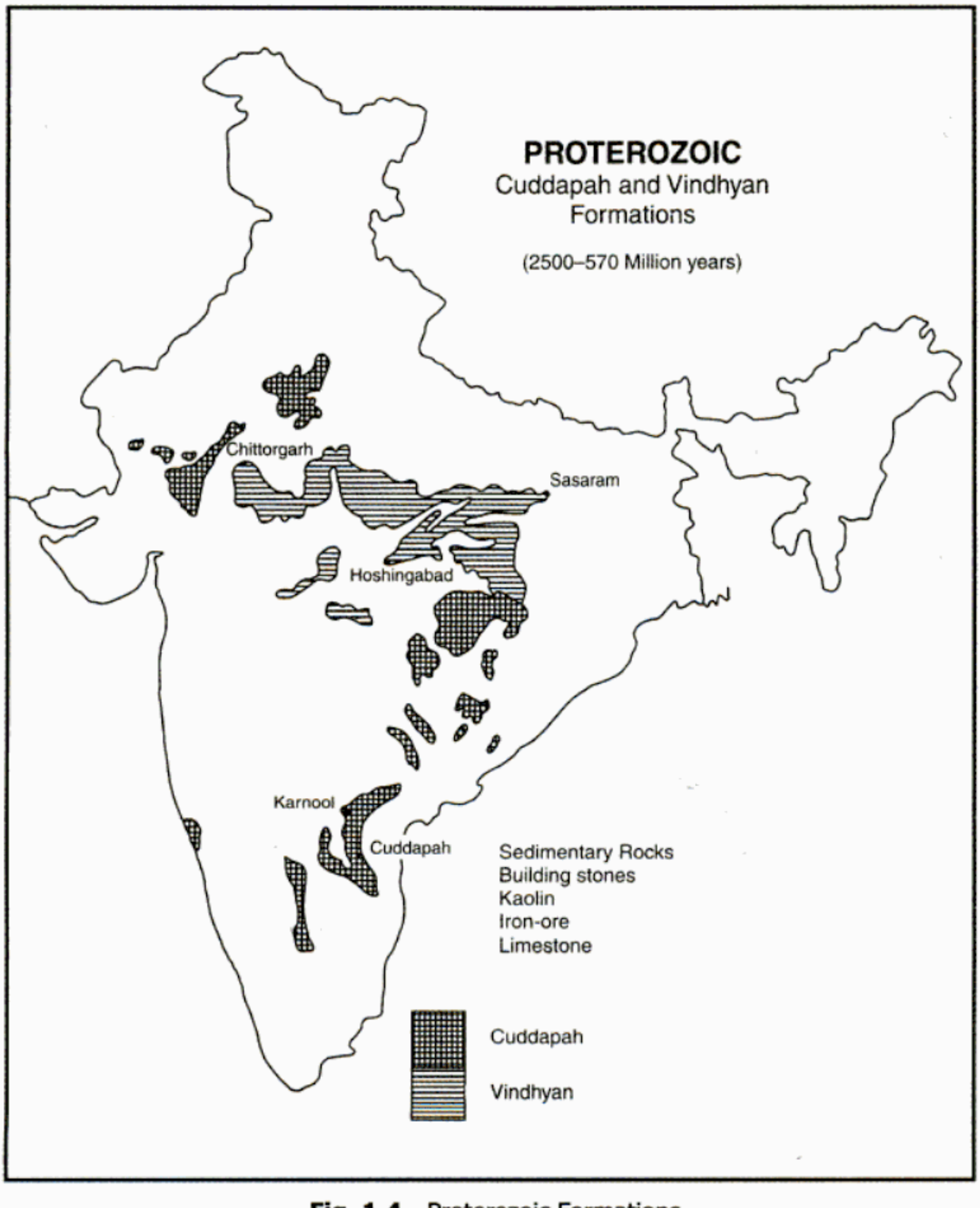


Fig. 1.4 Proterozoic Formations

At places the Cuddapah formations are six thousand metres in thickness. The enormous thickness of these rocks indicates the sinking of beds of the basin with growing sedimentation.

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.

4. 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 metres. 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. 1.4**).

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.

Bhander Series

This series spreads over the western parts of the Vindhyan formation. The main rocks of the series are sandstones, shales and limestone. The series provides good quality of building material besides diamonds and precious stones.

Bijwar Series

Stretching over the districts of Chhatarpur and Panna, this series belongs to the Vindhyan system. It is composed of sandstone, red-sandstone, and quartzite. It has basaltic intrusions whose dykes are rich in diamonds.

Kaimur Series

This series sprawls over Bundelkhand (U.P.) and Baghelkhand (M.P.). The main rocks in this series are sandstone, conglomerate and shale. It is also rich in red sandstone used in historical monuments.

5. 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 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).

6. 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 Gondwana group begins with the Permo-Carboniferous period which, in the Standard Geologic Time Scale, is known as a period of coal formation **(Fig. 1.5).** 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 Orissa. It is rich in good quality coal used for smelting and in thermal power plants.

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, Jharia, Karanpura and Bokaro of the Damodar basin, Singrauli, Korba, and Pench valley in Chhattisgarh and Madhya Pradesh, Talcher in Mahanadi Basin in Orissa, and Singreni of Satpura Basin in Madhya Pradesh. The *Jhingurda Coal Seam* with a thickness of about 131 metres is the thickest coal seam in India. The

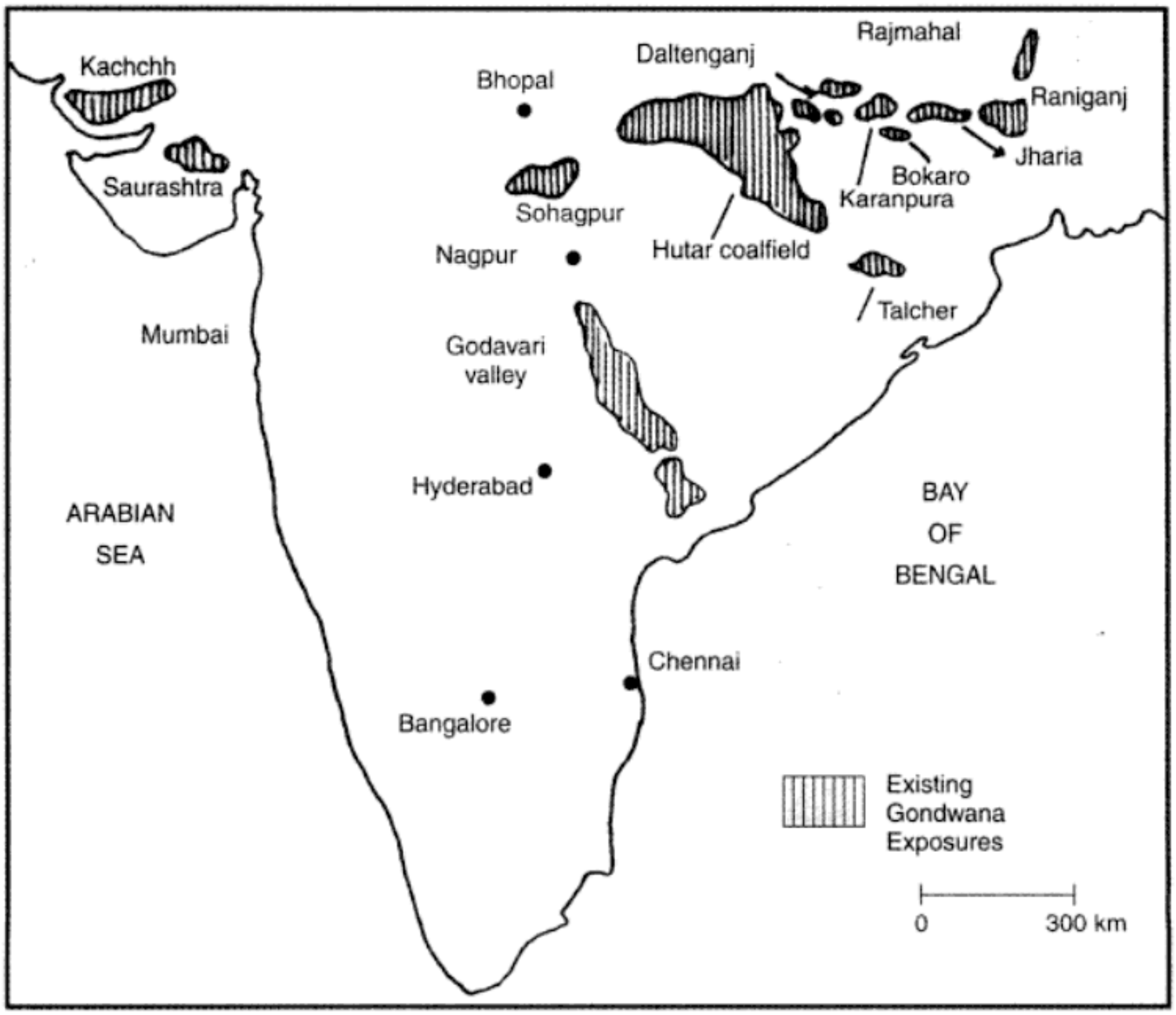


Fig. 1.5 Gondwana System

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. 1.5**).

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 Orissa and Chhattisgarh, the Godavari valley of Andhra Pradesh and the Satpura basin of Madhya Pradesh (**Fig. 1.5**).

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.

7. 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 three thousand metres. The Lava Plateau (the Deccan Trap) is the result of that lava eruption. The Deccan lava covers about five lakh sq km of area in Gujarat (Kachchh, Kathiawad), Maharashtra, Madhya Pradesh (Malwa Plateau), Chhattisgarh, Jharkhand, northern Andhra Pradesh and north-western Karnataka **(Fig. 1.6).**

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.

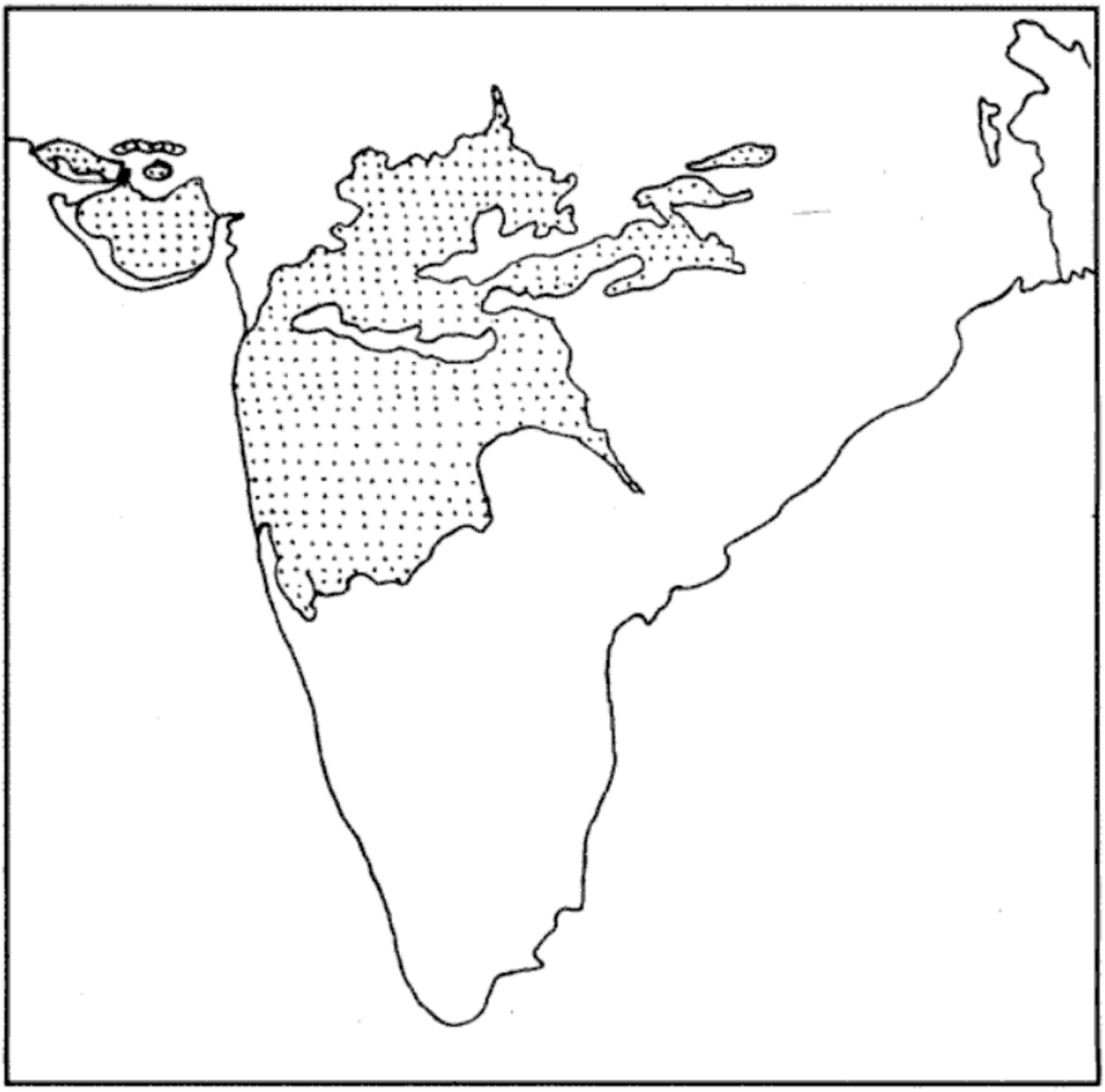


Fig. 1.6 The Cretaceous System (The Deccan Trap)

8. THE TERTIARY SYSTEM (THE CENOZOIC ERA)

Cenozoic means recent life. The beginning of the Tertiary Period is about 66 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 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 India collided with Tibet, 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. 1.7).**

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.

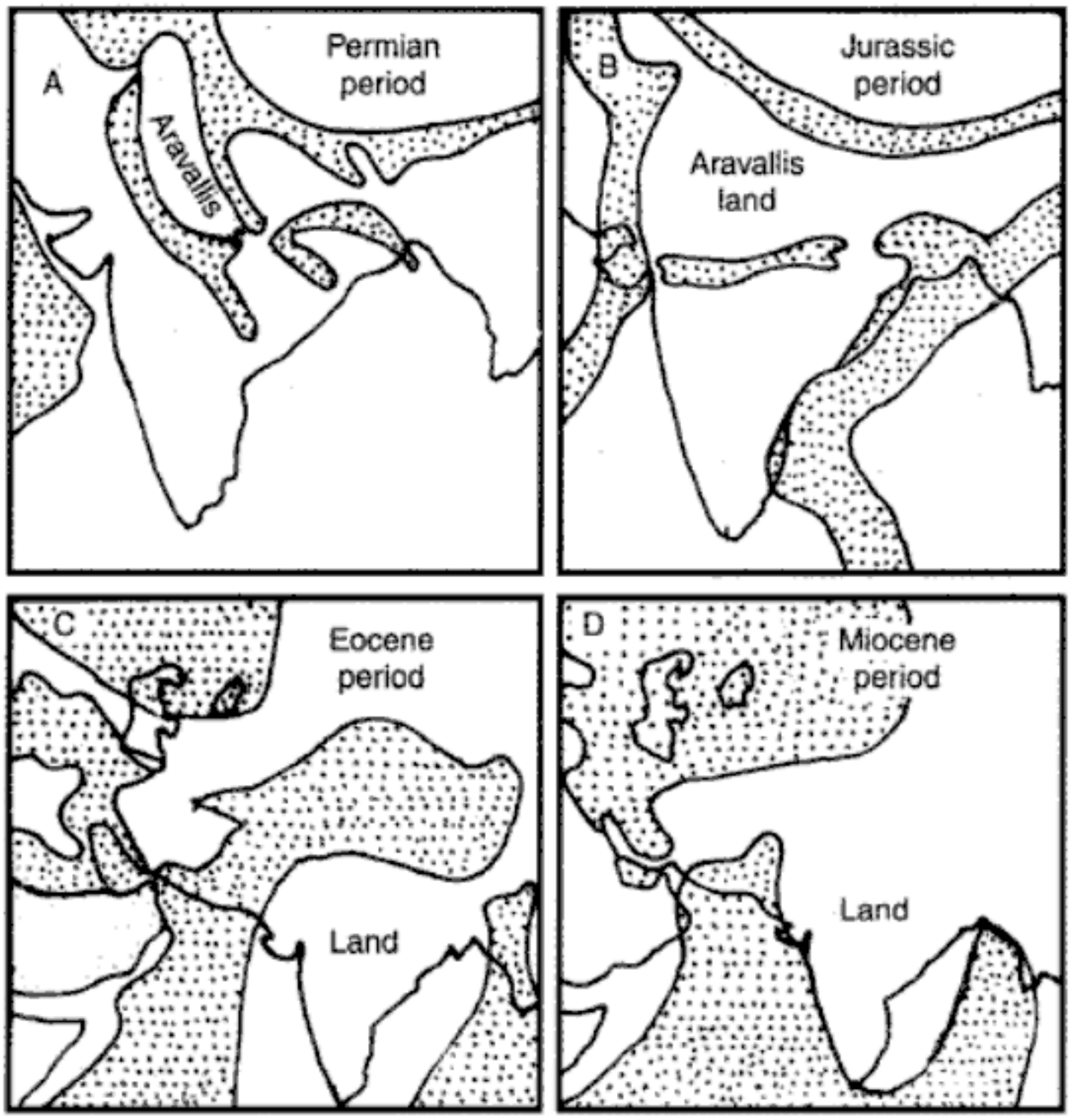


Fig. 1.7 Change in Topography of Subcontinent

(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.

9. 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. 1.8**). During the Quaternary Period, the ice-sheets descended to as low as 1500 metres 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 metres. 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.

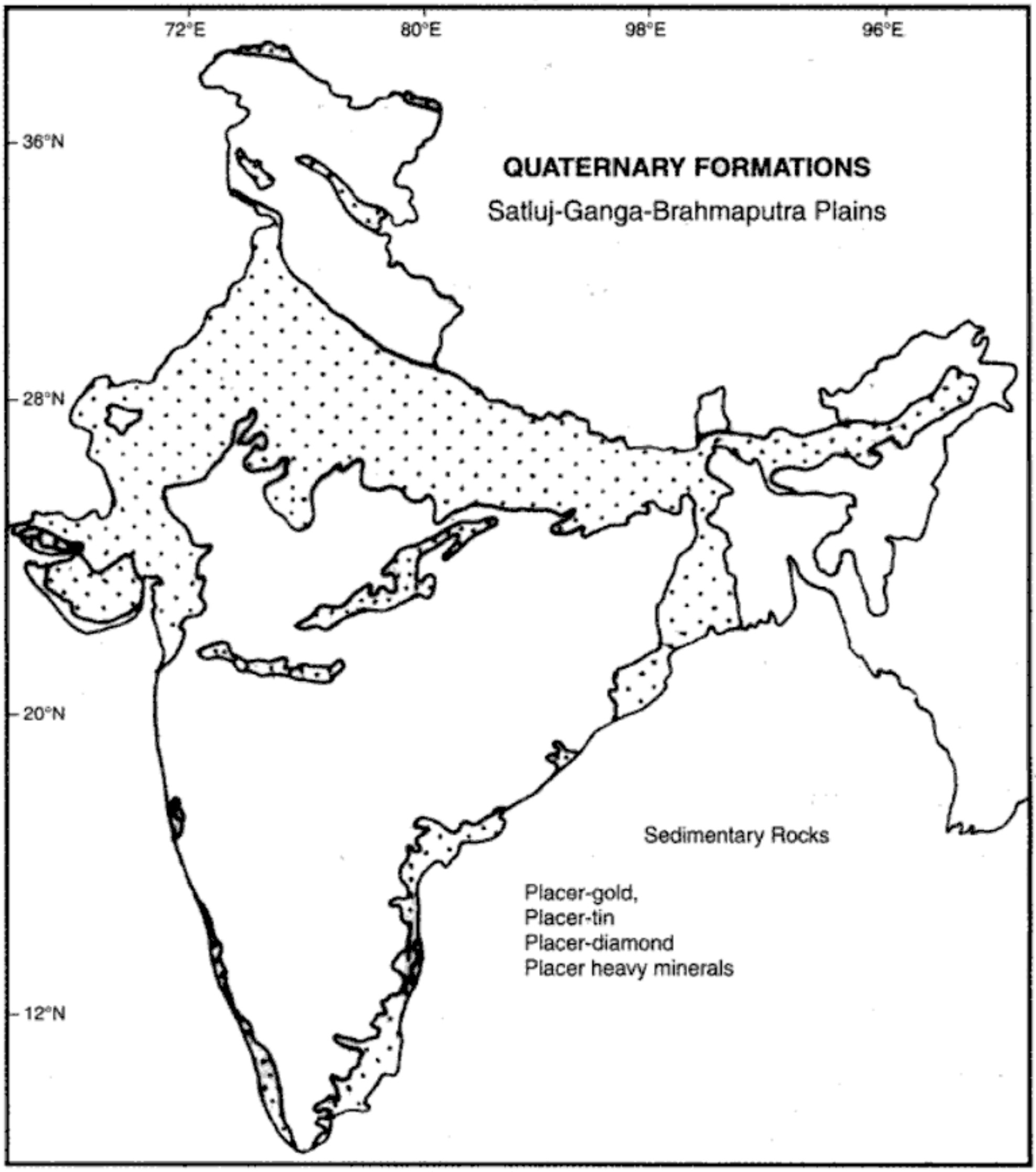


Fig. 1.8 Quaternary Formations

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