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BGYCT-137: STRATIGRAPHY AND PALAEONTOLOGY

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Block 2 Stratigraphy of India

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BLOCK 2: STRATIGRAPHY OF INDIA

The surface of Earth is covered by various physical features like mountains, valleys, plateaus, deserts etc. All these features are made up of rocks over millions of years. During their formation, many geological processes such as weathering, erosion, sedimentation, volcanism, tectonism, marine transgression and regression played an important role. India has a marked diversity in its physical features as it contains the folded Himalayan mountain system, Peninsular plateau, Indo-Gangetic plains, Thar desert, Eastern and Western Ghats as well as Islands of the west and east coasts. Importantly, these regions are made up of rocks belonging to various geological ages, ranging from Precambrian to Holocene (Present). In short, Indian rock record is rich and diverse and its different regions contain rocks of various geological periods, extending from the Archaean.

Stratigraphy of India refers to the understanding of the sequential arrangement of its rock record from Archaean to Holocene. Rock record constitutes all type of rocks including igneous, sedimentary and metamorphic, occur in an area or in a country. However, the rock record of an area is never complete or continuous as it is usually witnessed by non-depositional or erosional periods in the forms of diastems, unconformities and disconformities. This is the reason that the Archaean and Proterozoic rocks are well developed in Peninsular India, whereas Palaeozoic-Mesozoic rocks are almost fully preserved in the Himalayan region.

In Stratigraphy, the rocks are classified into supergroups, groups, formations, members, beds, etc. based on criteria mentioned in the stratigraphic classification, that you have studied in Block 1 of this course. This block deals with stratigraphy of India and comprises five units. The block will acquaint you with the main stratigraphic supergroups or groups of India belonging to different geologic time such as Precambrian, Palaeozoic, Mesozoic and Cenozoic, which occur in various parts of the country.

Unit 4 deals with Precambrian stratigraphy of India particularly Archaean and Proterozoic successions of Peninsular India. It discusses one Archaean aged craton, i.e., Dharwar and three Proterozoic supergroups, namely, Cuddapah, Vindhyan and Delhi. This unit emphasizes on the stratigraphic classification, lithology, age and fossil contents of these Precambrian successions.

During the Palaeozoic, major portion of the northern margin of India was under the Tethys Sea and witnessed extensive cover of marine sedimentation, which led to the deposition of almost complete and continuous successions of Palaeozoic rocks in the northwest Himalayas as compared to Peninsular region.

Unit 5 covers Palaeozoic stratigraphy of India especially Palaeozoic successions of the Himalayan region. In this unit, you will learn about stratigraphic classification, lithology, age, fossil contents and environment of deposition of two well developed Palaeozoic successions one in Spiti (Himachal Pradesh) and second in Kashmir (Jammu and Kashmir) of the Himalaya.

Unit 6 deals with Mesozoic stratigraphy of India. The Mesozoic successions, ranging from Triassic to Cretaceous are well developed in both Peninsular and Himalayan regions of India. In this unit, you will learn about the distribution, stratigraphy, lithology, fossil content, age and environment of deposition of the main Mesozoic successions of India, which are exposed in Spiti (Himachal Pradesh), Kachchh (Gujarat), Jaisalmer (Rajasthan) and Tiruchirapalli (Tamil Nadu).

Unit 7 covers Gondwana Supergroup and Deccan Traps of Peninsular India. The Gondwana Supergroup ranging from Upper Palaeozoic to Mesozoic (Upper Carboniferous to Lower Cretaceous) in age is well known for coal deposits and rich assemblages of plant and vertebrate fossils. The end of

Mesozoic era in India is marked by tremendous volcanic eruption of the Deccan Traps. In this unit, you will learn about the classification, lithology, age, environment of deposition, duration and economic importance of Gondwana Supergroup and Deccan Traps.

Unit 8 deals with Cenozoic stratigraphy of India particularly the Cenozoic successions of the Himalayan region. The Cenozoic era in the Himalayan region represents a distinct phase in the tectonic and sedimentational history of India. The Himalayan region dominantly witnessed the marine sedimentation during Upper Precambrian to Mesozoic time, however, a majority of freshwater sedimentation commenced in this region during the Cenozoic. This unit will familiarise you with the classification, lithology, distribution and age of various Palaeogene-Neogene successions such as Subathu, Murree, Dharamsala, Siwalik, Jaintia, Barail, Surma and Tipam groups and Langpar Formation, exposed in the northwest and northeast Himalayan regions of India.

Expected Learning Outcomes

After studying this block, you should be able to:

- ❖ describe the stratigraphy and economic importance of the major Precambrian supergroups of Peninsular India;
- ❖ explain the stratigraphy of Palaeozoic successions of Spiti and Kashmir;
- ❖ discuss the stratigraphy of the Mesozoic successions of Spiti, Kachchh, Rajasthan and Tiruchirapalli;
- ❖ elucidate the stratigraphic classification and economic importance of the Gondwana Supergroup and the Deccan Traps; and
- ❖ outline Palaeogene–Neogene successions of the northwest and northeast Himalaya.

We hope that after studying this block, you will acquire basic knowledge of Precambrian, Palaeozoic, Mesozoic and Cenozoic successions of Peninsular and Himalayan regions of India.

Wishing you success in this endeavour!!

PRECAMBRIAN OF INDIA |

Structure

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4.1 INTRODUCTION

You have read about Precambrian while discussing geological time scale in Unit 1 Fundamentals of Stratigraphy. You have learnt that the history of the geological past of the Earth is written on rocks and preserved as stratigraphic sequences. The Precambrian time covers almost 90% of entire history of the Earth. It has been divided into three eons: the Hadean, the Archean and the Proterozoic. The records of the Hadean eon of Earth are not yet found on the Indian subcontinent.

In this unit, we will discuss the stratigraphy with few examples of Archean and Proterozoic eons from Indian shield. In the following sections, we will discuss about stratigraphy of Dharwar Supergroup of Archean age and Cuddapah, Vindhyan and Delhi supergroups of Proterozoic age.

Expected Learning Outcomes

After studying this unit, you should be able to:

- ❖ outline the major Precambrian successions of India;
- ❖ describe the stratigraphy of the main Precambrian supergroups of Peninsular India such as Dharwar, Cuddapah, Vindhyan and Delhi; and
- ❖ discuss the lithology, life, environment and economic importance of major groups/formations of Dharwar, Cuddapah, Vindhyan and Delhi supergroups.

4.2 DHARWAR CRATON

The Dharwar craton of Archaean age is one of the classical and best-studied terrains of Peninsular India covering an area of about 450,000 km² (Figs. 4.1 and 4.2). It is bounded to the south by the Pandyan mobile belt (PMB), to the north by the Deccan Traps, to the north-east by the Karimnagar granulite belt (KGB), to the east by the Eastern Ghat Mobile Belt (EMBG) and to the west by the Arabian Sea. Dharwar craton is a dominant suite of tonalite-trondhjemite-granodiorite (TTG) gneisses, which are collectively described as **Peninsular gneisses**.

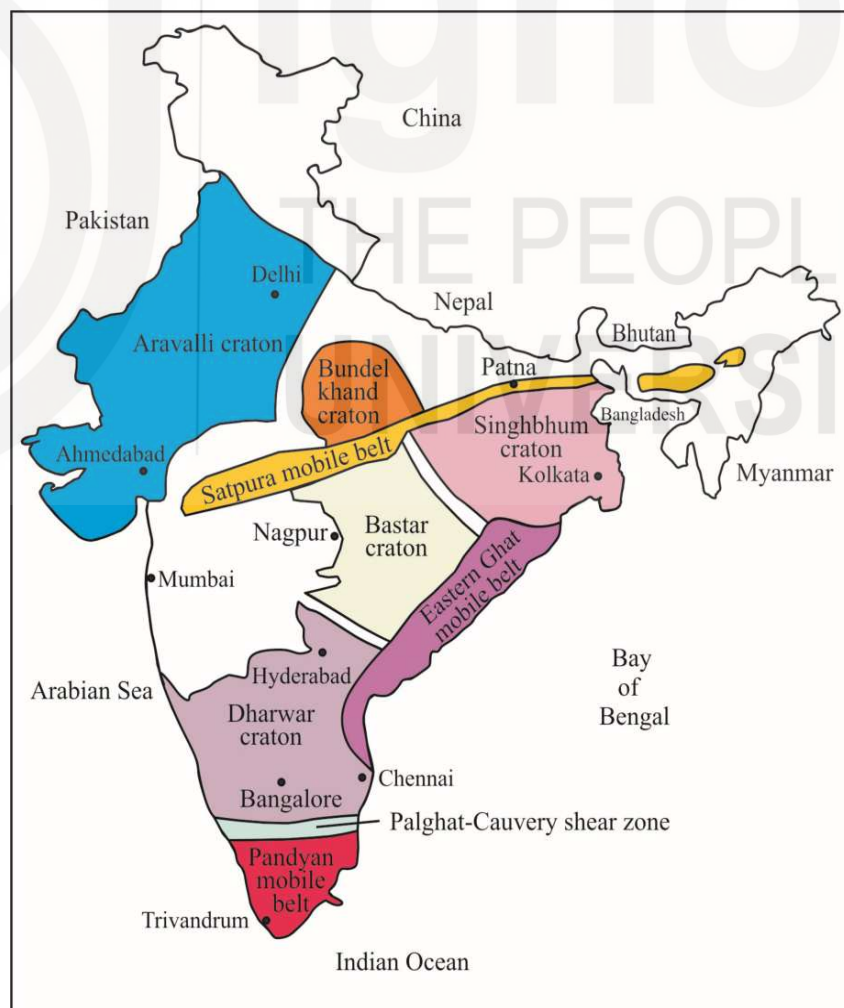


Fig. 4.1: Map of India showing major Precambrian cratons and mobile belts of peninsular India, Map not to scale. (Source: simplified from Ramakrishnan and Vaidyanadhan, 2008)

The second category of rocks in the Dharwar craton is greenstones or schist belts with sedimentary associations. The greenstones comprise mainly voluminous basalts with subordinate fine clastics and chemical sediments. In certain areas greenstones comprise of basal conglomerate and shallow water clastics and shelf sediments like limestones and dolomites. The greenstone belts together with the intercalated metasediments are designated as Dharwar Schist Belts. They have characteristic regional trend NNW-SSE and show a gradual increase of metamorphic grade from N to S. These schists and gneisses gradually give way to the granulites (charnockites and khondalites) in the southern part of craton.

Do you know?

Ages yielded between 3.5 and 3.2 Giga annum/years (Ga) is considered as the oldest rocks of the Indian plate. The zircons from the felsic lavas from the upper part of the Holenarsipur greenstone belts (Dharwar craton) have been dated at 3.4 Ga. Banded Gneissic Complex (BGC) of Rajasthan has yielded the age of 3.2 Ga. Similarly, Older Metamorphic Group of Singhbhum craton yielded an age as old as 3.4 Ga. This appears that Indian subcontinent does not have geological history older than 3.5-3.4 Ga.

4.2.1 Stratigraphic Classification

The term “Dharwar craton” was introduced in 1978 by the Geological Survey of India, in order to accommodate the known Dharwar Supergroup (Dharwar greenstone granite) and Sargur Schist complex (Sargur type high grade terrain). Early studies on the Dharwar craton were controversial in regard to the status of gneisses and schistose. This controversy continued for over three decades until geochemical and geochronological data were generated. This enhanced the clarity with respect to stratigraphic relationship of Dharwarian rocks.

Let us briefly discuss the classifications earlier proposed for the Dharwar craton.

W.F. Smeeth in 1915 -16 proposed a two-fold division of the Dharwar succession: the lower Hornblendic Division and the Upper Chlorite division. B. Ramarao in 1936 proposed three-fold divisions: the Lower Dharwar, the Middle Dharwar and the Upper Dharwar. Radhakrishnan in 1967 proposed five-fold stratigraphic scheme. S.V.P. Iyengar in 1976 suggested a four-fold classification based on lithostratigraphy. The classification and correlation of various greenstone belts by Geological Survey of India brought major revolution in the geology of Dharwar craton.

Swami Nath *et al.* (1976) divided the Dharwar craton into two tectonic blocks: the **Western Block** and the **Eastern Block** on the basis of differences in the character of schist belts, their inter-relationships with the surrounding Grey gneisses, grades of metamorphism and temporal evolution (Fig. 4.2). Later these blocks were designated as Western Dharwar Craton (WDC) and Eastern Dharwar Craton (EDC). The Grey gneisses [2500 - 2700 Million annum (Ma)] previously known as Peninsular gneisses cover the EDC (Fig. 4.3). Now, the term Peninsular gneisses is restricted to gneisses older than 3000 Ma which

are restricted to WDC. The granitic terrain of EDC is also called the **Dharwar Batholith** (> 2500 Ma). The WDC and EDC are separated by Chitradurga Schist belt close to the margin of Closepet Granite. This contact is not sharp, and there is a transition zone. The differences between WDC and EDC are summarised in Table 4.1.

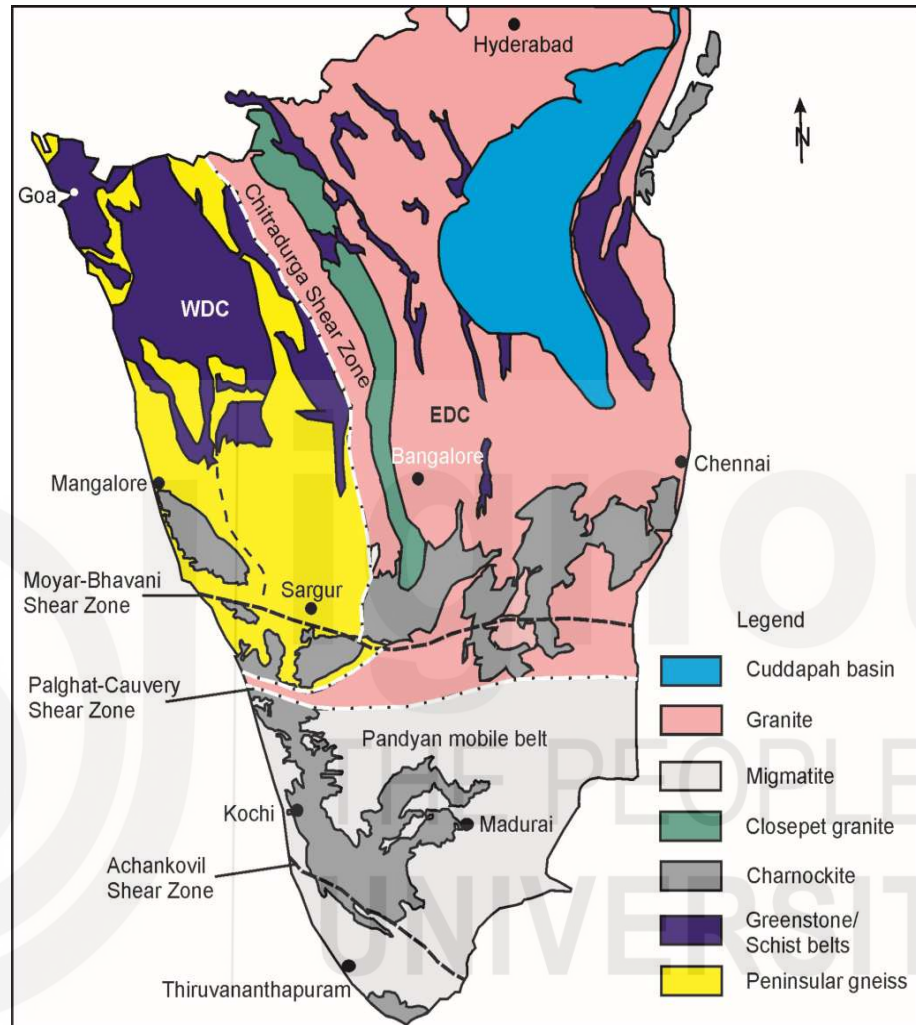


Fig. 4.2: Essential features of the Dharwar craton. Abbreviations: WDC- Western Dharwar Craton; EDC-Eastern Dharwar Craton. (Source: simplified from Ramakrishnan and Vaidyanadhan, 2008)



Fig. 4.3: Peninsular Gneiss exposed at National Monument at Lalbagh, Bangalore. (Source: http://www.portal.gsi.gov.in/portal/page?_pageid=127,529542&_dad=portal&_schema=PORTAL)

Table 4.1: Distinguishing characteristics of the Western Block and the Eastern Block of Dharwar Craton. (Source: simplified after Swami Nath et al. 1976)

Western Block	Eastern Block
1. Large schist belts of the Dharwar Supergroup with volcanics and subordinate sediments, e.g. (i) Chitradurga (ii) Shimoga-Bababudan	Narrow linear belts of the Dharwar Supergroup with dominant pillowed basalts, e.g. (i) Kolar-Kadiri-Hutti (ii) Ramagiri-Penakacherla-Hungund (iii) Veligalu-Raichur-Gadwa
2. Three lithostratigraphic associations: i. Quartz–arenite–metabasalt-Banded Iron Formation (BIF) ii. Polymict conglomerate stromatolitic carbonate-arenite, metapelite-BIF iii. Greywacke–submarine volcanics BIF association	Three lithostratigraphic association unclassified belts: i. Komatiite–tholeiite amphibolite, BIF, metapelitic, quartzite ii. Submarine bimodal volcanics, BIF pelite iii. Immature clastic sediments, BIF and felsic volcanics
3. Peninsular Gneiss (>3000 Ma) basement cover relation best preserved, with angular unconformity with the Dharwar marked by Quartz Pebble Conglomerate (QPC). Basement gneiss inliers within schist belts	Dharwar Batholith (2500-2700 Ma) intrusive on all sides. Diapiric gneiss domes common
4. Intermediate pressure metamorphism (kyanite-sillimanite)	Low pressure metamorphism (andalusite-sillimanite)
5. Mainly 3000 Ma terrain consisting of basement gneisses with narrow belts and enclaves of 3300 Ma older sequence (Sargur Group)	Mainly 2500 Ma terrain consisting of gneisses and younger granite with remnants of schist belts ~ 2600 - 2700 Ma.

4.2.2 Western Dharwar Craton

Western Dharwar Craton (WDC) also called as **Karnataka nucleus** by Radhakrishna and Naqvi (1986) and was grouped into two orogenic cycles separated in time (Table 4.2) viz., the older Sargur Group (3100-3300 Ma) and the younger Dharwar Supergroup (2600-2800 Ma). Dharwar Supergroup is regionally correlatable and exhibits coherent stratigraphy. Whereas the Sargur Group is represented by disarrayed enclaves of diverse rock-types exposed in the same locality. WDC consists mainly of Peninsular Gneiss comprising TTG gneisses, which forms the basement to Dharwar Supergroup and the contact is marked by a profound regional unconformity signifying cessation of Sargur orogeny. This unconformity is defined by the presence of locally uraniferous quartz-pebble conglomerate (QPC). Numerous narrow linear belts and enclaves of the Sargur Group (3100 - 3300 Ma) are seen within Peninsular gneisses, mainly in the south.

Western Dharwar craton is occupied by vast area of Peninsular Gneiss along with two prominent superbelt belonging to the Dharwar Supergroup. They are:

- Bababudan - Western Ghats - Shimoga; and
- Chitradurga - Gadag.

The greenstone belts of the Western Block are characterised by supracrustal rocks dominantly consisting of mature sediments with subordinate volcanism and intermediate pressure (kyanite - sillimanite type) Barrovian metamorphism. Let us discuss the regional stratigraphy of WDC represented by the various lithological units mentioned in Table 4.2.

Table 4.2: Regional stratigraphic of the Western Dharwar craton. (Source: Swami Nath and Ramakrishnan, 1981)

		Proterozoic mafic dykes Charnockites (2500-2600 Ma) Younger granites (2600 Ma)
DHARWAR SUPERGROUP (2600-2800 Ma)	CHITRADURGA GROUP	Hiriyur Formation Greywacke-argillite suite with volcanics, pyroclastics, cherts, polymict conglomerate
		Ingaldhal Formation Mafic-felsic volcanics (bimodal volcanics), pyroclastics, cherts and phyllites
		Vanivilas Formation Manganese and iron formations, stromatolitic carbonates, biogenic cherts, pelites, quartzites and polymict conglomerates
	-----Disconformity-----	
	BABABUDAN GROUP	Mulaingiri Formation BIF with chloritic and graphitic schists, phyllites and rare ultramafic-mafic sills
		Santaveri Formation Metabasalts, felsic volcanics, ultramafic schists, cross bedded quartzite
		Allampura Formation Metaproxenite, metabasalts, cross bedded quartzite
		Kalsapura Formation Metabasalts, gabbros, ultramafic schists, phyllites, cross bedded quartzite, basal quartz pebble conglomerate
	-----Deformed angular unconformity-----	
	Peninsular Gneiss (>3000Ma)	
	-----Intrusive/Tectonic contact-----	
SARGUR GROUP (3100-3300Ma)	Ultramafic-mafic layered complexes, tholeiitic amphibolites, komatiites, BIF Quartzites, pelites, marbles and calc-silicate rocks	
	-----Intrusive/Tectonic contact-----	
		Gorur Gneiss (3300-3400 Ma)

- **Gorur Gneiss:**

It is the oldest gneiss (3300-3400 Ma) in WDC consisting of suite TTG gneisses. The relationship of Gorur Gneiss with Sargur enclaves is uncertain.

- **Sargur Group:**

Numerous narrow linear belts, e.g. Holenarsipur, Nuggihalli and Nagamangla occur as rafts within Gorur gneissic complex of Sargur Group (3100-3300 Ma) in WDC, along a intrusive contact. The lithology consists of ultramafic-mafic layered complexes, tholeiitic amphibolites, komatiites, BIF, quartzites, pelites, marbles and calc-silicate rocks. They are comparable to true greenstones in having rocks with high mafic-ultramafic component.

- **Dharwar Supergroup:**

Dharwar Supergroup has been divided into two groups (Table 4.2):

- Upper Chitradurga
- Lower Bababudan

The supergroup is exposed in two large schist belts that may be called superbelts. They are:

- 1) Bababudan - Western Ghats - Shimoga; and
- 2) Chitradurga - Gadag.

Let us briefly discuss the lithology of these schist belts.

- **Bababudan Group/Schist Belt:** This is a squarish crescent shaped belt occupying an area of about 2500 sq. km in Bababudan region of Karnataka state. It has a normal contact in the south marked by basal QPC and resting mainly on the basement consisting of TTG gneisses and Dharwar Supergroup. The schist belt comprises mainly of basaltic volcanics and a range of detrital and chemical sediments. The stratigraphy of Bababudan Group in this belt consists of four formations arranged in stratigraphic order as follows:

- Mulaingiri Formation
- Santaveri Formation
- Allampura Formation
- Kalsapura Formation

The lower three formations are dominated by amygdular and massive tholeiitic metabasalts with local cross-bedded and rippled marked quartz arenites (sandstones) and minor pelites. Mulaingiri Formation consists essentially of BIF with phyllites and minor mafic-ultramafic rocks. Bababudan sediments and volcanics suggest nearshore to shallow marine and subaerial to shallow marine environment.

- **Chitradurga Group/Schist Belt:** Chitradurga Schist belt is probably one of the longest (450 km) greenstone belts of Dharwar craton where volcano-sedimentary sequences of large span of geological time are preserved. It extends from Gadag in the north to Mysore in the south in N-S direction.

The schist belt predominantly comprises bimodal (mafic-felsic) volcanics, pillow basalt (Fig. 4.4b), greywacke, conglomerates, phyllites, BIF, quartzite and chert. It is divided into three main formations separated by BIF horizons:

- Hiriyr Formation
- Ingaldhal Formation
- Vanivilas Formation



Fig. 4.4: a) Bimodal (mafic-felsic) volcanics in Ingaldhal Formation exposed along Chitradurga Schist Belt in Chitradurga; b) Pillow Lava in the metabasalts hosted within Chitradurga schist belt, Dharwar Supergroup exposed at Chitradurga District, Karnataka.

The **Vanivilas Formation** corresponds to Volcanic Formation consisting of manganese and iron formations, stromatolitic carbonates, biogenic cherts, pelites, quartzites and polymict conglomerates and metabasites. This is

followed by **Ingaldhal Formation** consisting of bimodal volcanics (Fig. 4.4a), pyroclastics, cherts and phyllites. The overlying **Hiriyur Formation** constitutes of greywacke-argillite suite with volcanics, pyroclastics, cherts, polymict conglomerate. The sedimentary units exhibit sedimentary structures characteristic of turbidites. The Chitradurga Subgroup is intruded by Chitradurga granite with an age of 2600 Ma, which gives younger limit of Dharwar sequence.

4.2.3 Eastern Dharwar Craton

The Eastern Dharwar Craton (EDC) is characterised by volcanic-dominated, sediment poor and gold-rich greenstone belts, in contrast to WDC. These greenstone belts are engulfed on all sides by younger granitoids. They are preserved as linear arcuate belts with limited width dismembered and punctuated by different types of granitoids of variable ages, but mostly 2.5 - 2.6 Ma. Neoarchaeon rocks of EDC have three major lithological types:

- Greenstone Belts (GSB)
- Tonalite Trondhjemite Granodiorite (TTG)
- Granitoids

Unlike WDC, the basement-cover unconformities are not present in EDC. You have read about the distinct stratigraphic divisions in WDC. But such divisions in EDC are not evident. The linear arrays greenstone belts of EDC are called superbelt. Yeshwantanagar Formation of Sandur belt has similarities with Bababudan Group. Most of the greenstone belts of EDC are correlateable with Chitradurga Group of WDC. These greenstone belts are auriferous. Kolar belt is regarded as the type area and the rocks are called **Kolar Group**. It has been considered as type area of the eastern greenstone belts and has been correlated with the Chitradurga Group. The amphibolites of the Kolar schist belt yields ~2700 Ma age like metabasalts of Ramagiri schist belt (Fig. 4.5a). At the eastern margin of belt occurs a prominent horizon of felsic volcanic and volcanoclastic suite of "Champion Gneiss" (Fig. 4.5b).





Fig. 4.5: Field photographs showing: a) Metabasalt (amphibolite) from Ramagiri greenstone belt, Ananthapur district; and b) Pyroclastics in Champion gneiss hosted in Kolar Schist Belt at Kolar.

The generalised stratigraphy of the Eastern Dharwar Craton is given in Table 4.3.

Table 4.3: Composite stratigraphy of the Eastern Dharwar Craton.

(Source: Ramakrishnan and Vaidyanadan, 2008)

DHARWAR SUPERGROUP (2600 - 2800 Ma)	KOLAR GROUP (Chitradurga Group)	Proterozoic mafic dykes Charnockites (2500-2600Ma) Dharwar Batholith (2500-2700 Ma)
		Champion Gneiss Felsic volcanics with volcanoclastics, wacke, volcanogenic polymict conglomerate, minor metabasalt with BIF.
		Goldfield Volcanics Bimodal mafic-felsic volcanics, pyroclastics, Komatiites, BIF, cherts, greywackes, pelites, carbonate rocks and minor polymict conglomerate, minor basalt and BIF.
	Sakarsanahalli Formation	Quartzite, manganiferous marbles, stromatolitic carbonate rock, calc silicate rock, pelitic schists with cordierite, andalusite, staurolite and garnet, amphibolites, BIF and basic-ultrabasic sills.
	Yashantanagar Formation (Bababudan Group)	Mafic-ultramafic rocks, quartzites, BIF
	Base not seen (>3000 Ma)	

The prominent greenstone superbelt in the Dharwar Supergroup in EDC are mentioned below:

- Ramgiri - Penakacherla Belt - Hungund Superbelt
- Kolar - Kadiri - Hutti Superbelt
- Velligallu - Raichur - Gadwal Superbelt

The generalised lithology of greenstone belts consists of pyroclastic rocks, quartzites and local conglomerates, greywackes with BIF, limestones and dolomites, bimodal volcanics and ultramafics.

A comparison between WDC and EDC is summarised in Table 4.4.

“Closepet Granite” is marked by the granitic intrusion reflects the end of Dharwar cycle. This belt of younger potassic granites marks a major geo-suture or joint between two distinct crustal blocks, western block and eastern block.

- **Life:** The stromatolite *Batiola indica* has been reported from sediments of the Chitradurga Group. Microbial trichomes are recorded from a black chert band interlayered with the BIF belonging to the Sandur Schist Belt. Microbiotic remains have been reported from the stromatolite structures of the Bababudan Group.

Table 4.4: Simplified stratigraphy of Archaean Dharwar craton. (Source: Swami Nath and Ramakrishnan, 1981)

Age	Western Dharwar Craton (WDC)	Eastern Dharwar Craton (EDC)
2500 Ma	Younger granite (Chitradurga, Arsikere) Charnockite	Younger granite/gneiss (Closepet and equivalents) Charnockite
2600-2800 Ma	Chitradurga Group Bababudan Group	Kolar Group Yashwantanagar Formation
	-----unconformity-----	
~3000 Ma	Peninsular Gneiss	Enclaves of older gneiss
3100-3300 Ma	Sargur Group	(?) Warangal Group (?) Salem Group
3200-3400 Ma	Gorur Gneiss	Putative Basement

- **Mineral Potential:** The western block is characterised by the mineralisation of copper, iron and manganese along with the minor occurrence of gold, i.e. Gadag. Bababudan schist belt has important deposits of economic importance particularly iron ores at Kudremukh besides minor occurrence of gold, uranium and asbestos are also known. The important auriferous belts are Kolar, Ramagiri - Penakacherla, Hutti, Maski in EDC. They are also known for iron and manganese mineralisation.

4.3 CUDDAPAH SUPERGROUP

Proterozoic sedimentary basins in peninsular India also known as the *Purana Basins* were formed between Late Palaeoproterozoic and Mesoproterozoic time. The Vindhyan, Chhattisgarh and Cuddapah basins (Fig. 4.6) are the three most extensively developed Proterozoic basins on the Archaean cratons of Bundelkhand, Bastar and Dharwar, respectively. We shall discuss the

sedimentary sequences of Vindhyan and Cuddapah basins in the following sections.

The Cuddapah basin is spectacular crescent shaped, easterly concave N-S trending basin located in the south-central part of Andhra Pradesh and Telangana covering an area of 44,500 sq. km². The basin extends for a length of about 450 km along the eastern margin of Indian peninsula (Figs. 4.6 and 4.7). It consists mainly of orthoquartzite - carbonate suite and basic to acid volcanics and sills in the lower part and siliceous shales with quartzites in the upper part, having estimated thickness varying from 6-12 km. The lithostratigraphy of Cuddapah basin is formalised in terms of the Cuddapah Supergroup and the Kurnool Group. The Cuddapah Supergroup is predominantly arenaceous to argillaceous with subordinate calcareous to dolomitic units. The Upper Proterozoic succession of the Cuddapah basin is known as Kurnool Group, which rests unconformably over the rocks of the Cuddapah Supergroup. The Kurnool Group mainly consists of carbonate sediments with subordinate fine clastics.

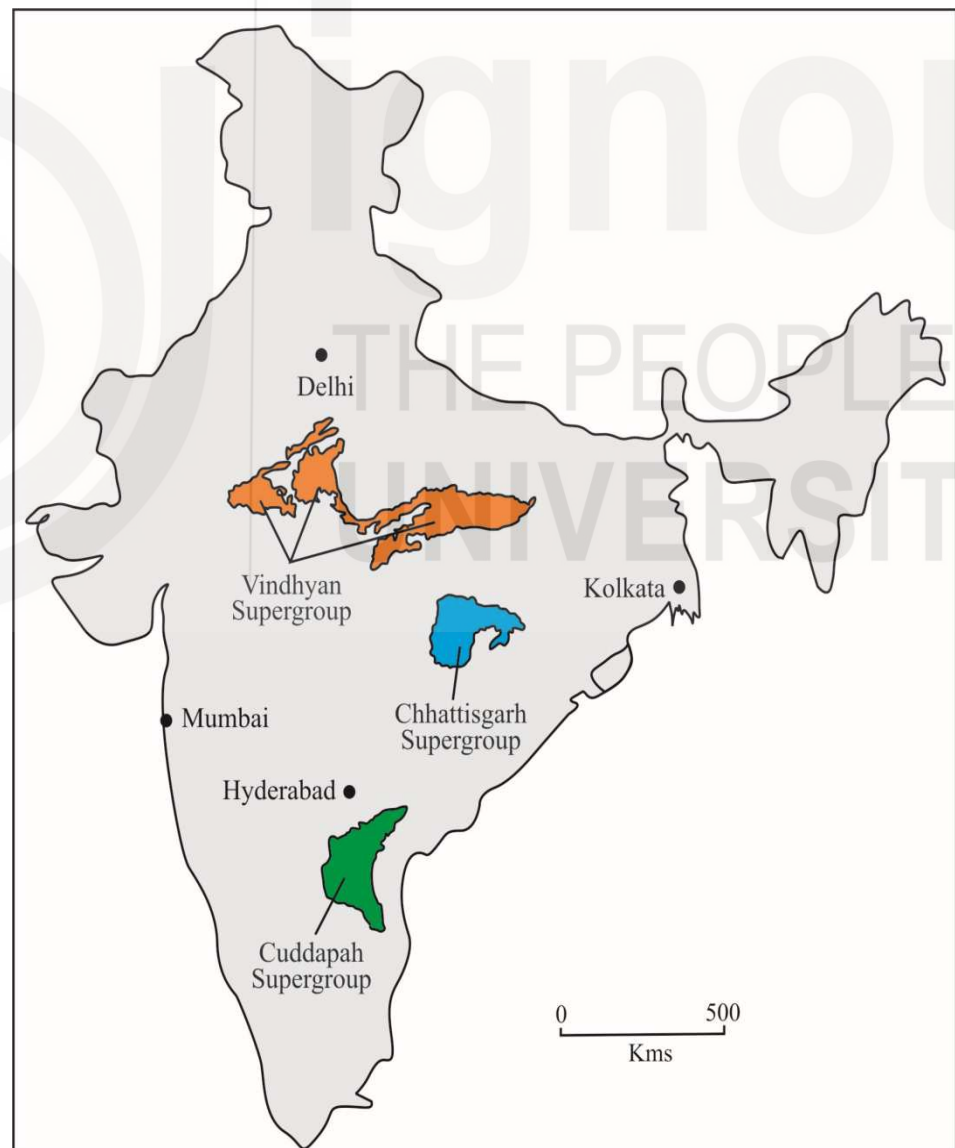


Fig. 4.6: Map showing major Proterozoic basins of peninsular India. (Source: simplified from Vaidyanadhan and Ramakrishnan, 2008)

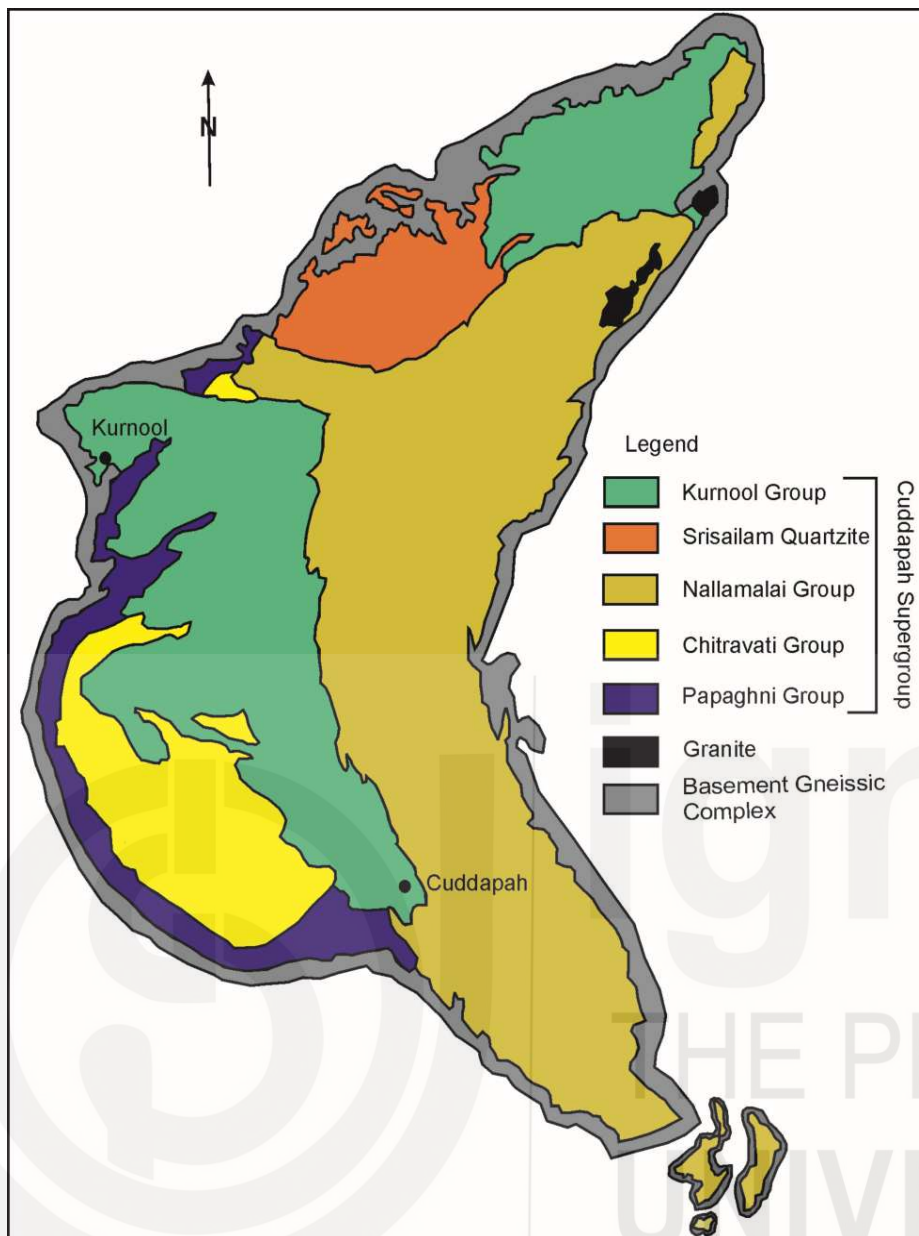


Fig. 4.7: Cuddapah basin in the Eastern Dharwar craton. (Source: GSI, 1981b)

4.3.1 Stratigraphic Classification

A fourfold stratigraphic classification was proposed for the first time by King in 1872 remained unchallenged for over century. After King's monumental work, no detailed work was carried out by any agency for about 60 years.

Narayanaswami in 1976 proposed five-fold classification. Subsequently, Nagaraja Rao et al. (1987) presented a revised three-fold classification in accordance with the stratigraphic code. Cuddapah Supergroup has been divided into three groups. They are:

- Papaghni;
- Chitravati; and
- Nallamalai.

Each group starts with quartzite and ends with a shale unit representing cycle of quartzite – shale sequence reflecting successive transgressions in the basin. The stratigraphy of Cuddapah Supergroup is presented in Table 4.5.

4.3.2 Lithology

Now let us discuss the lithological units of Cuddapah Supergroup stratigraphically starting from the lowermost.

1. Papaghni Group:

It is best exposed in the Papaghni river valley. The group has been further subdivided into two formations:

- Vempalle Formation
- Gulcheru Quartzite

The **Gulcheru Quartzite** is the lowest formation of Cuddapah Supergroup. It rests over the Archaean granitic basement with classic angular unconformity known as Eparchaeon unconformity over the greenstone belts of Eastern Dharwar Craton. It is well exposed in the temple town Tirupati and has been declared as National Geological Monument (Fig. 4.8). This formation consists mainly of conglomerates, arkoses and quartzites. The pebbles of Gulcheru conglomerate are derived from the Archaean basement (Fig. 4.9a).

Gulcheru Quartzite is conformably overlain by the **Vempalle Formation**. It is mainly a calcareous unit consisting of stromatolitic dolomites (Fig. 4.9b), dolomitic shales, sandstones, quartzites and cherts. It is associated with phosphatic and uraniferous horizons in lower part. Kuppalapalle Volcanics consist of tholeiitic basalt and basaltic andesite occurs at the top of Vempalle Formation. The mafic igneous activity is dated at ~1800 Ma. The sedimentation in the Papaghni subbasin begins with the deposition of fluvial quartzites and conglomerates with minor intercalations of sandstone–shale of peritidal origin.



Fig. 4.8: Panoramic view of Eparchaeon unconformity. Dharwar craton is unconformably overlain by rocks of the Cuddapah basin, i.e. Gulcheru Quartzite. (Photo credit: Dr. M. Prashanth)

2. Chitravathi Group:

This group is well exposed in Chitravathi and Cheyiar river. The group is divided into three formations:

- Gandikota Quartzite
- Tadpatri Formation
- Pulivendla Quartzite

Table 4.5: Stratigraphic Succession in the Cuddapah Supergroup. (Source: Nagaraja Rao et al. 1987)

Super group	Group	Formation	Lithology
KURNOOL GROUP (200-450 m)			
-----Unconformity-----			
		Srisailem Quartzite (300m)	Glaucanitic ferruginous quartzite and shale
-----Unconformity-----			
CUDDAPAH SUPERGROUP	NALLAMALAI GROUP (3500-6000 m)	Cumbum (Pullampet) Formation	Cumbum: Slate and phyllite, quartzite, dolomite Pullampet: Shale, dolomite, quartzite, felsic tuff, baryte
		Bairenkonda (Nagari) Quartzite	Bairenkonda Quartzite : Quartzite, quartz wacke, shale Nagari: Conglomerate, quartzite, quartz wacke, shale with intrusives
		-----Angular Unconformity-----	
		Gandikota Quartzite	Shale-quartzite, alternations, glauconitic quartzite interbeds
	CHITRAVATI GROUP (4900-5000 m)	Tadpatri Formation	Shale, felsic tuff, basic sills and flows, chert stromatolitic dolomite quartzite
		Pullivendla Quartzite	Quartzite and conglomerate
	PAPAGHNI GROUP (2100 m)	Vempalle Formation with Kuppalapalle Volcanics	Stromatolitic dolomite, dolomitic mudstone, chert breccia, quartzite with basic sills and flows
		Gulcheru Quartzite	Basal conglomerate, arkose, quartzite with shale
	-----Eparchaeon Unconformity-----		
	Crystalline basement of Dharwar Craton		

Pulivendla Quartzite constituting of quartzites and conglomerates is thin and persistent horizon exposed all along the western margin disconformably overlying the Vempalle Formation of the Papaghni Group with a basal conglomerate marking the hiatus.

Tadpatri Formation has a gradational contact with the underlying Pulivendla Quartzite. It is mainly argillaceous unit with thin intercalations of quartzites,

stromatolitic dolomites and volcanogenic sediments. Large thickness of felsic pyroclastics is seen in Tadpatri Formation.

The conformably overlying **Gandikota Quartzite** is named after its type locality Gandikota Fort that has a gradational contact with the Tadpatri Formation. It consists of shales, quartzites (glauconite-bearing) and alternate sequence of thick quartzites which is rippled-marked and cross laminated. The depositional environment ranges from sub-tidal to shallow marine with overlap of carbonate tidal flat.

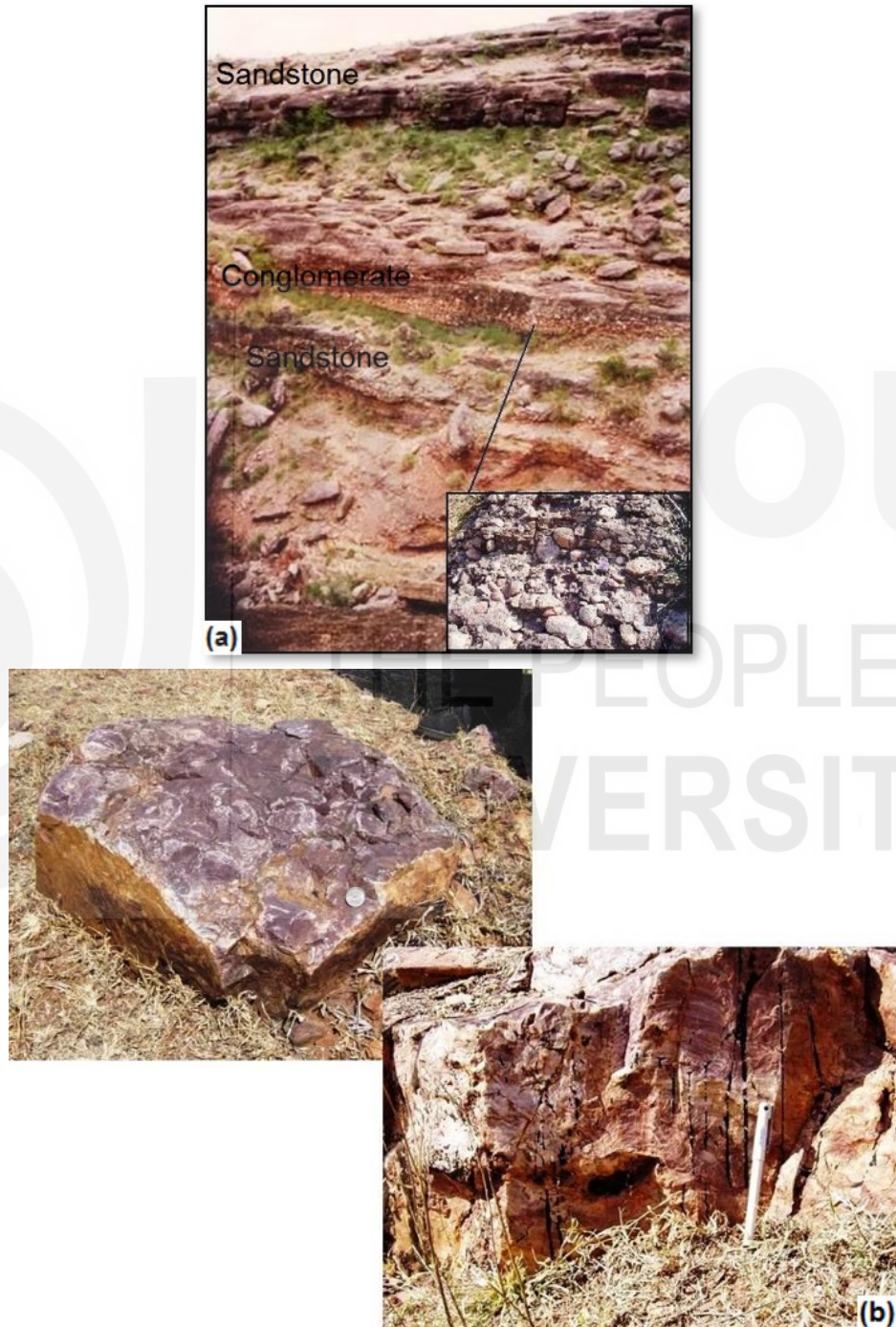


Fig. 4.9: Field photographs showing: a) Well-bedded and low dipping Gulcheru sandstone. The photograph in the inset shows the close up of the Basal Gulcheru conglomerate at intervals, Tirupati; b) Chertified stromatolites in plan and cross section within cherty dolomite of the Vempalle Formation. [Photo credit: Prof. R.C. Hanumanthu (Retd.), Sri Venkateswara University, Tirupati]

3. Nallamalai Group:

The succession is best exposed in the Nallamalai hill range has been divided into two formations:

- Cumbum Formation correlated with Pullampet Formation
- Bairenkonda Quartzite correlated with Nagari Quartzite

The lower formation known as **Bairenkonda Quartzite** is best exposed in the hill and its type locality Bairavunikonda. It consists mainly of a quartzite-pelitic cycle in the lower part and a thick mature quartz arenite in upper part. **Nagari Quartzite** is a thick-bedded arenaceous unit with basal conglomerates.

Cumbum Formation, named after Kambhan village, is essentially shaly sequence with intercalations of quartzites and dolomites. **Pullampet Formation** consisting of purple and calcareous shales with interbeds of dolomite and quartzite conformably overlies **Nagari Quartzite**. The deposition ranges from shallow marine to shallow subtidal environment.

- **Srisailam Quartzite:**

The rocks of this formation are exposed along the Krishna river cutting a deep gorge in the Nallamalai plateau. It is horizontally bedded comprises of red quartzites, glauconite bearing ferruginous quartzites overlying Papagani and Nallamalai Groups with unconformity. The evidences suggest that the deposition took place under shallow marine to tidal flat environment.

- **Igneous activity:** The major igneous activity associated with Vempalle and Tadpatri Formations in the western part of the basin are dolerite, picrite and gabbro sills, basaltic flows, ignimbrites and ash fall tuffs. Nagari Quartzite, Pullampet and Cumbum Formation are traversed by dolerite sills. Kimberlite dykes and syenite stocks are found in Cumbum rocks. Kimberlitic rock of Chelima emplaced in Cumbum sediments have yielded an age of 1225 Ma.
- **Life:** Lower Cuddapah carbonate rocks are full of significant columnar stromatolites. The stromatolite structures of the Vempalle and Tadpatri formations have yield organic remains such as *Conophyton*, *Kussiella*, *Colomnella* and algal mats of the Riphean age.
- **Mineral Potential:** Cuddapah basin is the repository of a number of mineral deposits. The world-famous Koh-i-noor diamond comes from this basin. Ancient mining activity is believed to extend as far as 5th century B.C. The basin holds dominant position in terms of industrial minerals chrysotile asbestos, baryte, base metals, diamond, phosphorite, uranium, steatite, clay and ochre. It's potential for other raw materials like high-grade limestones, dolomite, flooring stones and slate. The dolomite from Cumbum Formation hosts a marginal lead-zinc deposit at Agnigundala. Pullampet Formation at Mangampeta hosts largest deposit of bedded baryte in the world. It has been declared as a National Geological Monument. Lead and copper mineralization has been reported from the rocks of Nallamalai Group. Steatite is reported from Vempalle Formation (Fig. 4.10).

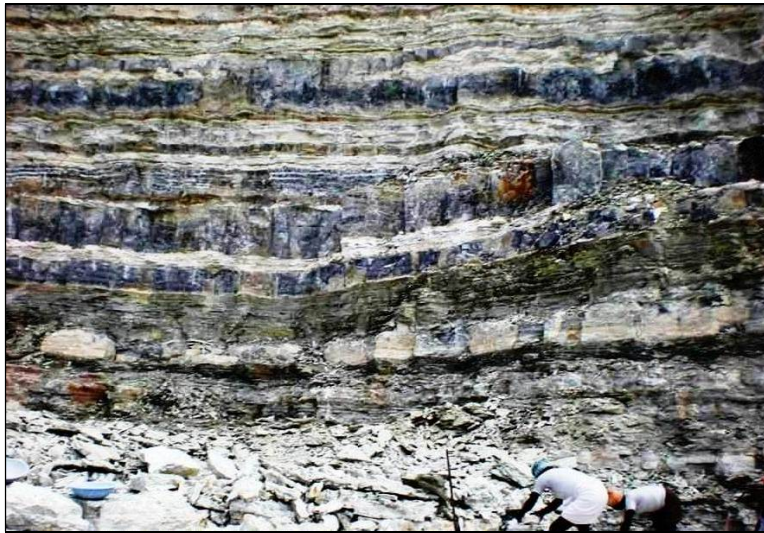


Fig. 4.10: Steatite mine in Vempalle Formation near Rayalacheruvu. (Photo credit: Prof. R.C. Hanumanthu)

Learners, you have learnt about the stratigraphic classification of Dharwar Craton and Cuddapah Supergroup. Before discussing about the Vindhyan Supergroup, spend few minutes to perform an exercise to check your progress.

SAQ 1

- Mention the basis for division of Dharwar into two blocks.
- What is the significance of quartz-pebble conglomerate (QPC)?
- List two greenstone belts of WDC and EDC.
- Write about the life reported in the Cuddapah Supergroup.
- List formations of Cuddapah Supergroup with igneous activity.

4.4 VINDHYAN SUPERGROUP

The Vindhyan basin is the spectacular, sickle shaped largest single Proterozoic basin in the Indian Peninsular shield situated on the Bundelkhand craton (Figs. 4.1 and 4.6). The ENE trending Vindhyan basin spreads over the parts of Rajasthan, Madhya Pradesh, Uttar Pradesh and Bihar extending from Sasaram in Bihar to Chittaurgarh in Rajasthan (Fig. 4.11). Vindhyan sediments, spreading over an area of 100,000 sq. km of which about 60,000 sq. km is exposed for direct observation and rest is covered by Deccan Traps in the south-west and Indo-Gangetic alluvium towards the north. The basin is separated from Aravalli-Delhi orogenic belt by westerly dipping Great Boundary Fault Zone (GBFZ) in the west. The Vindhyan basin has been divided into three sub-basins (from west to east) Rajasthan, Bundelkhand and Son valley sector of which the latter two are larger (Fig. 4.11). The Vindhyan succession in the Bundelkhand sector is dominated by carbonates while siliciclastics (sandstones and shales) and carbonates are equally prevalent in the Son valley and Rajasthan sectors. The first Director of Geological Survey of India, Thomas Oldham in 1856 introduced the term 'Vindhyan' for this Supergroup. The name

'Vindhyan' is derived from the great 'Vindhyan Mountains' of Central India. The Vindhyan Supergroup consists of about 4500m thick sedimentary pile comprising a sequence of sandstone and shale in almost equal proportion with subordinate carbonates, in the lower part. Vindhyan rocks show the excellent preservation of sedimentary structures.

4.4.1 Stratigraphic Classification

The studies on Vindhyan basin commenced from the work of D.H. Williams in 1848. Three-fold division of the supergroup: Kaimur, Rewa and Bhandar was proposed by T. Oldham in 1856. Lower Vindhyan was designated as Semri by F.R. Mallet in 1869. Vindhyan Supergroup has been divided into four groups by Auden in 1933 as follows in chronological order:

- Bhandar Group
- Rewa Group
- Kaimur Group
- Semri Group

The common terms in usage are the Lower Vindhyan (for the Semri Group) and the Upper Vindhyan (for Kaimur, Rewa and Bhandar groups). The general stratigraphic scheme of the Vindhyan Supergroup is summarised in Table 4.6. The alternative names of the formations have been mentioned in the Table 4.6

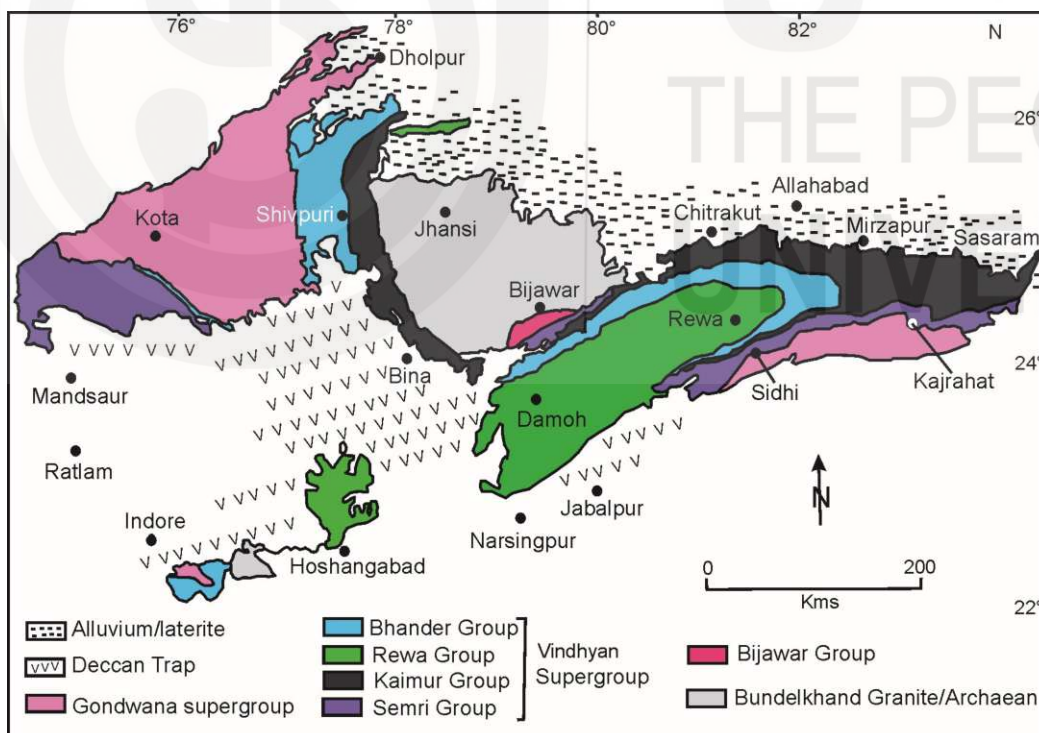


Fig. 4.11: The regional geological map of Vindhyan Basin. (Source: Soni et. al. 1987)

4.4.2 Lithology

Let us discuss the lithology of the groups mentioned in Table 4.6.

Table 4.6: Stratigraphic classification for the Vindhyan Supergroup.

(Source: Ramakrishnan and Vaidyanadhan, 2008)

VINDHYAN SUPERGROUP (Meso-Neoproterozoic)	Group	Formation	Alternative Names
	Bhander Group (1300-1500 m)	Maihar Sandstone	Upper Bhander Sst.
		Sirbu Shale	
		Bundi Hill Sandstone	Lower Bhander Sst.
		Lakheri Limestone	Bhander Lst., Nagod Lst.
		Ganurgarh Shale	Simrawal Shale
	-----Unconformity/Gradational contact-----		
	Rewa Group (100-300 m)	Govindgarh Sandstone	Upper Rewa Sst.
		Drummondganj Sandstone	
		Jhiri Shale	Variegated Shale
		Asan Sandstone	Upper Rewa Sst.
		Panna Shale	
	-----Normal contact/Facies change-----		
	Kaimur Group (400 m)	Dhandraul Quartzite	Upper Kaimur Sst.
		Mangesar Formation	Scarp Sandstone
		Bijaigarh Shale	
		Markundi Sandstone	Ghaghar Sandstone
		Ghurma Shale	Susnai Breccia
		Sasaram Sandstone	Lower Kaimur Sst.
	-----Unconformity/Normal contact-----		
	Semri Group (3000-4000 m)	Suket Shale	Baghwar Shale
		Rohtas limestone	Nimbahera Lst.
		Chorhat Sandstone	Glaucconitic bed, Rampur Sst., Basuhari Sst.
		Bargawan Limestone	Salkhan Lst., Fawn Lst., Chorhat Lst.
		Kheinjua Shale	Olive Shale, Binota Shale, Koldaha Shale
		Chopan Porcellanite	Deonar Porcellanite
		Kajrahat Limestone	Kuteshwar Lst., Tirohan Lst.
		Arangi Shale	
		Deoland Sandstone	Khardeola Sst., Pandwafall Sst.
	-----Angular Unconformity/Non-conformity-----		
	Gneisses and supracrustals		

- **Semri Group:**

The name Semri comes from the Semri River, its type locality near Bijawar. Semri Group rests with non-conformity on the Bundelkhand granite (Fig. 4. 12a), and on the Banded Gneissic Complex (BGC) with angular unconformity. The basal succession consists of conglomerates, ferruginous sandstones and shales mainly exposed in Rajasthan (Khardeola Sandstone). In Bundelkhand and Son valley, the basal unit consists of sandstones (Deoland or Pandwafall Sandstone) overlain by shales (Arangi Shale). The overlying stromatolitic limestones and dolomites (Kajrahat/Tirohan Limestone and Lohar Dolomite) suggest a continental shelf setting. The basal succession is overlain by felsic

pyroclastics and volcanics known as Chopan/ Deonar Porcellanite Formation. The Porcellanite consists of tuffaceous beds (Fig. 4.13b), pumice tuffs, agglomerates, breccia, bedded chert and volcanic bombs. Olive Shale also known as Kheinjua Shale is olive green in colour with well developed pencil fracture. It is overlain by stromatolite bearing Fawn coloured limestones or Bargawan Limestone in which *Collenia clappii* and *Conophyton garganicus* are profusely developed (Fig. 4.14). Fawn Limestone is overlain by the Glauconitic Sandstone (also called Chorhat Sandstone). Rohtas Limestone of the Semri Group (Lower Vindhyan) is conformably overlain by the Sasaram Sandstone of the Kaimur Group (Upper Vindhyan) (Fig. 4.12b). The lithologies of Semri Group suggest a composite environment of deposition varying from lagoonal to subtidal.

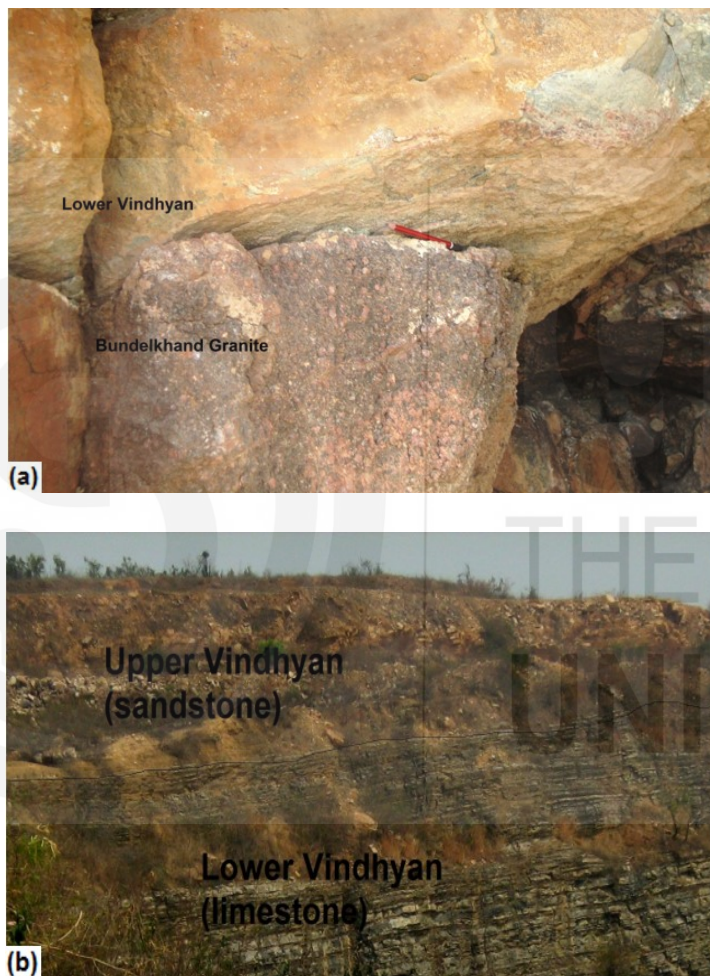


Fig. 4.12: a) Unconformable contact between sandstone of Lower Vindhyan deposited on Bundelkhand Granite, Chitrakoot, U.P.; and b) Field photograph showing Sasaram sandstone of Upper Vindhyan conformably resting over the Rohtas limestone of Lower Vindhyan in Son valley, Sonbhadra district.

- **Kaimur Group:**

It is named after Kaimur scarp and exhibits conformable contact with the Semri Group in the Son valley and Chittorgarh. Kaimur Group is essentially most extensively developed argillo-arenaceous succession. Sasaram Sandstone is the basal part of Kaimur Group which is overlain by the Markundi Sandstone. They are intervened by the Ghurma Shale or Susnai Breccia. They have been

interpreted to have deposited in barrier beach dune or tidal flat environment. The overlying Bijaigarh pyritiferous shale with pyrite beds near Amjhore (40% sulphur) suggests quiet lagoonal environment. Mangesar Formation and the overlying Dhandraul Quartzite (Fig.4.13a) consisting of arkosic and arenitic sandstones is interpreted as a braided ephemeral stream deposit or as sandy intertidal flat or tidal channel deposit.

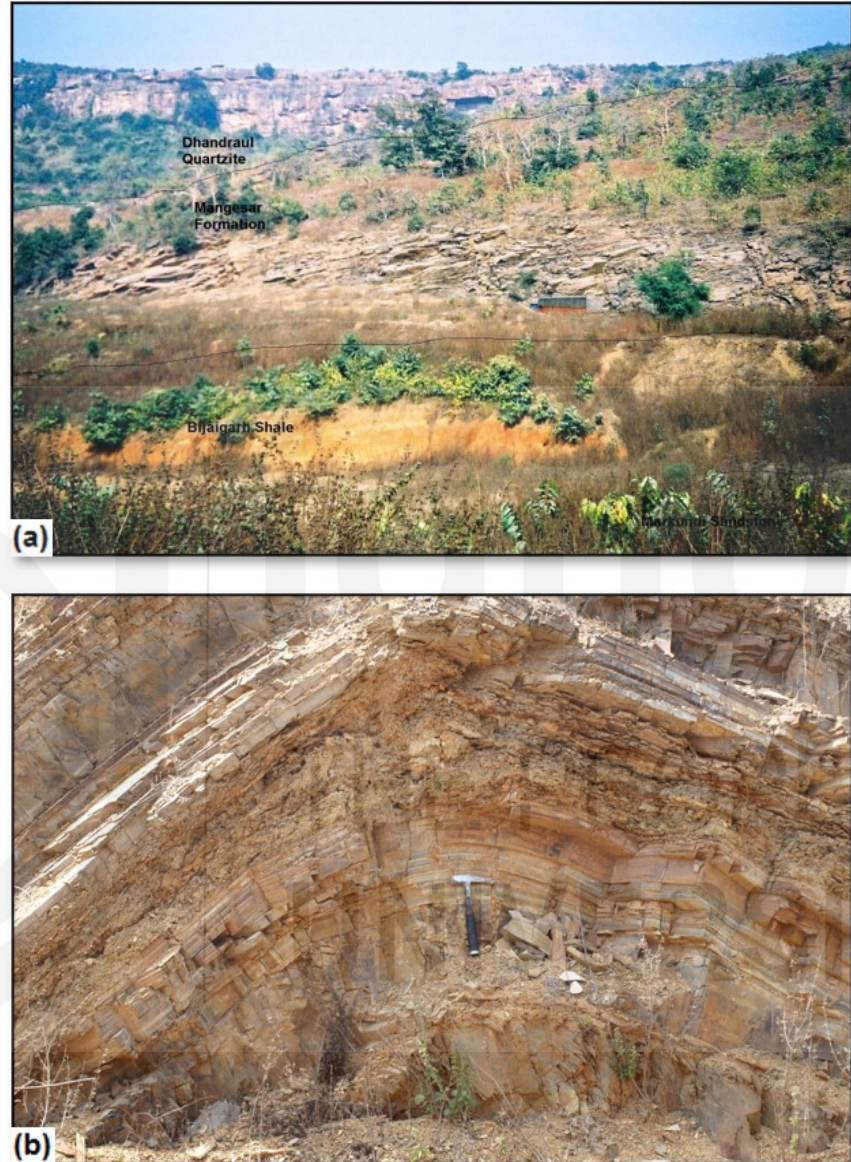


Fig. 4.13: a) Panoramic view of Kaimur Group rocks in Son valley, Sonbhadra district, and b) Tuffaceous beds in Porcellanite Formation.

- **Rewa Group:**

This name is derived from the then Rewa State. The basal Panna Shale, without any basal conglomerate, indicates continuity of deposition from the Kaimur Group. Panna Shale and Asan Sandstone consisting of red shales, limestones, barytes and glauconitic siltstones indicate a lagoonal environment. This is overlain by the Jhiri Shale by a gradational contact and is separated from the Asan Sandstone by a diamondiferous conglomerate at Panna. Red shale, with glauconitic siltstones indicate lagoonal, lacustrine or offshore environment. The overlying Drummondganj Sandstone is deposited in shore

face environment. This is overlain by the Govindgarh Sandstone which is poorly sorted and texturally immature, indicating either fluvial, deltaic or near shore muddy tidal flat environment.

- **Bhander Group:**

It is named after Bhandar Upland. The basal unit of Ganurgarh Shale is the diamondiferous conglomerate in Panna area, but elsewhere has a gradational contact with the Rewa Group. The Ganurgarh is chocolate coloured shale with stromatolitic limestone and sandstone interbeds that contain intraformational breccia and halite clasts. Lakheri Limestone with algal mats and stromatolites, dessication structures, gypsum layers suggest an evaporitic environment. The overlying Bundi Hill Sandstone is a fining upward sequence. The overlying Sirbu Shale with halite casts indicates oxidising to arid conditions. The overlying Maihar Sandstone is a blanket deposit with sedimentary structures and intercalated stromatolitic limestone beds. Bhandar Group lithology is indicative of shoreline-lagoon-tidal flat environment.

- **Age:** Data from radiometric dating has fixed the initiation of Vindhyan sedimentation around 1600-1720 Ma. Pb-Pb age has yielded 1720 Ma for the Kajrahat Limestone. Felsic volcanics of the Chopan Porcellanite from the Semri Group provide zircon U-Pb age of 1632 Ma. Rb-Sr ages from Kimberlites of Panna suggest age of Kaimur Group to be about 1100-1150 Ma. The ages of Rewa and Bhandar Groups have been estimated to be 1100-700 Ma. Many workers advocate the time span of over 1000 Ma between 1700-600 Ma as a period of uninterrupted sedimentation of the Vindhyan Supergroup.



Fig. 4.14: Stromatolites preserved in Fawn Limestone at Salkhan Fossil Park in Sonbhadra district.

- **Life:** Direct (mega- and micro- fossils) or indirect (stromatolites, trace fossils, algal mats) evidences indicate the presence of life during Vindhyan period. The stromatolites *Collenia clappii* and *Conophyton garganicus* have been reported from the Fawn limestone. Microfossils have been reported from Semri and Bhandar groups which include cyanobacterial, bacterial, algal, fungal and acritarchal remains. Several instances of small shelly fauna, primitive brachiopod, Ediacaran fauna as well as trace fossils have been

reported from the Semri Group to suggest that Vindhyan extend to Lower Cambrian period.

- **Mineral Potential:** The Vindhyan basin is well known for its resources of diamond, limestones and dolomites, base metals, building stones, laterite, ochre and glass sand. Occurrence of mineralisation and native sulphur are noted at Semri in Bundelkhand.

In the previous sections you have studied about the Cuddapah Supergroup and Vindhyan Supergroup. Now in the following section we will discuss about the Delhi Supergroup.

4.5 DELHI SUPERGROUP

Delhi Supergroup is a part of the Aravalli craton. The Aravalli craton is exposed in the NE-SW trending Aravalli Mountain Range and occupies the northwestern part of the Indian shield. It is mainly exposed in the state of Rajasthan with sporadic occurrences in Haryana, Delhi, Gujarat and Madhya Pradesh. It is bounded by the Himalayas in the north, the Vindhyan basin and the Deccan Traps in the east, the Cambay graben in the south-west and recent alluvium lies to the west. It is well known for its rich base metal resources. Aravalli craton is composed of three fundamental geological units namely Banded Gneissic Complex (BGC), Aravalli Supergroup and Delhi Supergroup in ascending order.

Aravalli and Delhi supergroups are Palaeoproterozoic and Mesoproterozoic in age, respectively and occupied by the rocks of fold belts. Alternatively, the Aravalli Supergroup is also termed as **Aravalli Fold Belt** and the Delhi Supergroup as **Delhi Fold Belt**.

The Delhi Supergroup constitutes a major portion of the Aravalli Mountain Range and extends over a strike distance of about 700 km in Gujarat in southwest to Delhi in northeast, from where the supergroup derived its name. The rocks of the supergroup prominently occur in southwestern, northeastern and central Rajasthan in the form of a linear belt.

4.5.1 Stratigraphic Classification

Delhi Supergroup consists of about 3000 m thick upward-fining sequence of conglomerates and sandstones. It lies above the rocks of Archaean BGC and the Palaeoproterozoic Aravalli Supergroup and below the rocks of the Neoproterozoic Marwar Supergroup. The supergroup has been divided into three groups such as Raialo, Alwar and Ajabgarh in chronological order.

The stratigraphic succession of Delhi Supergroup has been summarised in Table 4.7.

- **Raialo Group:**

It is the basal most group of the Delhi Supergroup, and constitutes of texturally mature well-sorted Basal conglomerates which is an indicative of a beach environment. The conglomerates and pebbly quartzites are overlain by basic volcanics with sedimentary interbeds. Basic volcanics comprise explosive phase consisting of agglomerates, volcanic breccia and welded tuffs. The group

is made up of three formations such as Dogeta, Serrate and Tehla in the order of superposition (Table 4.7).

Table 4.7: Stratigraphic sequence of the Delhi Supergroup of northeastern Rajasthan. (Source: Roy and Jakhar, 2002)

Group	Formation	Lithology
DELHI SUPERGROUP	AJABGARH GROUP	Acid intrusives
		Granite, pegmatite and quartz veins
		Basic intrusives
		Amphibolite and metadolerite
		Arauli-Mandhan Formation
		Quartzite, staurolite-garnet schist, carbon phyllite, slate
		Bharkol Formation
		Quartzite with interbedded phyllite and carbon phyllite, slate
		Thana-Ghazi Formation
		Carbon phyllite, tuffaceous phyllite, sericite schist, quartzite and marble
	ALWAR GROUP	Seriska/Weir Formation
		Brecciated and ferruginous quartzite, chert, breccia, carbon, phyllite and marble
		Kushalgarh Formation
		Impure marble with lenses of phosphorite, back flows, agglomerate tuff
	-----unconformity-----	
	ALWAR GROUP	Pratabgarh Formation (=Bayana and Damdama Formation)
		Quartzite and quartz-sericite schist (conglomerate)
		Kankwarhi Formation (=Badalgarh Formation)
		Quartz-sericite schist, quartzite schist, quartzite with thin lenses of marble and conglomerate
	RAIALO GROUP	Rajgarh Formation (=Jogipura Formation)
		Quartzite, marble gritty quartzite, conglomerate
		-----unconformity-----
	RAIALO GROUP	Tehla Formation (=Jahaj-Govindpura Volcanics)
		Lava flow, pillow lava, agglomerate, spatter, pyroclastics, breccia, tuff, epiclastic breccia and associated conglomerate, quartzite, schist, phyllite, marble
		Serrate Quartzite (=Nithar Formation)
	RAIALO GROUP	Quartzite with wedge and lenses of oligomictic conglomerate
		Dogeta Formation
		Banded siliceous marble, quartzite phyllite, dolomitic marble with bands of conglomerate, quartzite, phyllite and schist

- **Alwar Group:**

It overlies the Raialo Group. It is largely arenaceous and made up of conglomerates, feldspathic quartzites, orthoquartzites and arkoses, along with minor shales. The lithology of Alwar Group is indicative of braided stream, subtidal and tidal flat depositional environments. It is made up of three formations namely Rajgarh, Kankwarhi and Pratapgarh.

- **Ajabgarh Group:**

It is the youngest group of the Delhi Supergroup, which disconformably overlies the Alwar Group. It is predominantly composed of carbonaceous shales, phyllites and quartzites. It is further divisible into five formations comprising Kushalgarh, Sariska, Thanagazi, Bhakrol and Arauli in ascending order. The Arauli Formation is overlain by the basic and acid intrusives.

- **Life:** Delhi Supergroup yields evidences of multicellular animal life in the form of trace fossils, fusiform and spindle shaped structures. The bioturbation signatures such as trails and tracks of organisms are also found in quartzites exposed in Jaipur, Alwar and Jhunjhunu districts.
- **Mineral Potential:** Delhi Supergroup is an important storehouse for base metals, other metallic and non-metallic minerals. About 50% of country's copper production comes from the Delhi Supergroup (i.e. Khetri copper belt in Jhunjhunu district). Other mineral resources are asbestos, baryte, calcite, china clay, fire clay, marble, mica, glass sand and flexible sandstone, building stones and ornamental stones.

Learners, you have learnt the stratigraphic classification of Vindhyan and Delhi Supergroup. Now, spend few minutes to perform an exercise to check your progress.

SAQ 2

- Mention the fundamental units of Aravalli craton.
- List the groups of the Vindhyan Supergroup.
- Name the three groups of Delhi Supergroup in ascending order.

4.6 ACTIVITY

Draw a map of India and mark the Precambrian cratons, Mobile belts and Proterozoic basins of Peninsular India.

4.7 SUMMARY

Now let us summarise what we have learned in this unit:

- Dharwar Craton has been divided into two tectonic blocks—the Western Block and the Eastern Block on the basis of differences in the character of schist belts, their inter-relationships with the surrounding Gray gneisses, grades of metamorphism and temporal evolution.
- Gray gneisses (2500-2700 Ma) cover the entire EDC. Peninsular gneisses are restricted to gneisses older than 3000 Ma which are restricted to WDC.
- WDC hosts large schist belts of the Dharwar Supergroup with volcanics and EDC hosts narrow linear belts of the Dharwar Supergroup.
- Western Dharwar Craton (WDC) has been grouped into two orogenic cycles separated in time, viz. the older Sargur Group and the younger Dharwar Supergroup.
- Proterozoic sedimentary basins are less disturbed and unmetamorphosed thick pile of sedimentary sequences overlying the deformed and metamorphosed Archaean basement.
- The Cuddapah basin hosts sedimentary successions ranging in age from the Paleoproterozoic through the Neoproterozoic with internal unconformities, i.e. Cuddapah Supergroup and Kurnool Group.

- Cuddapah Supergroup has been divided into three groups: Papaghni, Chitravati and Nallamalai. Each group represents a cycle of quartzite–shale sequence reflecting successive transgressions in the basin.
- Vindhyan basin has been divided into three sub-basins: Rajasthan, Bundelkhand and Son valley. Vindhyan Supergroup has been divided into four groups: Semri, Kaimur, Rewa and Bhandar.
- Aravalli craton constitutes of two major fundamental geological units: Banded Gneissic Complex and two Proterozoic fold belts (Aravalli and Delhi).
- Delhi Supergroup is Mesoproterozoic in age and has been divided into Raialo, Alwar and Ajabgarh groups.

4.8 TERMINAL QUESTIONS

1. Elaborate the four differences between Western Dharwar Craton and Eastern Dharwar Craton.
2. Describe the stratigraphic succession of the Dharwar Supergroup of Western Dharwar craton.
3. Discuss in detail the stratigraphy of Cuddapah Supergroup. Add a note to the igneous activity and mineral potential.
4. Elucidate the stratigraphic succession of Vindhyan Supergroup.
5. Give an account on the stratigraphy of the Delhi Supergroup.

4.9 REFERENCES

- GSI Map (1981b) Geological and Mineral Map of the Cuddapah basin. Scale 1:250,000 with Explanatory Brochure, 26p.
- Gupta, S.N., Arora, Y.K., Mathur, R.K., Iqbaluddin, Prasad, B., Sahai, T.N. and Sharma, S.B. (1980) Lithostratigraphic map of the Aravalli region. Geol. Surv. India, Calcutta.
- Nagaraja Rao, B.K., Rajurkar, Ramalingaswamy and Ravindra Babu, B. (1987) Stratigraphy, Structure and Evolution of the Cuddapah Basin. Purana Basins of Peninsular India. Memoir 6. Geological Society of India. Pp. 33-86.
- Naqvi S.M., Rogers J.J.W., (1996) Precambrian Geology of India, Clarendon, New York.
- Ramakrishnan, M. and Vaidyanadhan, R. (2008) Geology of India, v.1, 556p. Geol. Soc. India, Bengaluru.
- Roy, A.B. and Jakhar, S.R (2002) Geology of Rajasthan (Northwest India): Precambrian to Recent. Published by Scientific Publishers (India), Jodhpur, India.
- Soni, M.K., Chakraborty, S. and Jain, V. K. (1987) Vindhyan Supergroup-A Review. In: (B.P. Radhakrishnan) Purana Basins of Peninsular India. Memoir 6, Geological Society of India. Pp. 87-138.
- Swaminath J., Ramakrishnan M. and Viswanathan M.N. (1976) Dharwar stratigraphic model and Karnataka craton evolution, Rec. Geol. Surv. Ind., 107, 149–179.

- Swaminath J., Ramakrishnan, M., (1981) Early Precambrian supracrustals of southern Karnataka, Mem. Geol. Surv. Ind., 112, 350.

4.10 FURTHER/SUGGESTED READINGS

- Mazumdar, R. and Eriksson, P.G. (2015) Precambrian Basins of India: Stratigraphic and Tectonic Context. Geological Society of London, Memoir 43, 352p.
- Naqvi, S.M. (2005), Geology and Evolution of the Indian plate (from Hadean to Holocene – 4Ga to 4Ka), Capital Publishing Company, New Delhi.
- Ramakrishnan, M. and Vaidyanadhan, R. (2008), Geology of India Vol. 1, Geological Society of India, Bangalore.
- Sharma, Ram (2010) Cratons and Fold Belts of India. Volume 127 of Lecture Notes in Earth Sciences, Springer, 304p.

4.11 ANSWERS

Self Assessment Questions

- a) Dharwar Craton has been divided into two tectonic blocks—the *Western Block* and the *Eastern Block* on the basis of differences in the character of schist belts, their inter-relationships with the surrounding Grey gneisses, grades of metamorphism and temporal evolution.
 - b) WDC consists mainly of Peninsular Gneiss comprising TTG gneisses which forms the basement to Dharwar Supergroup and the contact is marked by a profound regional unconformity signifying cessation of Sargur orogeny. This unconformity is defined by the presence of locally uraniferous quartz-pebble conglomerate (QPC).
 - c) WDC: Bababudan-Western Ghats-Shimoga and Chitradurga-Gadag. EDC: Ramgiri- Penakacherla belt-Hungund and Kolar-Kadiri-Hutti Superbelt
 - d) Lower Cuddapah carbonate rocks are full of significant columnar stromatolites. The Vempalle and Tadpatri are based on stromatolite assemblage Lower Cuddapah is indicated to range from Early to Late Riphean (1600 -900Ma). Algal mats are common in these dolomitic rocks. *Conophyton*, *Kussiella*, *Colomnella* has been reported from Vempalle and Tadpatri Formations.
 - e) The major igneous activity associated with Vempalle and Tadpatri Formations. Nagari Quartzite, Pullampet and Cumbum Formation are traversed by dolerite sills. Kimberlite dykes and syenite stocks are found in Cumbum rocks. Kimberlitic rock of Chelima emplaced in Cumbum sediments.
- a) Aravalli craton constitutes of two major fundamental geological units: Banded Gneissic Complex and Proterozoic fold belts, i.e. Aravalli Fold Belt and Delhi Fold belt.
 - b) Bithur-Pisangan Line or Rajgarh-Pisangan Line.

- c) There are three main sedimentary subbasins from east to west, namely: Bayana-Lalsot basin, Alwar basin and Khetri basin.
- d) There are three main sedimentary subbasins; Eastern Bhim-Shyamgarh, Western Sendra-Barotia and Raigarh-Ajmer Basin.
- e) Phulad Ophiolite Suite constitutes of dismembered linear bodies of epidiorite, amphibolite, pyroxene granulite, metagabbro and ultramafics.

Terminal Questions

1. Refer to Table 4.1.
2. Refer to subsection 4.2.2 and Table 4.2.
3. Refer to subsection 4.3.2 and Table 4.5.
4. Refer to subsection 4.4.2 and Table 4.6.
5. Refer to subsection 4.5.2 and Table 4.7.



PALAEOZOIC OF INDIA |

Structure

- | | |
|---|--------------------------------|
| 5.1 Introduction | 5.4 Activity |
| Expected Learning Outcomes | 5.5 Summary |
| 5.2 Palaeozoic Successions of Northwestern Himalaya | 5.6 Terminal Questions |
| Palaeozoic Succession of Spiti | 5.7 References |
| Palaeozoic Succession of Kashmir | 5.8 Further/Suggested Readings |
| 5.3 Palaeozoic Stratigraphy of Spiti and Kashmir: A Synoptic View | 5.9 Answers |

5.1 INTRODUCTION

Palaeozoic successions of India comprise those rock systems, which were deposited during the Palaeozoic times ranging from Cambrian to Permian. During the Palaeozoic era, India mostly witnessed marine deposition, which largely took place in the Himalayan region under the Tethys Sea. The Palaeozoic marine successions are almost absent in the peninsular India except a few successions occur in Umaria and Jabalpur areas of Madhya Pradesh and in Bikaner-Nagaur area of Rajasthan.

On the other hand, Palaeozoic successions are best developed in many places of the Himalayan region such as Kashmir and Zaskar in Jammu and Kashmir, Spiti in Himachal Pradesh, Uttarakhand and Arunachal Pradesh. However, the best exposures of the Palaeozoic rocks can be seen in Spiti and Kashmir parts of the Himalaya. In contrast, the freshwater sediments of Upper Palaeozoic (Carboniferous to Permian) age were deposited in peninsular India and constitute the Gondwana Supergroup.

Palaeozoic successions lie above the Precambrian crystalline basement. In Unit 4, you have studied the main Precambrian supergroups of peninsular India. In this unit, we will discuss the two important Palaeozoic successions of the Himalaya exposed at Spiti in Himachal Pradesh and Kashmir in Jammu and Kashmir.

Expected Learning Outcomes

After reading this unit, you should be able to:

- ❖ describe the classification of Palaeozoic successions of Spiti and Kashmir; and
- ❖ discuss lithology, age, biota and depositional environment of different groups/formations of Palaeozoic successions of Spiti and Kashmir.

5.2 PALAEOZOIC SUCCESSIONS OF NORTHWESTERN HIMALAYA

Himalayan range is one of the longest mountain chains in the world extending from over 2500 km from Pamir in the west to Mishmi Hills in the east located in the northern part of India. Its width ranges from 150 to 400 km. It may be noted that from west to east, the two sectors of the Himalaya are named as northwestern Himalaya and northeastern Himalaya. The northwestern Himalaya refers to the western half of the Himalayan mountain range, extending from northeastern Afghanistan through Kashmir to Nepal. Whereas the northeastern Himalaya refers to the eastern part situated between the Kali Gandaki river in the Central Nepal in the west and Myanmar in the east. The northeastern Himalaya covers southeast Tibet, Sikkim, North Bengal, northeast India and Bhutan.

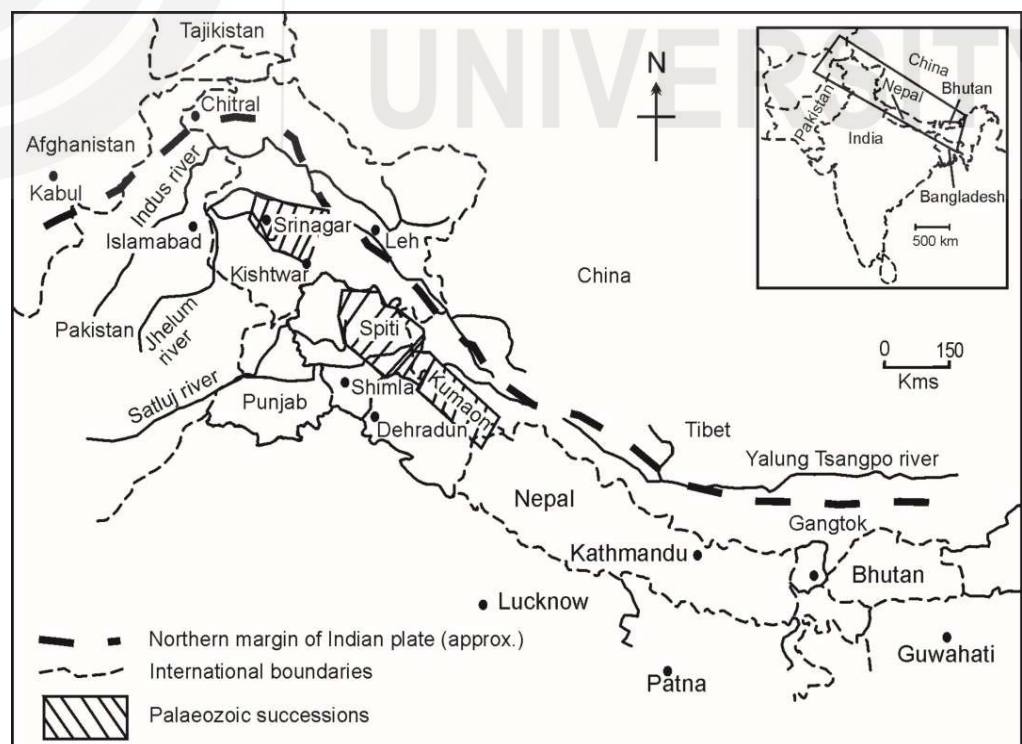


Fig. 5.1: Map showing Palaeozoic successions. (Source: modified after Talent and Bhargava, 2003)

Palaeozoic successions of northern India are well preserved in the Tethyan Himalayan basin of the northwest Himalaya. These successions occur in Kashmir basin, Spiti-Zaskar basin and Kinnaur-Uttarkhand (Kumaon) basin (Fig. 5.1). In addition, Palaeozoic rocks are also present in Bhutan in the northeastern Himalaya. The Lesser Himalayan part also contains some sequences of Palaeozoic rocks, which are present in Himachal-Uttarkhand and Nepal in the northwestern Himalaya and Darjeeling, Arunachal Pradesh and Bhutan in the northeastern Himalaya. The Kashmir and Spiti basins contain, by and large, most complete Palaeozoic successions of rocks. Therefore, we will discuss briefly above these two basins in this unit.

Do you know?

The Himalaya is divided into five parallel tectonic belts from north to south: Trans, Tethys, Greater, Lesser and Outer Himalaya. Each belt is bounded by prominent tectonic features consisting of fault or thrust zones. The Indus Tsangpo Suture Zone lies between Trans and Tethys Himalaya. The Tethyan Thrust marks the tectonic contact between Tethyan and Greater Himalaya. The Main Central Thrust represents the contact between Greater and Lesser Himalaya. The Main Boundary Thrust lies between Lesser and Outer Himalaya.

5.2.1 PALAEOZOIC SUCCESSION OF SPITI

Spiti is a part of the Lahaul and Spiti District of Himachal Pradesh in the northwestern Himalayan region. The Lahaul and Spiti District is bounded by two northwest to southeast trending mountain ranges such as the PirPanjal and the Greater Himalaya, which are separated by two major valleys namely Lahaul and Spiti. The Lahaul valley is situated in the northwestern part and the Spiti valley in the southeastern part of the district. The Spiti valley contains a complete, well developed, folded, marine fossiliferous succession of Palaeozoic to Mesozoic age (Fig. 5.2). This is an elongated succession exposed parallel to the general trend of the Himalaya from northwest to southeast direction. It represents well developed and best studied Palaeozoic to Mesozoic succession of India, which is well known for its rich fossil assemblages. As a result, the Spiti area is popularly known as “**Museum of Indian Geology**” while referring to the Geology of India.



Fig. 5.2: Field photograph of Palaeozoic succession of Spiti. (Photo credit: Prof. Trilochan Singh)

➤ Lithostratigraphy

The richly fossiliferous marine Palaeozoic succession of Spiti lies above the Precambrian crystalline basement and below the Lower Triassic Otoceras zone of the Lilang Group. It has received attention of many geologists around the globe from the middle of 19th century till date. The earlier remarkable work on the stratigraphy of this succession was carried out by F. Stoliczka, C.L. Griesbach, C. Dinner, H.H. Hayden and G. Fuchs and recently revised by S.V. Srikantia, A Ranga Rao, U. K. Bassi and O. N. Bhargava. Among them, the work carried out by Hayden in 1904 and Bhargava and Bassi in 1998 is more relevant. Hayden (1904) first provided a detailed account on stratigraphy of Spiti area, which was thoroughly updated by Bhargava and Bassi in 1998. A generalised lithostratigraphic classification of the Palaeozoic succession of Spiti is given in Table 5.1.

Table 5.1: Lithostratigraphy of Palaeozoic rocks of Spiti. (Source: modified after Bhargava and Bassi, 1998; Bhargava, 2008; Vaidyanadhan and Ramakrishnan, 2010)

Age	Group	Formation	Lithology
Lower Triassic Otoceras zone of the Lilang Group			
Permian	Kuling	Gungri	Black shales, silty shales, gray siltstones with phosphate and calcareous nodules with fossils of brachiopods, cephalopods and palynomorphs.
		Gechang	Sandstones, bands of shales and conglomerates with fossils of bivalves and corals.
		Ganmachidam	Polymictic conglomerates, quartzites, siltstones and shales with fossils of brachiopods, bryozoans and bivalves
Carboniferous	Kanawar	Po	Interbedded shales and quartzites with siltstones as well as some brachiopods and plant fossils.
		Lipak	Fossiliferous limestones, shales, sandstones and some pockets of gypsum
Devonian	-----	Muth	Hard, white quartzites with few bands of limestones, dolomites and shales. Trace fossils and stromatolites.
Silurian	-----	Takche	Limestones and marls. Fossiliferous with remains of brachiopods, trilobites, molluscs etc.
Ordovician	-----	Thango	Conglomerates with intercalation of red clays, interbedded quartzites, shales and limestones.

Cambrian	Haimanta	Kunzam La	Slates, quartzites, calcareous quartzites, shales, limestones, dolomitic limestones, siltstones and micaceous sandstones with fossils of trilobites, brachiopods, echinoderms and pteropods.
		Batal	Carbonaceous slates, phyllites, quartzites and gritstones, devoid of fossils.
Precambrian Salkhala Formation			

Now, let us discuss the Palaeozoic succession of Spiti in detail.

- **Haimanta Group:**

The Cambrian rocks of Spiti are known as Haimanta Group, which lies above the highly metamorphosed Precambrian Salkhala Formation. The group is divided into two formations such as Batal and Kunzam La.

The **Batal Formation** is the basal most unit, consists of carbonaceous slates, phyllites, quartzites and gritstones. The overlying **Kunzam La Formation** comprises slates, quartzites, calcareous quartzites, shales, limestones, dolomitic limestones, siltstones and micaceous sandstones. The Kunzam La is also known as the **Parahio Formation**. The greenish colour and gentle slopes of the Kunzam La Formation differentiate it from the underlying Batal Formation. The group is poorly fossiliferous. The fossils are almost lacking in the lower part (i.e. in the Batal Formation) of the group while the upper part has yielded the fossils of trilobites, brachiopods, echinoderms and pteropods. Although, the Haimanta Group is considered of Cambrian age, the age of the Batal Formation may extend to uppermost Precambrian.

Thango Formation: The Ordovician sequence of Spiti is designated as Thango Formation. It lies above the Kunzam La Formation of the Haimanta Group at a plane of angular unconformity. The formation can be easily recognised in the field by the prominence of red colour and rugged slopes. It is dominantly composed of thick conglomerates with intercalation of red clays, interbedded quartzites, shales and limestones. This formation is also termed as **Shian Quartzite Formation**. It may be noted that the formation is best developed in Thango area than the Shian area. Hence, the term Thango Formation is considered to be more appropriate. This formation, by and large, is unfossiliferous. However, a very few beds of the formation hosts fossils of Ordovician age. The Ordovician fauna includes elements of brachiopods, bryozoans, trilobites and cephalopods. A marine environment of deposition has been inferred to this formation.

Takche Formation: The Silurian rocks of Spiti are termed as Takche Formation. It lies above the Thango Formation and consists dominantly of limestones and marls. In addition, the formation also contains dolomites, siltstones, shales and calcareous sandstones. Takche Formation rich in brachiopods, trilobites yield is moderate and molluscs are rare. It also contains fossils of corals, algae and conodonts. The Takche Formation is considered to be of Silurian age, but its basal most part might have deposited during the Upper Ordovician.

Muth Formation: The Devonian rocks of Spiti are designated as Muth Formation. It has a sharp contact with the underlying Takche Formation. Muth Formation comprises hard, white quartzites with limestones, dolomites and shales in the upper part. The quartzite sequence is about 150 m thick and hence, it was also termed as **Muth Quartzites**. The formation is largely unfossiliferous and Devonian in age. However, some trace fossils and stromatolites are known from the Muth Formation.

- **Kanawar Group:**

The Carboniferous sequence of Spiti is known as Kanawar Group. The group is divided into two formations such as Lipak and Po in ascending order. The **Lipak Formation** lies above the Muth Formation and are separated from each other by a paraunconformity (Kumar, 1996). A succession of carbonate rocks is developed above the Muth Quartzites that marked the beginning of the Lipak Formation. Therefore, the commencement of carbonate bands is used to demarcate the boundary between the Muth and the Lipak Formations (Bhargava, 2008). Lithologically, the Lipak Formation consists of hard and black fossiliferous limestones, shales, sandstones and gypsiferous limestones. It contains well-preserved sedimentary structures such as ripple marks and cross-bedding. This formation has yielded remains of conodonts (*Icriodus*), ostracods, corals, trilobites, bivalves and brachiopods (*Syringothyris cuspidata*, *Linoproductus*, *Buxtonia*) as well as trace fossils. The fossils show that the formation is possibly of uppermost Devonian to Lower Carboniferous in age.

The conformably overlying **Po Formation** is made up of a thick sequence of interbedded shales and quartzites with siltstones. The common sedimentary structures present in the Po Formation are cross-bedding, parallel bedding and ripple marks. The lower part of the formation contains plant fossils (*Sphenopteridium furcillatum* and *Racopteris ovata*) of Lower Carboniferous age whereas upper part contains brachiopods (*Spirifer*, *Linoproductus*), bryozoans (*Fenestella* and *Protoretetpora*) of Upper Carboniferous age. It has also yielded a rich assemblage of trace fossils.

- **Kuling Group:**

The Permian rocks of Spiti are designated as Kuling Group. It is divided into three formations such as Ganmachidam, Gechang and Gungri from bottom to top. The **Ganmachidam Formation** is the basal unit of Permian strata and overlies the Po Formation of Upper Carboniferous age. It dominantly consists of polymictic conglomerates, quartzites, siltstones and shales. The formation is poorly fossiliferous and yielded the remains of brachiopods, bryozoans and bivalves. The stratigraphic contact between Po and Ganmachidam is gradational. An uppermost Carboniferous to Lower Permian age has been assigned to this formation.

The overlying **Gechang Formation** consists of sandstones with thin bands of shales and conglomerates occur at the base. The contact between Ganmachidam and Gechang formations is sharp. The formation is dated of Lower Permian in age based on the occurrences, age, diagnostics species of bivalves (*Eurydesma*) and corals (*Waagenophyllum*).

The topmost **Gungri Formation** of Kuling Group lies abruptly above the Gechang Formation and below the Lilang Group of Lower Triassic age. It consists of black shales, silty shales, gray siltstones with phosphate and calcareous nodules. The top of formation is marked by the presence of a ferruginous layer. The Gungri Formation can be easily identified in the field based on its black colour, gentle slopes and ferruginous layer. Based on the presence of brachiopods (*Waagenoconcha*), cephalopods (*Cyclolobus* and *Xenaspis*) and palynomorphs, an Upper Permian age has been proposed for this formation.

Learners, you have learnt about the Palaeozoic succession of Spiti. Before discussing about the Palaeozoic succession of Kashmir, spend few minutes to perform an exercise to check your progress.

SAQ 1

- a) Name the Palaeozoic successions of northwest Himalaya.
- b) List the formations of the Palaeozoic succession of Spiti in ascending order.
- c) Match the following:

a. Gungri Formation	i. Kunzam La
b. Muth Formation	ii. Precambrian
c. Haimanta Group	iii. Devonian
d. Salkhala Formation	iv. Upper Permian
- d) Name few important fossils of the Kanawar Group.

5.2.2 PALAEOZOIC SUCCESSION OF KASHMIR

The beautiful Kashmir Valley of the Jammu and Kashmir state preserves an excellent, well-developed and more or less continuous marine sedimentary succession of the Palaeozoic age. The Kashmir Valley trends from northwest to southeast and lies between the Zaskar Range or Greater Himalayan Range in the northeast and Dhauladhar-PirPanjal Range in southwest. It is about 135 km long and around 40 km wide. The Draba and Karnah mountain ranges of Muzaffarabad lies on the western border. The Hundwara Tehsil covers the northeastern part and Kishtwar and Chamba regions lie on the southeast margin of the Kashmir Valley. The two subvalleys of the Kashmir Valley, namely Lolab and Lidder display the best exposures of the Palaeozoic rocks in Kashmir. The Lolab Valley is situated in the northwestern and Lidder Valley in the southeastern corners of the Kashmir Valley.

The Palaeozoic succession of Kashmir largely consists of marine fossiliferous rocks ranging from Cambrian to Permian periods. This succession is clearly folded in the form of anticlines and synclines and exposed along the Greater Himalayan and the PirPanjal ranges. However, some stratigraphic breaks in the sequence are also recorded. These breaks constitute disconformities covering Upper Cambrian-Lower Ordovician, Devonian and Upper Carboniferous times. It may be noted that Cambrian rocks are best exposed in the Lolab valley, notably in Handwara and Kupwara regions. Best outcrops of Ordovician and

Silurian are known in Liddar valley of Anantnag District. Devonian, Carboniferous and Permian rocks are best exposed in Zewan area in Pulwama District, Liddar Valley in Anantnag District and PirPanjal Range in the north of Banihal.

➤ **Lithostratigraphy**

The Palaeozoic rocks of Kashmir are well developed and richly fossiliferous, as a result many workers across the globe have worked on it. The earliest work on the Palaeozoic stratigraphy of Kashmir goes back to 1866. In 1883, R. Lydekker presented a detailed account on the Stratigraphy of Kashmir, which was subsequently revised by C.S. Middlemiss in 1910. Following him, many other workers, notably H.H. Hayden, D.N. Wadia, V.G. Fuchs, S.K. Shah, O.N. Bhargava and S.V. Srikantia had continuously updated the Palaeozoic stratigraphy of Kashmir. The Palaeozoic succession of Kashmir lies above the Precambrian unfossiliferous Dogra Slates/ Salkhala Formation and below the Triassic Sonamarg Group. A generalised lithostratigraphic classification of Palaeozoic succession of Kashmir is given in Table 5.2.

Table 5.2: A generalised lithostratigraphic classification of Palaeozoic succession of Kashmir. (Source: simplified after Srikantia and Bhargava, 1983; Naqvi, 2005; Bhargava, 2008; Vaidyanadhan and Ramakrishnan, 2010)

Age	Group	Formation	Lithology
Triassic Sonamarg Group			
Permian		Zewan	Limestones, shales, and calcareous sandstones with remains of brachiopods, bivalves, bryozoans, corals, ammonoids, crinoids and conodonts.
		Panjal Volcanics	Massive and bedded basaltic andesite lava flows and ash bed.
Upper Carboniferous		Agglomeratic Slate	Slates, sandstones, quartzites, conglomerates and a few bands of limestones with remains of brachiopods, bryozoans and bivalves.
~~~~~ Unconformity ~~~~~			
Lower Carboniferous	Lidder	Fenestella Shale	Alternating beds of shales and quartzites with rare bands of carbonates. The shale beds are rich in brachiopods, bryozoans, bivalves and coral.
		Syringothyris Limestone	Gray to dark blue limestones with bands of shales, quartzites and traps with remains of brachiopods, bivalves, algae, corals, bryozoans and conodonts.
Devonian		Muth	White quartzites, siltstones, shales and dolomitic limestones
~~~~~ Unconformity ~~~~~			
Silurian	Rishkabal	Gugaldhar	Cross-bedded sandstones, calcareous shales, calcareous sandstones and bands of limestones with corals, trilobites, brachiopods and molluscs remains.

Ordovician		Hallamulla	Siltstones and shales with fossils of crinoids and brachiopods.
~~~~~ Unconformity ~~~~~			
Cambrian	Hapatnar	Rangamal	Siltstones, shales, sandstones and limestones with remains of trilobites, bivalves, gastropods and algae.
		Shumal	Gray shales and siltstones with trilobite fossils.
		Lolab	Siltstones, laminated shales and sandstones with trilobite fossils.
Precambrian Dogra Slates/ Salkhala Formation			

#### • Hapatnar Group:

The Cambrian sequence of Kashmir is known as **Hapatnar Group**. It rests over either the crystalline rocks of the Salkhala Formation or the Dogra Slates. The Salkhala Formation is named after a village Salkhala in the Kishanganga Valley and the name Dogra Slates was given by Indian famous geologist, D. N. Wadia for a thick sequence of argillaceous rocks occur in the southwest Kashmir and Poonch regions of Jammu and Kashmir. These Precambrian rocks form the basement for the deposition of the Tethyan sediments. The Cambrian Hapatnar group is divided into three formations: Lolab, Shumal and Rangamal in ascending order.

The **Lolab Formation** is the basal most formation of the Cambrian sequence, rests over Salkhala Formation along a non-conformity. It is made up of siltstones, laminated shales, and sandstones. Cross-bedding and ripple bedding are common sedimentary structures present in this formation. The Lolab Formation has yielded trilobites (*Redlichia takeoensis*, *Chittidilla plana* and *Yuehsienzellaszzechuanensis*), which indicate a Lower Cambrian age.

The **Shumal Formation** is conformably lies above the Lolab Formation and below by the Rangamal Formation. It consists of gray shales and siltstones. Sedimentary structures like ripple marks and cross-bedding occur in the siltstones. This formation is deposited under subtidal environment. It yields rich assemblage of trilobites (*Xingrenaspis dardapurensis*, *Tonkinella breviceps*, *Bailiellalantenoisi*, *Parachittidillakashmirensis*, *Shahaspishimalayensis* etc.). A Middle Cambrian age has been assigned to this formation.

The overlying **Rangamal Formation** is made up of siltstones, shales, sandstones and limestones. It yields remains of trilobites (*Damesellashergoldi*, *Cyclolorenzella* sp. etc), bivalves, gastropods and algae. An Upper Cambrian age has been assigned to the Rangamal Formation. The Rangamal Formation would have been deposited from the subtidal to supratidal environment. It may be noted that both the Shumal and Rangamal formations of Kashmir are equivalent to the Kunzam La Formation of the Spiti region.

#### • Rishkoba Group:

The Ordovician and Silurian rocks of Kashmir are designated as the Rishkoba Group. This group is made up of two formations: Hallamulla and Gugaldhar.

The **Hallamulla Formation** lies abruptly above the Rangamal Formation. It consists of gray to green siltstones and purple green shales. It contains fossils

of crinoids and brachiopods. A Lower Ordovician age has been assigned to this formation.

The conformably overlying **Gugaldhar Formation** consists of cross-bedded sandstones, calcareous shales and sandstones and bands of limestones. The calcareous shales contains corals, trilobites, brachiopods and molluscs. This formation appears to be deposited under subtidal to intertidal environment. An Upper Ordovician to Lower Silurian age is suggested to this formation. The Gugaldhar Formation is also considered nearly equivalent to the Takche Formation of the Spiti basin.

- **Lidder Group:**

The Devonian to Lower Carboniferous sediments of Kashmir are termed as Lidder Group. It comprises Muth Formation, Syringothyris Limestone and Fenestella Shale in ascending order.

The **Muth Formation** (widely known as Muth Quartzites) rests unconformably over the Gugaldhar Formation. The stratigraphic contact between these two formations is sharp. Lithologically, it is made up of white quartzites, siltstones, shales and dolomitic limestones. The Muth Formation is lacking age diagnostic fossils. The shale band of the formation is rich in fossils and yielded abundant shells of brachiopods belonging to the genus *Dalmanella*. A Lower to Middle Devonian age has been assigned to this formation based on its stratigraphic position. Muth Formation of Kashmir is considered to be equivalent to the Muth Formation of Spiti basin.

The **Syringothyris Limestone** (also named as **Aishmuqam Formation**) conformably lies above the Muth Formation. It is a sequence of gray to dark blue limestones with bands of shales, quartzites and traps. This formation has yielded the remains of brachiopods (*Syringothyris cuspidate*, *Linoproductus*), bivalves, algae, corals, bryozoans and conodonts. In addition, the basal part of the formation contained some plant fossils such as *Lepidodendropsis*, *Lepidosigillaria*, *Archaeosigillaria*, *Rhacopteris* etc. The limestone of the formation is rich in brachiopods especially the genus, *Syringothyris*, after which this formation was named. Devonian to Lower Carboniferous age has been assigned to it. The Syringothyris Limestone of Kashmir basin is to be correlated with the Lipak Formation of Spiti.

**Fenestella Shale** (also named as **Ganeshpur Formation**) rests over the Syringothyris Limestone. It is composed of alternating beds of fossiliferous shales and unfossiliferous quartzites with rare bands of carbonates. The shale beds are richly fossiliferous and full of brachiopods, bryozoans, bivalves, coral and a very few trilobites and crinoids. It may be noted that one genus of bryozoans such as *Fenestella* is more dominant faunal element in this formation. Hence, this formation is named as Fenestella Shale. *Linoproductus*, *Dielasma*, *Buxtonia* and *Spirifer* are other dominant genera of brachiopods known from this formation. The formation is dated as Lower Carboniferous in age and correlated with the Po Formation of Spiti.

**Agglomeratic Slate:** The Upper Carboniferous rocks of Kashmir are termed as Agglomeratic Slate. It conformably overlying the Fenestella Shale. It bears pyroclastic and ash material together with sediments known as Agglomeratic

Slate and contains angular fragments of various rocks and minerals. It consists of slates, sandstones, quartzites, conglomerates, tilloids and a few bands of limestones. Generally, Agglomeratic Slate is devoid of fossils, however, it contains some fossiliferous beds, which yield remains of brachiopods (*Syringothyris*, *Linoproductus*, *Spirifer*, *Buxtonia* etc), bryozoans (*Fenestella*) and bivalves (*Eurydesma*, *Pinna*, *Lima*). Agglomeratic Slate is also named as **Pindahol Formation** and correlated to the Gechang Formation of Spiti. The fluvio-glacial to deltaic environment is noted for its deposition. The age of the Agglomeratic Slate is Upper Carboniferous.

**Panjal Volcanics and Zewan Formation:** The Permian rocks of Kashmir include the Panjal Volcanics and the Zewan Formation. Permian rocks commence with the volcanic lava flows that continued intermittently throughout Permian and even in parts of Triassic though the main volcanic event occurred in Lower and Middle Permian.

- The **Panjal Volcanics** conformably lies above the Agglomeratic Slate and occurs along the central axis of the PirPanjal Range. The Panjal Volcanics consist of a thick sequence of compact, massive and bedded basaltic andesite lava flows and ash beds (Fig. 5.3a). The occurrences of dolerite dykes and sills are known from the older rocks/formations such as Syringothyris Limestone and Fenestella Shale. A Lower Permian age is given to the Panjal Volcanics.
- **Zewan Formation** rests over the Panjal Volcanics and consists a thick sequence of marine fossiliferous limestones, shales and calcareous sandstones. This formation is named after the Zewan village in the Vihi area of Kashmir province, where it is well exposed. It yielded the remains of brachiopods (*Linoproductus*, *Waagenoconcha*, *Neospirifer*, *Spiriferella*, *Dielasma*, *Lamnimagushimalayensis*), bivalves, bryozoans (*Protoretetpora*, *Fenestella*), corals, ammonoids (*cyclolobus*, *Xenaspis*), crinoids and conodonts. An Upper Permian age is assigned to the Zewan Formation. It is overlain by the Triassic Sonamarg Group.



**Fig. 5.3: Field photographs: a) Panjal Volcanics; and b) Gangamopteris Beds.**

(Photo credit: Dr. Rakesh Chandra)

It is interesting to note that at several places, there are fossiliferous beds that occurred between upper part of the Panjal Volcanics and lower part of the Zewan Formation. These beds are known to yield Gondwana plant fossils such as *Gangamopteris*, *Glossopteris*, *Vertebraria*, *Psygmyphyllum* etc. similar to those forms known from the Lower Gondwana rocks of the Talchir and Damuda

basins of Peninsular India. In addition, these beds also yielded some remains of vertebrates (amphibians and fish) and insects. These beds are mainly composed of cherts, siliceous, carbonaceous and tuffaceous shales, sandstones and limestones (Fig. 5.3b). These beds represent northern most occurrence of the Gondwana Supergroup in India and are popularly known as **Gangamopteris Beds** and also named as **Nishatbagh Formation**.

Learners, you have learnt the Palaeozoic succession of Kashmir. Now, spend few minutes to perform an exercise to check your progress.

## SAQ 2

- a) List the breaks in the Palaeozoic succession of Kashmir.
- b) Name the formations of the Palaeozoic succession of Kashmir in ascending order.
- c) Match the following:
 

a. Lolab Formation	i. Vertebrates and fish
b. Panjal Volcanics	ii. Hallamulla Formation
c. Rishkoba Group	iii. Lower Cambrian
d. Gangamopteris Beds	iv. Lower Permian

## 5.3 PALAEOZOIC STRATIGRAPHY OF SPITI AND KASHMIR: A SYNOPSIS VIEW

You may have noted while studying the Palaeozoic successions of Spiti and Kashmir that these two areas contain well developed and most complete successions of Palaeozoic rocks. As a consequence, these are as remain the focus of study to many geologists. In Spiti area, the earlier works on the stratigraphy were dated back to 1904, when H.H. Hayden gave a detailed account on the stratigraphy of Spiti. After a long time, Bhargava and Bassi in 1998 presented a revised version on the stratigraphy of Spiti. In addition, many other workers also worked on the stratigraphy of the Spiti area and created many new formations/groups with new names.

On the other hand, Palaeozoic stratigraphy of Kashmir also has a same story. In 1910, C.S. Middlemiss first presented a detailed account on the Stratigraphy of Kashmir. While Srikantha and Bhargava in 1983 revised the Palaeozoic stratigraphy of Kashmir. The Indian geologists such as O.N. Bhargava, S.V. Srikantha and U.K. Bassi of the Geological Survey of India, while carrying out geological mapping of Spiti and Kashmir noted that some of the names given to the various geological formations for example, Fenestella Shale, Syringothyris Limestone by Middlemiss did not meet the rules specified by the code of stratigraphic nomenclature of India or they were not named as per the rules specified in stratigraphic nomenclature. For example, Fenestella Shalere presents a Formation. As per the code of stratigraphic nomenclature, a formation should consist of a geographic name combined with formation, for example Zewan Formation where Zewan is a geographic name. In case of

Fenestella Shale, Fenestella is genus of bryozoans and Shale is a lithological name, therefore it does not fulfil the code of stratigraphic nomenclature.

It should be noted that some of the names given at formations level in the stratigraphy of Spiti and Kashmir are so deep rooted in the literature that their complete removal in this unit is not justifiable. Thus, in order to avoid any confusion and make the understanding of Palaeozoic stratigraphy of Spiti and Kashmir, a comparison of old and new stratigraphy classifications of both areas are shown in Tables 5.3a and 5.3b.

**Table 5.3a: Old and revised Palaeozoic stratigraphy of Spiti.**

After Hayden (1904)		After Bhargava and Bassi (1998)	
Age	Formation	Age	Formation
Permian	Productus Shale	Permian	Gungri
	Calc Sandstone		Gechang
	Permian Conglomerate		Ganmachidam
Carboniferous	Po	Carboniferous	Po
	Lipak		Lipak
Devonian	Muth Quartzites	Devonian	Muth
Silurian	Silurian	Silurian	Takche
Ordovician	Haimanta	Ordovician	Thango
Cambrian		Cambrian	Kunzam La
			Batal

**Table 5.3b: Old and revised Palaeozoic stratigraphy of Kashmir.**

After Middlemiss (1910)		After Srikantia and Bhargava (1983) and Bhargava (2008)	
Age	Formation	Age	Formation
Permian	Zewan	Permian	Zewan
	Gangamopteris Beds		Nishatbagh
	Panjal Volcanics		Panjal Volcanics
Carboniferous	Agglomeratic Slate	Carboniferous	Pindahol
	Fenestella Shale		Ganeshpur
	Syringothyris Limestone		Aishmuqam
Devonian	Muth Quartzites	Devonian	Muth
Silurian	Upper Silurian	Silurian	Gugaldhar

Ordovician	Lower Silurian and (?) Cambrian		
Cambrian		Ordovician	Hallamulla
		Cambrian	Rangamal
			Shumal
			Lolab

## 5.4 ACTIVITY

Table given below shows the Palaeozoic succession of Spiti (Table 5.4). Try to fill-up the group, formation and lithology in the missing rows.

**Table 5.4: Palaeozoic succession of Spiti**

Age	Group	Formation	Lithology
Lower Triassic Otoceras zone of the Lilang Group			
Permian		Gungri	
			Sandstones, bands of shales and conglomerates with fossils of bivalves and corals.
		Ganmachidam	
Carboniferous	Kanawar		
			Fossiliferous limestones, shales, sandstones and with some pockets of gypsum.
Devonian	-----	Muth	
Silurain	-----		Limestones and marls. Fossiliferous with remains of brachiopods, trilobites, molluscs, etc.
Ordovician	-----	Thango	
Cambrian			
		Batal	Carbonaceous slates, phyllites, quartzites and gritstones that are devoid of fossils.
Precambrian Salkhala Formation			

## 5.5 SUMMARY

Now let us summarise what we have learned in this unit:

- Palaeozoic successions are best developed in many places in the Himalayan region such as Kashmir and Zaskar in Jammu and Kashmir, Spiti in Himachal Pradesh, Uttarakhand and Arunachal Pradesh.

- Palaeozoic successions are almost absent in the peninsular India except a very few successions occur in Umaria and Jabalpur areas of Madhya Pradesh and in Bikaner-Nagaur area of Rajasthan.
- The Spiti valley of Himachal Pradesh contains a complete, well developed, folded, marine fossiliferous succession of Palaeozoic to Mesozoic age. It represents a best studied Palaeozoic to Mesozoic succession of India with rich fossil assemblages. Therefore, the Spiti valley is popularly known as “Museum of Indian Geology” in Geology of India.
- The marine Palaeozoic succession of Spiti lies above the Precambrian crystalline basement and below the Lower Triassic Otoceras zone of the Lilang Group.
- The Batal, Kunzam La, Thango, Takche, Muth, Lipak, Po, Ganmachidam, Gechang and Gungri are the main formations of Palaeozoic succession of Spiti, ranging from Cambrian to Permian.
- Palaeozoic rocks of Spiti yield rich assemblages of invertebrates such as trilobites, brachiopods, cephalopods, bryozoans, bivalves, pteropods etc. and indicate that major portion of the succession was deposited under marine conditions.
- Palaeozoic succession of Kashmir consists of marine fossiliferous rocks ranging from Cambrian to Permian age and lies between the Zaskar Range or Great Himalayan Range in the northeast and Dhauladhar-PirPanjal Range in southwest in the Kashmir Valley.
- Palaeozoic succession of Kashmir lies either above the Precambrian unfossiliferous Dogra Slates or crystalline rocks of Salkhala Formation and below the Triassic Sonamarg Group.
- The Lolab, Shumal, Rangamal, Rishkoba, Muth, Syringothyris Limestone, Fenestella Shale, Agglomeratic Slate, Panjal Volcanics and Zewan are the main formations ranging from Cambrian to Permian known in the Kashmir Valley.
- Although Palaeozoic rocks of Kashmir are rich in invertebrate fossils, the Upper Palaeozoics specially Permo-Carboniferous yield some plant fossils of Gondwana affinities and vertebrate remains.
- Panjal Volcanics are absent in the Spiti basin.

## 5.6 TERMINAL QUESTIONS

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1. Explain the distribution of Palaeozoic rocks in India.
2. Describe the lithostratigraphic succession of Palaeozoic of Spiti
3. Give an account on the Palaeozoic Stratigraphy of Kashmir.

## 5.7 REFERENCES

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- Bhargava, O.N. (2008) An updated introduction to the Spiti Geology. Journal of the Palaeontological Society of India. 53(2): 113-129.
- Bhargava, O.N. and Bassi, U.K. (1998) Geology of Spiti-Kinnaur, Himachal Himalaya. Memoir of the Geological Survey of India, 124:1-210.

- Hayden, H.H. (1904) The geology of Spiti with parts of Bashahr. Memior of the Geological Survey of India, 36(1): 1-121.
- Kumar, R. (1996) Fundamentals of Historical Geology and Stratigraphy of India, Fourth Reprint, New Age International Publishers, New Delhi.
- Middlemiss, C.S. (1910) A revision of the Silurian-Trias sequence in Kashmir. Record of the Geological Survey of India, 40(3): 206-260.
- Naqvi, S.M. (2005) Geology and Evolution of the Indian Plate (From Hadean to Holocene – 4 Ga to 4 Ka), Capital Publishing Company, New Delhi.
- Srikantia, S.V. and Bhargava, O.N. (1983) Geology of the Palaeozoic sequence of the Kashmir Tethys Himalayan basin in the Lidder valleys, Jammu and Kashmir. Journal of the Geological Society of India, 24: 363-377.
- Talent, J.O. and Bhargava, O.N. (2003) Silurian of the Indian subcontinent and adjacent regions. In: Silurian Land and Seas Paleogeography outside Laurentia. The University of the State of New York. The State Education Department, New York State Museum Bulletin 493: 221-239.
- Vaidyanadhan, R. and Ramakrishnan, M. (2010) Geology of India, Volume II, Geological Society of India, Bangalore.

## 5.8 FURTHER/ SUGGESTED READINGS

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- Krishnan, M.S. (1949) Geology of India and Burma. The Madras Law Journal Office, Madras.
- Mukerjee, P. K. (1997) A Textbook of Geology, The world Press Pvt Ltd, Calcutta.
- Shah, S.K. (2018) Historical Geology of India, Scientific Publishers, Jodhpur.
- Wadia, D.N. (1966) Geology of India, McMillan Press, London.

## 5.9 ANSWERS

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### Self Assessment Questions

- The Palaeozoic successions of northwest Himalaya occur in the Kashmir basin, Spiti-Zaskar basin and Kinnaur-Uttarkhand basin.
- The Batal, Kunzam La, Thango, Takche, Muth, Lipak, Po, Ganmachidam, Gechang and Gungri are the formations of Palaeozoic succession of spiti, ranging from Cambrian to Permian.
- iv.
  - iii.
  - i.
  - ii.
- The Kanawar Group of Spiti is divided into two formations: Lipak and Po. The Lipak Formation lies above the Muth Formation and consists of hard and black fossiliferous limestones, shales, sandstones and gypsiferous limestones. Important fossils of this formation are *Icriodus*

(conodonts) and *Syringothyris cuspidata*, *Linoproductus*, *Buxtonia* (brachiopods). The overlying Po Formation is made up of a thick sequence of interbedded shales and quartzites with siltstones. The *Sphenopteridium furcillatum*, *Racopteris ovata* (plant fossils), *Spirifer*, *Linoproductus* (brachiopods) and *Fenestella*, *Protoretetepora* (bryozoans) are the characteristic fossils of the formation.

- 2a) At least three sedimentological breaks have been recorded in the Palaeozoic succession of Kashmir. These breaks occur at Upper Cambrian-Lower Ordovician, Devonian and Upper Carboniferous times.
- b) The Lolab, Shumal, Rangamal, Rishkabal, Muth, Syringothyris Limestone, Fenestella Shale, Agglomeratic Slate, Panjal Volcanics and Zewan are the main formations ranging from Cambrian to Permian in Kashmir valley.
- c) a. – iii.  
b. – iv.  
c. – ii.  
d. – i.

### **Terminal Questions**

1. Refer to section 5.2.
2. Refer to sub-section 5.2.1.
3. Refer to sub-section 5.2.2.

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# MESOZOIC OF INDIA |

## Structure

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### 6.1 Introduction

Expected Learning Outcomes

### 6.2 Mesozoic Successions of India

Triassic of Spiti

Mesozoic of Kachchh

Mesozoic of Rajasthan

Cretaceous of Tiruchirapalli

### 6.3 Activity

### 6.4 Summary

### 6.5 Terminal Questions

### 6.6 References

### 6.7 Further/Suggested Readings

### 6.8 Answers

## 6.1 INTRODUCTION

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In Units 4 and 5, you have read the Precambrian and Palaeozoic rock systems of India. You must have noted while studying these units, that the Precambrian successions are well-developed in the peninsular India and the Palaeozoic successions in the Himalayan region. The Mesozoic successions of India comprise those rock groups, that were deposited during the Triassic, Jurassic and Cretaceous times, spanning from 252.2 to 66 million years/annuals (Ma) ago, a total duration of 186.2 Ma.

The Mesozoic era was marked by the break-up of Pangea, the supercontinent of the Palaeozoic era, into Laurasian and Gondwana landmasses. India, once a part of Gondwanan landmasses, started to separate and disperse from the Gondwana during the Middle Jurassic and collided with Asia during Early Cenozoic. The Mesozoic witnessed considerably warmer temperatures and high sea levels due to continental movements and tectonic activity. There were many marine transgressions events recorded during the Mesozoic in different parts of India. These marine transgressions brought the

deposition of marine sediments inside the continental areas. As a result, Mesozoic successions are present in both the Himalayan and peninsular regions of India.

The well-preserved outcrops of the Mesozoic successions occur in different parts of the country. In this unit, we will discuss the distribution, stratigraphy, lithology, fossil content, age and environment of deposition of the main Mesozoic successions of India, which are exposed in Spiti (Himachal Pradesh), Kachchh (Gujarat), Rajasthan and Tiruchirapalli (Tamil Nadu).

## Expected Learning Outcomes

After studying this unit, you should be able to:

- ❖ outline the Mesozoic successions of India;
- ❖ define and classify the main Mesozoic rock systems of India;
- ❖ discuss the lithology of important Mesozoic groups/ formations;
- ❖ describe the fossil content, age, palaeoenvironment and economic significance of important Mesozoic groups/ formations; and
- ❖ explain the stratigraphy of the Mesozoic rocks of Spiti, Kachchh, Rajasthan and Tiruchirapalli.

## 6.2 MESOZOIC SUCCESSIONS OF INDIA

The Mesozoic in India is marked by marine transgressions occupying the Himalayan region and many parts of the peninsular India (Fig. 6.1). During the Triassic and Jurassic, the marine sedimentation mostly took place in the Himalayan region. However, peninsular region of India also witnessed a considerable deposition of sediments in the Jurassic and Cretaceous. It is noteworthy to mention that the Mesozoic sedimentation was not continuous either in Himalayan region or in peninsular India. In India, the Mesozoic sedimentation ceased with the volcanic eruption of the Deccan traps at the end of Cretaceous.

The Triassic rocks are well developed and widely distributed in the Himalayan region stretching from Kashmir (Jammu and Kashmir) in the northwest through Spiti (Himachal Pradesh) to Kumaon (Uttarakhand) in the south east (i.e. along the Himalayan belt). It is important to note that the Triassic rocks are best developed in the Spiti region. The rocks of Jurassic age are developed in the Higher Himalaya, in the Kashmir-Zaskar-Spiti region and in Kachchh and Rajasthan within the western sector of India. The Cretaceous rocks are deposited in both Himalaya as well as in the peninsular regions of India. In Himalaya, these rocks occur in Ladakh (Jammu and Kashmir), Spiti, Kumaon and Assam. Whereas, the Godavari, Krishna, Palar and Cauvery basins of South India, the Cambay, Kachchh and Jaisalmer basins of Western India and the Narmada basin of Central India contain outcrops of Cretaceous rocks within peninsular India. In addition, sedimentary sequences associated with the Rajmahal and the Deccan traps also yield rocks of Cretaceous age.

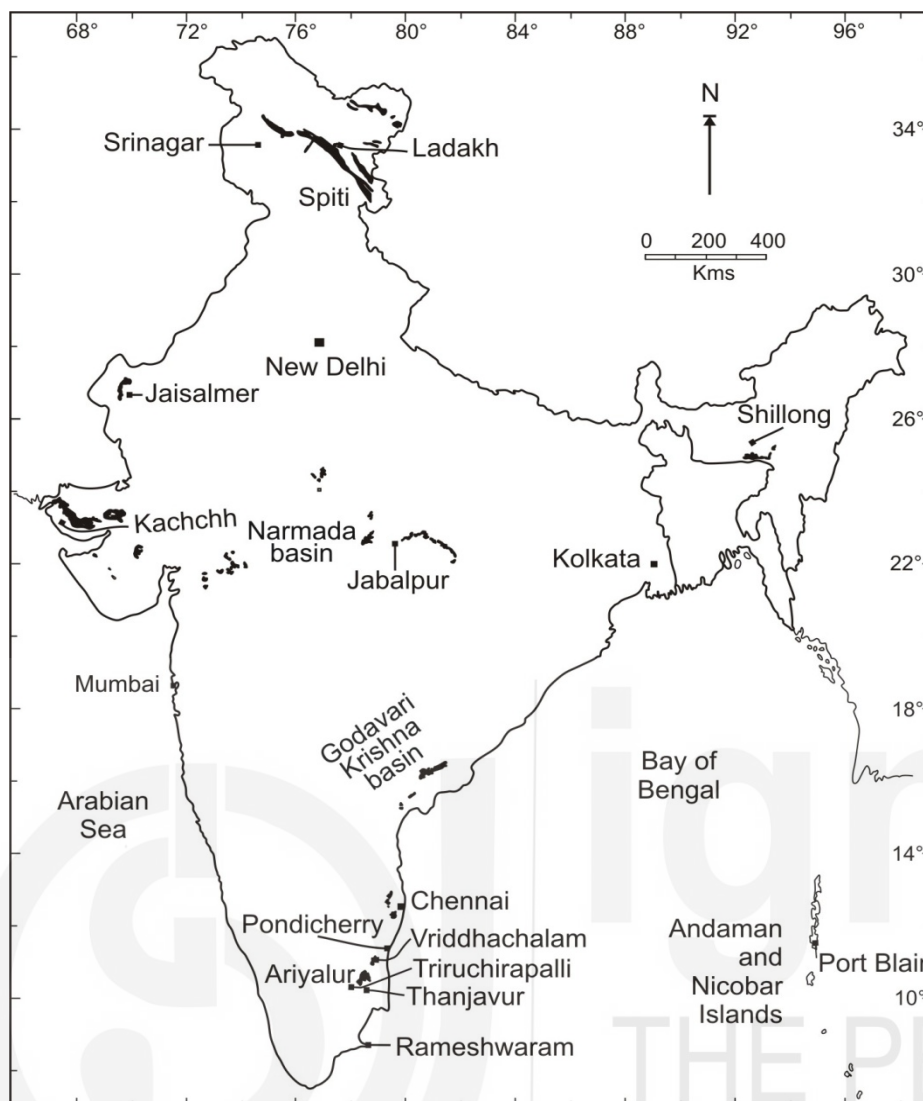


Fig. 6.1: Map of India showing marine Mesozoic successions of India.

### 6.2.1 TRIASSIC OF SPITI

Spiti is a part of the Lahaul and Spiti District of Himachal Pradesh in the northern Himalayan region. It contains a complete and well developed succession of the Mesozoic rocks, which conformably lies between the Productus Shale or Gungri Formation of Permian age and the Tagling Limestone of Jurassic age. It is one of the most complete and best-preserved successions consisting rocks of Triassic age and occur near the Lilang village in Spiti. Therefore, the Triassic of Spiti is also termed as the **Lilang Group**. The group dominantly consists of dark limestones and dolomites with subordinate blue-coloured shales. The succession is entirely marine, fossiliferous and deposited in a clear and deep-water environment without any significant addition of terrigenous material. The sequence contains abundant remains of ammonites, brachiopods, bivalves, belemnites, planktic foraminifers and rare corals.

#### ► Classification

The Triassic succession exposed in Spiti is divided into three parts such as Lower, Middle and Upper Triassic (Table 6.1). As mentioned above, Triassic rocks in Spiti lie between the Productus Shale or Gungri Formation of Permian

age (below) and the Tagling limestone of Jurassic age (above). It should be noted that limestones, dolomites and shales are main lithology of the group that exhibits a striking uniformity in lithology with abundant ammonites.

**Table 6.1: Triassic succession of Spiti.**

Group	Age	Series	Beds	Lithology
Lilang	Jurassic	----	Tagling limestone	Massive limestones and dolomites
Lilang	Triassic	Upper Triassic	Megalodon limestone (Para Stage)	Massive limestones and dolomites
			Quartzite series	White and brown quartzite with grey limestones and black shales
			Monotis shales	Sandy and shaly limestones with brown weathering shales and sandstones
			Coral limestone	Limestones
			Juvavites beds	Brown-weathering shales, limestones and shales
			Tropites beds	Dolomite limestones, shales and dark limestones with ammonite beds
			Gray beds	Gray shales and shaly limestone with pelecypod bed and an ammonite bed
			Halobia beds	Dark splintery limestones
		Middle Triassic	Daonella limestone	Hard dark limestones
			Daonella shales	Dark shales and grey limestones
			Upper Muschelkalk	Concretionary limestones with shale bands
			Lower Muschelkalk	Dark shales and grey limestones
			Nodular limestone	Hard nodular limestones
			Basal Muschelkalk	Shaly limestones
		Lower Triassic	Hedenstroemia beds	Limestones, shaly limestones and shales alternating; thin-bedded limestones and shales
			Meekoceras zone	Thin-bedded limestones and shales
			Ophiceras zone	Grey limestones
			Otoceras zone	Brown limestones
	Permian		Productus shale/ Gungri Formation	Dark shales

Now, let us discuss the three parts of the Triassic succession of Spiti in detail.

- **Lower Triassic of Spiti:**

The Lower Triassic rocks lie conformably on the top of the Productus shale (Gungri Formation) and predominantly consist of dark coloured limestones and shales with abundant ammonite fauna. The lower part of succession is about 184 m thick. On the basis of ammonites, it is divided into four units: **Otoceras zone, Ophiceras zone, Meekoceras zone and Hedenstroemia beds**. Each of these units are characterised by the presence of zone fossils belonging to cephalopod molluscs such as *Otoceraswoodwardi*, *Ophicerasakuntala*, *Meekocerasvaraha* and *Hedenstroemiaojsisovicsi* in ascending order (Table 6.1).

- **Middle Triassic of Spiti:**

The Middle Triassic chiefly consists of concretionary and shaly limestone and shales with a very rich Muschelkalk fauna, especially of ammonites. It is about 125 m thick and lies conformably over the Hedenstroemia beds of Lower Triassic age and underlain by the Halobia beds of Upper Triassic age. The Middle Triassic succession of Spiti is divided into six units: **Basal Muschelkalk, Nodular limestone, Lower Muschelkalk, Upper Muschelkalk, Daonella shales and Daonella limestone** (Table 6.1). The succession is richly fossiliferous and contains the characteristic fossils of brachiopods (*Rhynchonella griesbachi*, *Spiriferinatracheyi*), cephalopods (*Sibiritesprahlada*, *Keyserlingitesdieneri*, *Ptychitesrugifer*) and bivalves (*Daonella indica*).

**Do you know?**

The Muschelkalk is a sedimentary sequence of Europe, primarily composed of carbonate rocks such as limestone and dolostone and is of a Middle Triassic age (247.2 to 237 Ma old).

- **Upper Triassic of Spiti:**

The Upper Triassic succession of Spiti is very well-developed and is about 1600m thick. It is the thickest of all the Himalayan Triassic subdivisions. Lithologically, the lower part of the sequence is composed of dark shales and marls, but the upper part contains limestones and dolomites. The Upper Triassic succession starts with the Carnian Halobia beds and end with the Rhaetian Megalodon limestone and lies below the Lower Jurassic Tagling limestone (Table 6.1). The Upper Triassic succession is subdivided into eight units: **Halobia beds, Grey beds, Tropites beds, Juvavites beds, Coral limestone, Monotis shales, Quartzite series and Megalodon limestone** (Para Stage) from the base to top (Table 6.1). The succession also contains some fossiliferous beds, which yielded species of brachiopods, bivalves, crinoids and corals. The part of the succession consisting of Halobia, Grey and Tropites beds is characterised by presence of cephalopods (*Joannitesthanamensis*) and brachiopods (*Spiriferinashalshalensis*, *Dielasmajulicum*). The upper part of the succession consisting of Juvavites beds, Coral limestone, Monotis shales, Quartzite series and Megalodon limestone, often yields characteristic fossil species of cephalopods (*Juvavites angulatus*) and brachiopods (*Spiriferinagriesbachi*).

### 6.2.2 MESOZOIC OF KACHCHH

The Mesozoic successions of Kachchh comprise rocks ranging in age from Middle Jurassic (Bathonian to Callovian) to the Lower Cretaceous (Albian-Aptian). These rocks are situated between the Great Rann of Kachchh in the north and the Kathiawar (Saurashtra) peninsula in the south in Gujarat, western India. The Mesozoic rocks of Kachchh are more than 2000m thick and indicate a phase of marine transgression along the western coast of India. These rocks are exposed in six isolated regions namely: **Kachchh Mainland, Wagad, Pachcham, Khadir, Bela and Chorar** in the Kachchh District of Gujarat. The Jurassic rocks represent shallow marine sediments deposited in sublittoral to infralittoral environment whereas the Cretaceous sediments were deposited in the deltaic environment.

#### ➤ Classification

The Mesozoic succession of Kachchh overlies the Precambrian crystalline basement and underlain by the Deccan traps. The succession has been intruded by various dykes and sills, as part of the Deccan traps igneous activity. Lithostratigraphically, the Mesozoic succession is divided into four formations such as **Pachcham, Chari, Katrol and Umia** in an ascending order, which are ranging in age from the Lower Jurassic to Lower Cretaceous (Table 6.2).

**Table 6.2: Lithostratigraphy of the Mesozoic rocks of Kachchh, Kachchh District, and Gujarat.** (Source: simplified after, Vaidyanadhan and Ramakrishnan, 2010)

Age	Stage	Formation	Member	Lithology
Deccan traps				
~~~~~ Unconformity ~~~~~				
Upper Jurassic to Lower Cretaceous	Tithonian to Albian	Umia	Bhuj beds Sandstones and shales Ukra beds Umia beds Barren sandstones and shales <i>Trigonia</i> beds Barren sandstones Umia ammonite bed	White, pale-brown and variegated sandstones with subordinate ferruginous, hard, black or brown grit and a few thin bands of shale with remains of cephalopods, brachiopods and plants
Middle Jurassic	Kimmeridgian to Tithonian	Katrol	Upper Katrol shales Gajansar beds Upper Katrol sandstones Middle Katrol sandstones Lower Katrol shales Kanthkot sandstones	Sandstones and shales with abundant remains of cephalopods and some plant fossils

~~~~~ Unconformity ~~~~~				
	Callovian to ?Middle Oxfordian	Chari	Dhosa oolite Athleta beds Anceps beds Rehmanni beds Macrocephalus beds	Sandy limestones, marls, calcareous, gypseous and sandy shales and oolitic limestones and contains fossils of molluscs and brachiopods
	~~~~~ Unconformity ~~~~~			
Middle Jurassic	Bathonian to Callovian	Pachcham	Pachcham coral bed Pachcham shelly limestones Pachcham basal bed (Kuar Bet beds)	Limestones with some sandstones and shales and richly fossiliferous (bivalves, cephalopods, corals are common)
~~~~~ Unconformity ~~~~~				
Precambrian basement (not exposed)				

**Pachcham Formation:** It is the basal most formation named after the Pachcham Island in the Rann of Kachchh, where formation is best exposed and has yielded a rich fossil assemblage of Middle Jurassic age and marks the commencement of the Mesozoic sedimentation within the Kachchh basin. The formation is about 300 m thick and principally composed of limestones with some sandstones and shales. The upper part of the formation has yielded a rich assemblage of bivalves (*Corbula*) cephalopods (*Macrocephalites*, *Sivajiceras*) brachiopods and corals of Middle Bathonian age. The formation is divided into three members: **Pachcham basal bed**, **Pachcham shelly limestones** and **Pachcham coral bed** (Table 6.2).

**Chari Formation:** Overlying unconformably the Pachcham Formation is the Chari Formation. It is about 360 m thick and consists of sandy limestones, calcareous, gypseous and sandy shales, marls and oolitic limestones. The formation is best developed in a village near Jumara. However, the name of the Formation is derived from rocks exposed at the Chari village, near Habo Dome. The Chari Formation is divided into five members such as **Macrocephalus beds**, **Rehmanni beds**, **Anceps beds**, **Athleta beds** and **Dhosa oolite** from base to top (Table 6.2). This formation is richly fossiliferous and has yielded characteristic fauna of the Callovian to ?Middle Oxfordian age on the basis of fossils belonging to cephalopods (*Macrocephalites*, *Kamptcephalites*, *Indocephalites*, *Perisphinctes*, *Hubertoceras*, *Mayaites*) with some brachiopods, bivalves, gastropods, etc. It should be noted that the Pachcham and Chari formations have yielded some index cephalopod ammonite fossils that are well-correlated with the European standard zones. The lithology and fauna of the formation suggests its deposition in deeper water condition during a transgressive phase.

**Katrol Formation:** It lies above the Chari Formation. It is around 300 m thick and is chiefly composed of shales although in the upper part, sandstones predominate and contain abundant remains of cephalopods and pelecypods. The formation is divided into six members such as **Kanthkot sandstones, Lower Katrol shales, Middle Katrol sandstones, Upper Katrol sandstones, Gajansar beds** and **Upper Katrol shales** in ascending order (Table 6.2). The formation has yielded abundant remains of cephalopods (*Ataxioceras*, *Prograyiceras*, *Hybonticeras*, *Aspidoceras*, *Taramelliceras* and *Aulacosphinctoides*) and some plant fossils. A Kimmeridgian to Tithonian age has been assigned to the formation.

**Umia Formation:** It is the youngest formation of the Mesozoic succession in Kachchh. It is about 1000 m thick and mainly composed of white, pale-brown, sometimes variegated sandstones with subordinate ferruginous, hard, black or brown grit and a few thin bands of shale. Lithologically, these beds are similar to the Gondwana rocks of peninsular India. Ammonites are rare, hence other groups and *Trigonia* and other pelecypods have become stratigraphically important. The Umia Formation is divided into eight members: **Umia ammonite bed, Barren sandstones, Trigonia beds, Barren sandstones and shales, Umia beds, Ukra beds, Sandstones and shales** and **Bhuj beds** (Table 6.2). The formation begins with the Umia ammonite bed and ends with the Bhuj beds. A large part of the formation is fossiliferous and yielded the remains of cephalopods (*Hemilytoceras*, *Micracanthoceras*, *Cleonoceras*, *Colombiceras* and *Australiceras*) and brachiopods. The topmost member, Bhuj beds, of the formation is considered to be deposited under continental condition and has yielded the plant fossils of the Gondwanan affinities (*Palmoxylon* and *Ptilophyllum*). A Lower Cretaceous age has been assigned to this formation.

Learners, you have learnt about the Mesozoic succession of Spiti and Kachchh. Before discussing about the Mesozoic succession of Rajasthan, and Cretaceous of Tiruchirapalli spend few minutes to perform an exercise to check your progress.

### SAQ1

- What is main lithology of Triassic succession of Spiti?
- List the names of the formations of the Mesozoic succession of Kachchh in the ascending order.
- Match the following: -
 

a. Productus shale	i. Bathonian to Callovian
b. Umia Formation	ii. Triassic of Spiti
c. Tropites beds	iii. Permian
d. Pachcham Formation	iv. <i>Trigoniabeds</i>

### 6.2.3 MESOZOIC OF RAJASTHAN

The Mesozoic successions of Rajasthan are exposed in the isolated outcrops in the western part of state covering the areas of Jaisalmer and Barmer. The Mesozoic successions of Rajasthan are located in the close proximity of the

Mesozoic successions of Kachchh (Gujarat) and it has been proposed that the sea, which flooded (marine transgression) Kachchh region during the Early Jurassic, also covered large parts of the western Rajasthan lying about 300 km to the north led to the deposition of the Mesozoic rocks in Rajasthan. Due to the proximity, the Mesozoic successions of the Kachchh and Rajasthan share great similarities in both lithological and faunal contents. The Mesozoic successions of Rajasthan that range in age from the Jurassic to Cretaceous are well-developed in the Jaisalmer areas compared to other areas. However, the succession is poorly exposed due to the vast cover of sand and alluvium.

### ➤ Classification

The base of the Jurassic-Cretaceous succession is nowhere exposed in Rajasthan, but the succession lies unconformably above the Precambrian basement probably over the Malani igneous suite. The entire Mesozoic succession in Rajasthan especially in Jaisalmer area, has been divided into six formations, ranging in age from Jurassic to Cretaceous as shown in Table 6.3.

**Table 6.3: Stratigraphy of the Mesozoic succession of Jaisalmer, Rajasthan.**

(Source: simplified after Kumar, 1996; Naqvi, 2005; Vaidyanadhan and Ramakrishnan, 2010)

Age	Stage	Formation	Lithology
Palaeocene	~~~~ Sanu Formation ~~~~		Variegated sandstones and shales
Cretaceous	Lower to middle Cretaceous (Aptian)	Habur	Fossiliferous limestones, very coarse grained sandstones and conglomerates
	Lower Cretaceous (Neocomian)	Pariwar	Sandstones, silty shales, ferruginous oolites
Jurassic	Upper Jurassic (Tithonian)	Bhadesar	Fossiliferous grits, sandstones, shales, black clays and lignite
	Upper Jurassic (Kimmeridgian)	Baisakhi	Sandstones, siltstones, shales and conglomerates with fossils
	Middle Jurassic (Bathonian to Upper Oxfordian)	Jaisalmer	Fossiliferous limestones, sandstones, shales and marls
	Lower Jurassic	Lathi	Mainly sandstones with fossil wood
Precambrian	~~~~~ Malani igneous suite ~~~~~		

**Lathi Formation:** The Mesozoic succession in Rajasthan commences with the laying down of the Lathi Formation. It is about 360 m thick sequence of plant-bearing cross-bedded sandstones of freshwater origin that gradually grading into limestones towards the top, indicating shallow marine depositional

conditions for the upper part of the formation. The higher horizons contain some hard to buff limestone and black to brown clayey layers with a gradational contact with the overlying Jaisalmer Formation. It overlies the Precambrian basement. The lower part of formation yield abundant remains of plants (gymnosperms), gastropods and fish teeth. The Lathi Formation is of Lower Jurassic age.

**Jaisalmer Formation:** It is over 400 m thick sequence, conformably lies above the Lathi Formation and is composed of dull, compact, oolitic and shelly limestones with layers of calcareous sandstones, shales and marls deposited in a shallow, rather unstable, marine environment near the shoreline. The formation is richly fossiliferous and includes the remains of brachiopods, cephalopods, bryozoans, corals and foraminifers. The age of this formation is Middle Jurassic from Bathonian to Upper Oxfordian.

**Baisakhi Formation:** It is about 350 m thick and gradationally lies above the Jaisalmer Formation. It consists of calcareous sandstones, siltstones, grey to black gypseous and silty shales, sandy limestones and conglomerates. The basal part of the formation is fossiliferous and has yielded the remains of cephalopods, belemnites and microfossils, where as fossils are absent in its upper part. An Upper Jurassic (Kimmeridgian) age has been assigned to the formation.

**Bhadesar Formation:** It is about 50 m thick sequence, consisting of calcareous grits, hard ferruginous sandstones with layers of shales, black clays and lignite. It rests over the Baisakhi Formation and represents a sequence deposited during the regressive phase of the sea. The lower part of formation contains fossils belonging to cephalopods, belemnites, corals that are indicative of marine origin. Its upper part yields fossil wood and suggests a near shore marine environment of deposition. An Upper Jurassic (Upper Tithonian) to Lower Cretaceous (Albian) age has been proposed to this formation.

**Pariwar Formation:** The Cretaceous sediments conformably overlie the Bhadasar Formation are represented by the Pariwar Formation. This formation is about 350 m thick and consists of thick, unfossiliferous, grit, gritty sandstones and quartzose sandstones. The sandstone bodies of the Pariwar Formation contain plant fossils such as *Pterophyllum*, *Anomozamites*, *Elatocladus*, *Cladophlebes* etc. The formation was deposited during the beginning of a phase of marine transgression. The Pariwar Formation is of Lower Cretaceous (Neocomian) age.

**Habur Formation:** It rests over the Pariwar Formation. It is about 150 m thick and composed of fossiliferous, buff limestones, gritty sandstones and shales. The lower part of the formation was deposited in an open marine shelf condition while the upper part was accumulated during the regressive phase. The Habur limestone contains a rich assemblage of fossils including ammonites, brachiopods, etc. A Lower Cretaceous (Aptian) age has been assigned to this formation. The Habur Formation marks the end of Mesozoic sedimentation in the Jaisalmer.

### 6.2.4 CRETACEOUS OF TIRUCHIRAPALLI

The Cretaceous rocks of South India crop out in five main sectors, viz., Tiruchirapalli, Sivaganga, Vriddhachalam and Thanjavur in the Tamil Nadu and in the Union Territory of Pondicherry. All these outcrops are the parts of the Cretaceous successions of the Cauvery basin, South India. The Cauvery basin is a large basin with an approximate aerial extent of about 25,000 km² and consisting of well preserved shallow marine Cretaceous sedimentary sequences of the Albian to Maastrichtian age, deposited along the eastern coast of the Tamil Nadu. Among these outcrops, the Cretaceous rocks are best developed in the Ariyalur area near the Tiruchirapalli sector. Here, the sequence represents one of the finest developments of the marine fossiliferous Cretaceous sequence in the world. The basin has yielded the rich and diversified assemblages of molluscs, brachiopods, cephalopods, echinoderms, corals, bryozoans, foraminifers, ostracods, algae and nanoplanktons, which have been extensively used to infer the age and depositional environment of the basin. Upper part of basin has yielded the fossils of freshwater and land vertebrates such as fish, dinosaurs, crocodiles, frogs and mammals. It may be noted that the marine transgressions invaded a large tract of the Coromandel Coast during the Cretaceous, which resulted the almost continuous shallow marine sedimentation from the Albian to Maastrichtian in the basin that continued upwards into the Lower Cenozoic, as well. However, some freshwater environment also prevailed during the sedimentation of the Upper Maastrichtian rocks in the basin.

#### ➤ **Classification**

The Ariyalur outcrop contains extensive, almost complete and well exposed Cretaceous to Palaeocene succession of the Cauvery basin as compared to other outcrops. Based on lithology and fossils, the sequence has been divided into **Uttattur**, **Trichinopoly** and **Ariyalur** groups in ascending order (Table 6.4). The Cretaceous sequence rests unconformably over the Archaean basement (crystalline gneiss and charnokites) and Upper Gondwana plant beds and underlain by the rocks of the Niniyur Group of Palaeocene age.

**Uttattur Group:** The Uttattur Group unconformably overlies upon the Archaean crystalline rocks. It attains a thickness of about 820 m and is subdivided into four formations namely, **Terani**, **Arogyapuram**, **Dalmiapuram** and **Karai** in chronological order (Table 6.4). The group as a whole is composed of fine silts, fossiliferous limestones, calcareous shales and sandy clays with phosphatic nodules, calcareous concretions and gypsum. At several places pale to pure and compact coral limestone is present at the base of the Uttattur sequence. The lower part of group yielded plant fossils of Gondwanan affinities and deposited in the fluvial to deltaic environmental conditions. The upper part of the group is arenaceous, exhibits current bedding and yields abundant fossils comprising brachiopods, belemnites, bryozoans, corals, algae, bivalves, cephalopods (*Eucalyoceras*, *Mammites* and *Lewesiceras*), gastropods, foraminifers, calcareous sponges, sharks and marine reptiles and is considered to be deposited under shallow marine conditions. The Albian to Turonian age has been assigned to the group based on fossils.

**Table 6.4: Lithostratigraphy of the Cretaceous rocks of Tiruchirapalli, Tamil Nadu.**

Age	Stage	Group	Formation	Lithology
Palaeocene		~~~~~Niniyur Group ~~~~~		
		~~~~~ Unconformity ~~~~~		
Cretaceous	Campanian to Maastrichtian	Ariyalur	Kallamedu Kallankurichchi Sillakkudi	Ferruginous arkosic sandstones, white to gray cross-bedded sandstones, calcareous sandstone, variegated clays, grit and fossiliferous limestones
		~~~~~ Unconformity ~~~~~		
	Turonian to Coniacian	Trichinopoly	Anaipadi Kulakkalnattam	Sandstones, limestones, siltstones and concretions of arenaceous limestones
		~~~~~ Unconformity ~~~~~		
	Albian to Turonian	Uttattur	Karai Dalmiapuram Arogyapuram Terani	Gypsiferous clays, sandstones, coral algal limestones, white, pink and yellow silty clay, kaolinitic clays, pebble conglomerates, phosphatic nodules and ferruginous sand interbeds
		~~~~~ Unconformity ~~~~~		
		~~~~~ Precambrian crystalline basement ~~~~~		

Trichinopoly Group: It unconformably overlies the Uttattur Group and is divided into two formations: **Anaipadi** and **Kulakkalnattam** (Table 6.4). It is composed of calcareous grit, sandstone and some shale and sandy clay with bands of shelly limestone, with gastropods and pelecypods, near the base. Granite pebbles commonly occur in the gravels and conglomerates. The beds contain abundant fossil wood, including huge tree trunks, false bedding and other features suggesting accumulation in shallow to coastal waters. A large number of invertebrates, especially pelecypods and gastropods with some cephalopods (*Placenticer* and *Kossmaticeras*), brachiopods, corals, marine reptiles, etc., occur within the Trichinopoly Group, but the assemblage is not as rich as that of the underlying Uttattur Group. The age of the group is from Turonian to Coniacian. The sediments of the group were deposited under a regressive shallow marine environmental condition.

Ariyalur Group: It is a poorly exposed and widely distributed group, lies unconformable above the Trichinopoly Group. It is subdivided into three formations: **Sillakkudi**, **Kallankurichchi** and **Kallamedu** in ascending order

(Table 6.4). The group consists of sandstones with some marly clays, calcareous shales and limestones that display uniform bedding and very low dips. The lower part of the group has yielded well preserved remains of cephalopods (*Karapadites* and *Hauriceras*), echinoderms, brachiopods, bryozoans, foraminifers, ostracods, etc. indicating a shallow, rather calm, marine environment of deposition of sediments. However, towards the upper part, it mainly yielded abundant remains of the terrestrial and freshwater vertebrates such as frogs, turtles, crocodiles and dinosaurs, suggesting a lacustrine environment of deposition. The Ariyalur Group is of Campanian to Maastrichtian age and unconformably overlain by the Niniyur Group of Paleocene age.

Learners, you have learnt the Mesozoic succession of Rajasthan and Cretaceous of Tiruchirapalli. Now, spend few minutes to perform an exercise to check your progress.

SAQ 2

- List the name of the formations of the Mesozoic succession of Rajasthan in ascending order.
- List the name of three groups of Cretaceous succession of Tiruchirapalli in ascending order.
- Match the following:

a. Ariyalur Group	i. Lower Cretaceous
b. Lathi Formation	ii. Kallamedu Formation
c. Habur Formation	iii. Lower Jurassic

6.3 ACTIVITY

Table below is showing the Triassic lithostratigraphic of Spiti (Table 6.5). Fill-up the series, beds and lithology in the blank spaces of rows.

Table 6.5: Triassic succession of Spiti.

Group	Age	Series	Beds	Lithology
Lilang	Jurassic	----	Tagling limestone	Massive limestones and dolomites
Lilang	Triassic		Megalodon limestone (Para Stage)	Massive limestones and dolomites
			Tropites beds	Dolomite limestones, shales and dark limestones with ammonite beds
			Gray beds	Gray shales and shaly limestone with pelecypod bed and an ammonite bed

			Lower Muschelkalk	Dark shales and gray limestones
			Nodular limestone	Hard nodular limestones
		Lower Triassic		
			Meekoceras zone	Thin-bedded limestones and shales
	Permian		Productus shale	Dark shales

6.4 SUMMARY

In this unit, you have learnt about the following:

- Mesozoic era in India is marked by extensive marine transgressions; which brought the marine sedimentation inside the continental areas. As a consequence, the Mesozoic successions are present both in peninsular and the Himalayan regions of India.
- Triassic of Spiti, Mesozoic of Kachchh and Rajasthan and Cretaceous of Tiruchirapalli contain some of the best developed Mesozoic successions in India.
- Triassic succession of Spiti lies above the Productus shale of Permian age and below the Tagling limestone of Lower Jurassic age. Limestones, dolomites and shales are main lithology of the succession and it is divided into the Lower, Middle and Upper Triassic.
- The Mesozoic rocks of Kachchh contain a sequence of more than 2000m thick, ranging in age from the Middle Jurassic to the Lower Cretaceous. The sequence is divided into four formations: Pachcham, Chari, Katrol and Umia in an ascending order.
- Mesozoic succession of Rajasthan is well developed in the Jaisalmer region. It ranges in age from the Lower Jurassic to Lower Cretaceous and is divided into six formations: Lathi, Jaisalmer, Baisakhi, Bhadesar, Pariwar and Habur.
- The Cretaceous succession of Tiruchirapalli is well developed in the Ariyalur area of the Cauvery basin. The age of sequence is Albian to Maastrichtian and is divided into three groups: Uttattur, Trichinopoly and Ariyalur in ascending order.
- Invertebrate assemblages known from the Mesozoic rocks of Spiti, Kachchh, Jaisalmer and Ariyalur are found to be very useful in dating of these rocks successions.
- The Mesozoic sedimentation was, however, terminated by the Upper Cretaceous, ending in the Deccan traps volcanic activity.

6.5 TERMINAL QUESTIONS

1. Explain the Triassic of Spiti.
2. Write a brief note on the Mesozoic stratigraphy of Kachchh.
3. Discuss the Mesozoic stratigraphy of Rajasthan.
4. Describe the Cretaceous succession of Tiruchirapalli.

6.6 REFERENCES

- Kumar, R. (1996) Fundamentals of Historical Geology and Stratigraphy of India. Fourth Reprint, New Age International Publishers, New Delhi.
- Naqvi, S.M. (2005) Geology and Evolution of the Indian Plate (From Hadean to Holocene – 4 Ga to 4 Ka). Capital Publishing Company, New Delhi.
- Vaidyanadhan, R. and Ramakrishnan, M. (2010) Geology of India. Volume II, Geological Society of India, Bangalore.

6.7 FURTHER/ SUGGESTED READINGS

- Krishnan, M.S. (1949) Geology of India and Burma. The Madras Law Journal Office, Madras.
- Kumar, R. (1996) Fundamentals of Historical Geology and Stratigraphy of India. Fourth Reprint, New Age International Publishers, New Delhi.
- Mukerjee, P. K. (1997) A Textbook of Geology, The world Press Pvt Ltd, Calcutta.
- Naqvi, S.M. (2005) Geology and Evolution of the Indian Plate (From Hadean to Holocene – 4 Ga to 4 Ka), Capital Publishing Company, New Delhi.
- Wadia D.N. (1966) Geology of India, McMillan Press, London.

6.8 ANSWERS

Self Assessment Questions

- 1 a) Limestones, dolomites and shales are main lithology of the Triassic succession of Spiti.
c) The name of various formations of the Mesozoic succession of Kachchh is Pachcham, Chari, Katrol and Umia in an ascending order.
d) Match the following: -
 - a. iii.
 - b. iv.
 - c. ii.
 - d. i.
- 2 a) The Mesozoic succession of Rajasthan ranges from the Jurassic to Cretaceous in age and is divided into six formations namely, Lathi, Jaisalmer, Baisakhi, Bhadesar, Pariwar and Habur.

- b) The Ariyalur area of Tiruchirapalli contains extensive, almost complete and well exposed Cretaceous to Palaeocene succession of the Cauvery basin. Based on lithology and fossils, the succession is divided in ascending order into three groups: Uttattur, Trichinopoly and Ariyalur.
- c) Match the following:
- a. ii.
 - b. iii.
 - c. i.

Terminal Questions

1. Refer to sub-section 6.2.1.
2. Refer to sub-section 6.2.2.
3. Refer to sub-section 6.2.3.
4. Refer to sub-section 6.2.4.



GONDWANA SUPERGROUP AND DECCAN TRAPS

Structure

7.1 Introduction

Expected Learning Outcomes

7.2 Gondwana Supergroup

Distribution

Classification

Description of Formations

Economic Significance

7.3 Deccan Traps

Distribution

Classification

Age and Duration

Economic Significance

7.4 Activity

7.5 Summary

7.6 Terminal Questions

7.7 References

7.8 Further/Suggested Readings

7.9 Answers

7.1 INTRODUCTION

The Precambrian (Archaean and Proterozoic) rocks are well developed in the peninsular India. You have already studied some of the rock supergroups that belong to Precambrian age such as Dharwar, Cuddapah, Vindhyan and Delhi in Unit 4. In peninsular India, Lower to Middle Palaeozoic rocks record is almost absent. However, Palaeozoic rocks are well developed in the extra-peninsular or Himalayan region which you have read in Unit 5. From the Upper Carboniferous to Lower Cretaceous, peninsular India witnessed the huge deposition of freshwater sediments in numerous

interconnected inland basins, which are collectively known as **Gondwana Supergroup**. This supergroup is famous for its coal deposits and plant fossils wealth. At the end of Cretaceous, western part of the peninsular India underwent numerous volcanic eruptions that resulted in the formation of the **Deccan Traps**. It has been proposed that these volcanic eruptions might have been responsible for the mass extinction at the Cretaceous/Palaeogene boundary.

In this unit, we will discuss the geographic distribution, classification, climate and lithology of the Gondwana Supergroup. We will also discuss the Deccan traps and associated sediments.

Expected Learning Outcomes

After studying this unit, you should be able to:

- ❖ define and classify Gondwana Supergroup;
- ❖ discuss the lithology of various formations of the supergroup;
- ❖ outline the economic significance of the supergroup;
- ❖ describe the distribution and classification of the Deccan traps; and
- ❖ explain the age and duration of the Deccan traps.

7.2 GONDWANA SUPERGROUP

Gondwana Supergroup comprises a thick sequence of fluvial and lacustrine sediments having a cumulative thickness of about 6 to 7 km with glacial sediments at the base. It covers a vast tract of India, particularly prominent in peninsular region, occupying about 50,000 km² areas. The deposition of the sequence began in the Upper Carboniferous and continued up to the Lower Cretaceous. It may be noted that the lower and upper boundaries of the supergroup are determined by marine fossil records and do not coincide with standard chronostratigraphic system. The Gondwana sequence is largely considered as a continental sedimentary sequence with occasional marine incursions and deposited either in the river valley grabens or in the down-faulted grabens (Kumar, 1988; Vaidyanadhan and Ramakrishnan, 2010). It is dominantly composed of sandstones and shales with rich coal seams as well as fossil remains of plants and animals.

The name "Gondwana" was given by H. B. Medlicott in 1872. It is derived from the Gond Kingdom of the Narmada river, Madhya Pradesh, where the supergroup was first studied by him. Later, investigations carried out in other parts of the world such as in South America, South Africa, Australia, Antarctica and Madagascar, which shows that these rocks are also present in these southern continents. The Gondwanan rocks of these areas bear spectacular similarities in terms of lithology and fossil contents. Keeping these facts in view, Edward Suess in 1885 coined the term "Gondwanaland" to refer all these southern continents into a supercontinent, which was separated from its northern counterpart known as "Laurasia" by then present equatorial sea called "Tethys".

7.2.1 Distribution

The rocks of the Gondwana Supergroup in peninsular India mainly occur in the four isolated patches represented by linear tracts. These tracts are Koel-Damodar basin of West Bengal and Jharkhand, Son-Mahanadi basin of Chhattisgarh and Madhya Pradesh, Satpura basin of Madhya Pradesh and Pranhita-Godavari basin of Telangana and Andhra Pradesh (Fig. 7.1). In addition, a few Gondwana outcrops also present in the eastern coastal area of India such as Athgarh basin of Odisha, Krishna trough of Andhra Pradesh and Palar-Cauvery troughs of Tamil Nadu. In the Himalayan region, a linear belt of the Lower Gondwana rocks occurs along the Himalayan foot-hills Assam and Arunachal Pradesh and also in Kashmir valley.

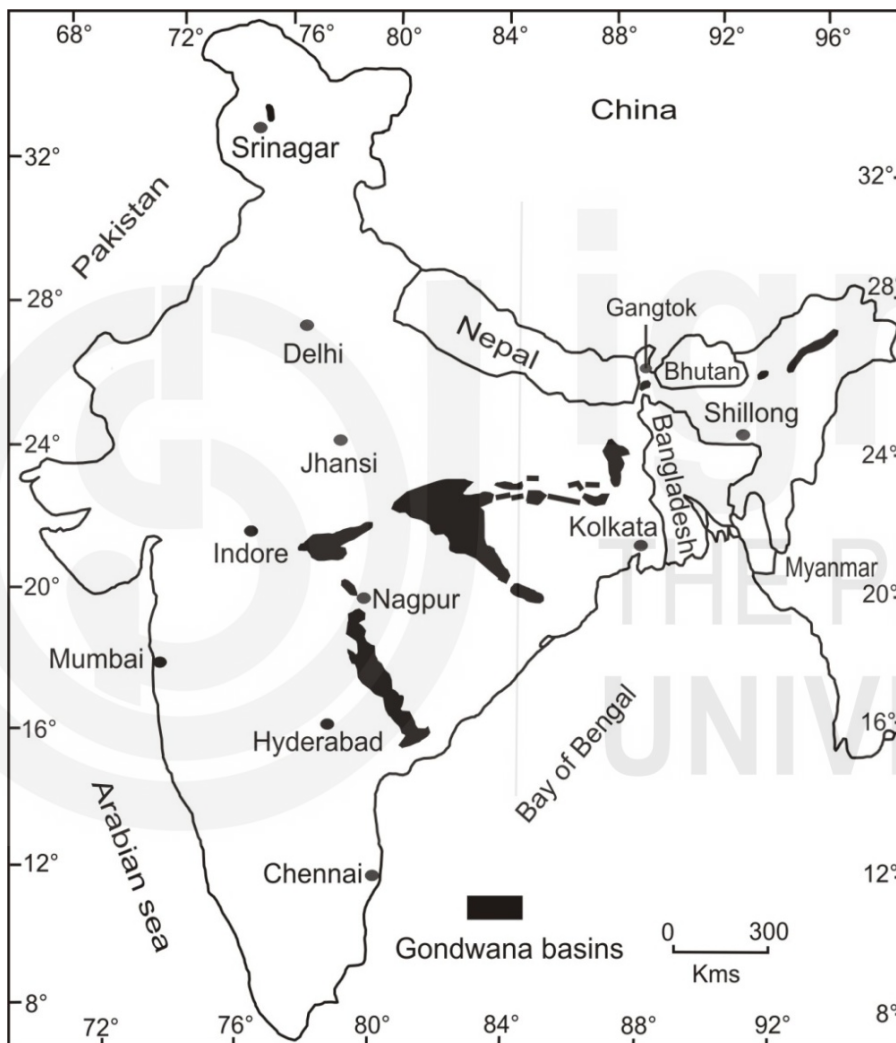


Fig. 7.1: Map of India showing the distribution of the Gondwana basins. (Source: simplified after Vaidyanadhan and Ramakrishnan, 2010)

7.2.2 Classification

Classification of the Gondwana Supergroup is always a topic of debate in Geology of India. On the basis of lithology and plant fossils, two schemes of classification have been proposed for the rocks of the supergroup. These schemes are:

- Two-fold classification
- Three-fold classification

➤ Two-fold Classification

Two-fold classification was proposed by W. T. Blanford. He divided the Gondwana sequence into two subdivisions namely, Lower Gondwana Sequence and Upper Gondwana Sequence. These two sequences are separated by a slight unconformity, which lies at the top surface of the Panchet Formation of the Lower Triassic age. Lower Gondwana Sequence is characterised by the dominance of *Glossopteris* flora whereas the Upper Gondwana Sequence is characterised by appearance of *Ptilophyllum* flora. The two-fold classification was strongly supported by C. S. Fox, R. D. Oldham, G. Cotter, M. S. Krishnan and other workers.

➤ Three-fold Classification

Three-fold classification was proposed by O. Feistmantal and further it was supported by E. Vredenburg and D. N. Wadia. This classification is primarily based on plant fossils and the prevailing characteristic climatic conditions of the Gondwana Supergroup. According to this classification, Gondwana Supergroup is divided into three sequences such as Lower, Middle and Upper Gondwana, corresponding roughly to the Permo-Carboniferous, Triassic and Jurassic, rock systems of Europe, respectively. The Lower Gondwana Sequence is characterised by presence of *Glossopteris* flora, a warm and humid climate with numerous coal seams. The Middle Gondwana Sequence is characterised by appearance of *Dicroidium* flora, a warm and dry climate and by the presence of amphibian and reptilian fossils. The Upper Gondwana Sequence is marked by the appearance of *Ptilophyllum* flora as well as a warm and humid climate (Fig.7.2).

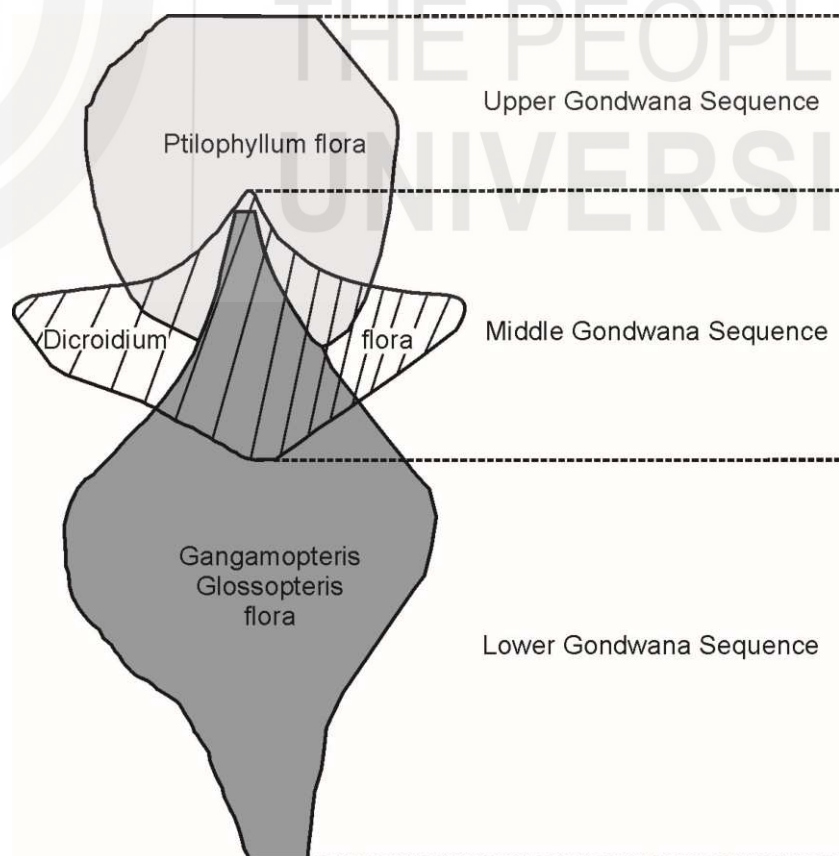


Fig. 7.2: Three-fold classification of the Gondwana Supergroup based on floral relationships.

Over the centuries, most of the workers have been following two-fold classification of the Gondwana Supergroup and hence, the same has been discussed here. A generalised stratigraphic classification of the Gondwana Supergroup is given in Table 7.1.

Table 7.1: Generalised stratigraphic classification of the Gondwana Supergroup.

Super group	Sequence	Group	Formation	Age
Gondwana Supergroup	Upper Gondwana Sequence	Jabalpur Group	Jabalpur Formation	Lower Cretaceous
		Rajmahal Group	Rajmahal Formation	Lower Cretaceous
		Mahadeva Group	Kota Formation	Middle Jurassic
			Maleri Formation	Upper Triassic
			Pachmarhi Formation	Lower Triassic
	~~~~~ Unconformity ~~~~~			
	Lower Gondwana Sequence	Panchet Group	Panchet Formation	Lower Triassic
		Damuda Group	Raniganj Formation	Upper Permian
			Barren Measures Formation	Middle Permian
			Barakar Formation	Lower Permian
			Karharbari Formation	Lower Permian
		Talchir Group	Talchir Formation	Upper Carboniferous

### 7.2.3 Description of Formations

The Permo-Carboniferous sedimentary successions of the Gondwana Supergroup is largely known as Lower Gondwana Sequence and the Mesozoic Gondwana succession forms the Upper Gondwana Sequence (Fig. 7.3). However, the Panchet Formation of the Lower Triassic age comes under the Lower Gondwana Sequence. The Lower Gondwana groups are characterised by the presence of *Gangomopteris-Glossopteris* flora and the Mesozoic Upper Gondwana groups by containing *Dicroidium-Lepidopteris* flora. It has been inferred that the Upper Carboniferous sediments of the Lower Gondwana sequence are deposited under a glacial/cold climate, whereas coal-bearing Permian sediments were deposited under warm and humid climate.

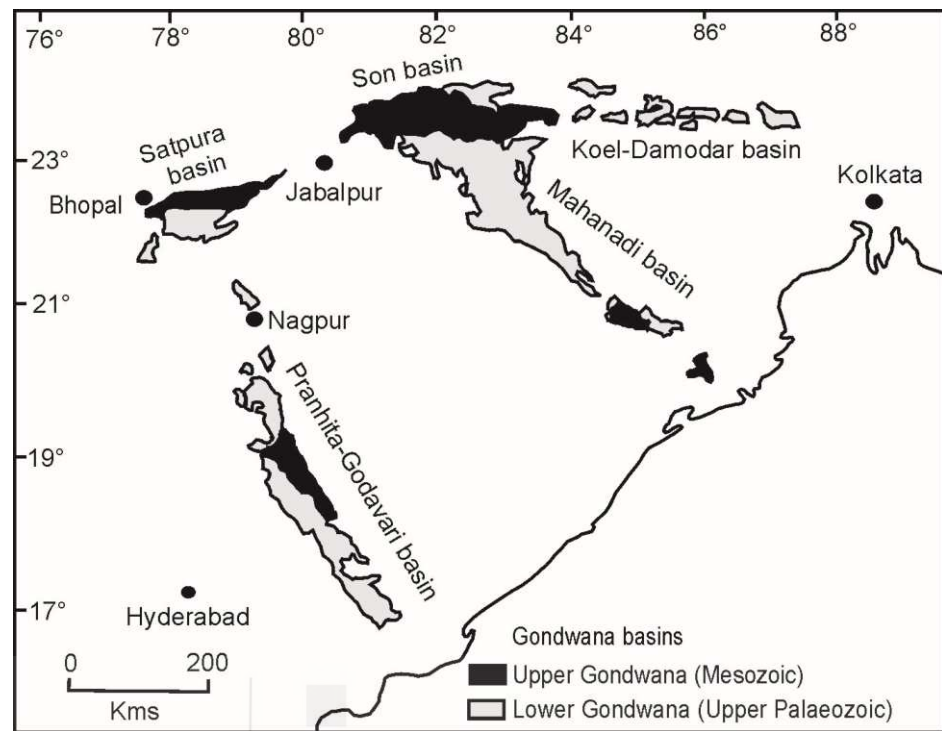


**Fig. 7.3: Distribution of Lower and Upper Gondwana sequences in the major Gondwana basins of India.**

During the beginning of the Upper Gondwana Sequence, sudden changes in climate took place in the Triassic. As a result, warm and humid climate of the Permian was replaced by warm and dry climatic conditions during the Triassic. This warm and dry climate was considered responsible for the disappearance of the *Glossopteris* flora of the Lower Gondwana. The warm and humid climatic conditions again appeared during the Late Triassic and most of the Jurassic, which resulted in the appearance of *Ptilophyllum* flora.

A generalised stratigraphic classification of the Gondwana Supergroup of India is presented in Table 7.1. All formations mentioned in the table may not occur in any single Gondwana basin of India. For example, Karharbari, Barakar, Barren Measures and Raniganj formations are well developed in the Damodar valley, where as Pachmarhi, Maleri and Kota formations are best developed in the Mahadev Hills. In addition, it may be noted that the equivalent formation of one group may be designated or present in other group/s. Therefore, do not get confused while studying the various formations of the supergroup. Now let us discuss the various formations of the Lower and Upper Gondwana sequences.

#### • Lower Gondwana Sequence

The sediments of the Lower Gondwana sequences largely lie above the Precambrian basement and well developed in the Talchir, Damuda and Panchet groups. Now let us discuss the various formations of the Lower Gondwana Sequence.

**Talchir Formation:** Talchir Formation named after the Talchir District of Odisha. It is the lowermost formation of the Gondwana Supergroup, which unconformably overlies the Precambrian basement. It consists of boulder beds, khaki green shales and light green sandstones. Boulder beds form the basal most part of the formation, which is succeeded by shales and sandstones. The

boulder beds comprise unsorted and unstratified mixture of boulders, pebbles, coarse sands and clays. The presence of faceted and striated boulders and pebbles in the boulder beds are indicative of their glacial origin. Hence, boulder beds of Talchir Formation are also known as **Talchir Tillites**. The sandstones contain mineral grains of undecomposed feldspar representing very cold climatic conditions at the time of deposition. The uppermost part of the formation, which dominantly contains sandstones and with some shaly beds yield some plant fossils indicating a warm climate. Carboniferous to Permian, Upper Carboniferous and Lower Permian ages have been assigned to the formation.

**Karharbari Formation:** The Talchir Formation overlain by the Damuda Group is well exposed in the Damodar valley situated in Jharkhand and West Bengal. The Damuda Group is divided into four formations, namely, Karharbari, Barakar, Barren Measures and Raniganj.

Karharbari Formation is the basal part of the Damuda Group, which is well developed in the Giridih coalfields. It consists of conglomerates, pebbly grit, sandstones, siltstones, shales and a few bands of coal. It is about 200 m thick and has gradational contact to the Talchir Formation. The formation is characterised by the development of two characteristic floral elements like *Gondwanidium validum* and *Buriadiasewardi*. *Gangamopteris* and *Glossopteris* are the dominant flora of the formation. A Lower Permian age has been assigned to the formation.

**Barakar Formation:** This formation is named after the Barakar river. It is about 250 m thick, conformably overlies the Karharbari Formation and well developed in the Jharia coalfields. It is the main store house of coal deposits in the Lower Gondwana Sequence. Lithologically, it consists of sandstones, shales, china clays and coal seams. In addition, at some places it is also composed of grit and conglomerate horizons. Importantly, Barakar Formation shows a fining upward cyclic arrangement of the lithofacies such as conglomerates, grits, sandstones, shales and coal seams. This cyclic arrangement of lithofacies has frequently occurred repeatedly in the formation. The china clay deposits of the formation are found to be of economic significance. It may be noted that lower and middle units of the formation are the main sources of coal. Interestingly, almost one ninth of the total thickness of the formation is constituted by coal deposits. The formation is rich in plant fossils and is characterised by the dominance of *Glossopteris*, *Gangamopteris*, *Sphenopteris*, *Taeniopteris*, *Barakaria*, *Phyllothea*, *Schizoneura* and *Sphenophyllum* plant fossils. Barakar Formation is of Lower Permian age.

**Barren Measures Formation:** The name of the formation indicates that it lacks coal seams. The formation conformably overlies the Barakar Formation. It consists of alternating units of cross-bedded sandstones and carbonaceous shales with clay-ironstone nodules. In the Raniganj basin of the Damodar valley, the Barren Measures Formation is known as **Ironstone Shale Formation**. Here, the formation once composed of workable deposit of iron ore particularly siderite iron. In other coalfields of the Damodar valley, it is known as Barren Measures Formation. The formation is generally devoid of plant fossils, but a very few plant fossils such as *Cyclodendron*, *Glossopteris*,

*Gangamopteris* etc. are known from it. A Middle Permian age has been assigned to this formation.

**Raniganj Formation:** This formation is well developed in the Raniganj coalfield in the Damodar valley, where it attains a thickness of about 800 m. It consists of sandstones, shales and coal seams. The sandstones of the Raniganj Formation being fine-grained as compared to those of the older and underlying Barakar Formation. Valuable coal seams are a part of the Raniganj Formation, which mainly occur in the Raniganj coal field. The coal seams of the formation contain high content of volatiles, but some of them have coal of superior quality. The Raniganj Formation shows the peak zone of *Glossopteris* flora. The characteristic flora of the formation includes *Glossopteris*, *Gangamopteris*, *Pecopteris*, *Vertebraria*, *Sphenopteris*, *Taeniopteris*, *Schizoneura*, *Phyllothea*, etc. An Upper Permian age has been assigned to the formation.

**Panchet Formation:** The Panchet Formation overlies the Raniganj Formation and contact between them is marked by a slight unconformity. The formation is named after the Panchet Hill in Manbhum of the Raniganj basin, where the formation is well developed and attained thickness from 500 to 600 m. The Panchet Formation is devoid of coal seams and presents a sharp contrast in lithology as compared to the underlying Raniganj Formation. The lower part of the Panchet Formation consists of greenish sandstones to khaki green siltstones and green clays. The upperpart of the formation is characterised by a rhythmic alternation of green clays and chocolate coloured shales and clays. The Panchet Formation is very rich in fossils and yielded the fossils of plants and animals including both vertebrates and freshwater invertebrates. The plant fossils are dominated by *Glossopteris*, *Cyclopteris*, *Dicroidium*, *Schizoneura* and a few other plant fossils. The formation also yielded crustacea of the Phylum Arthropoda (invertebrates) as well as vertebrates such as amphibians (labyrinthodonts) and reptiles (*Dicynodon* and *Epicampodon*). The occurrences of above-mentioned fauna and flora indicate a climate, which somewhat resembling the present-day monsoonal climate probably having heavier and longer spells of rainfall. The Panchet Formation is the topmost formation of the Lower Gondwana Sequence and is of Lower Triassic age.

### • Upper Gondwana Sequence

In peninsular India, the rocks of Lower and Upper Gondwana sequences are separated by a distinct unconformity. The Lower Gondwana sequences are well developed in the Talchir, Damuda and Panchet regions. On the other hand, the Upper Gondwana sequences are well developed in the Mahadeva, Rajmahal and Jabalpur areas. Now let us discuss the various formations of the Upper Gondwana Sequence.

**Pachmarhi Formation:** The Pachmarhi Formation represents the basal most part of the Upper Gondwana Sequence. It is well developed in the Pachmarhi hills of the Satpura basin. The formation is about 750 m thick and consists of buff and red sandstones with red clays and some associated patches of haematitic clay and ferruginous materials. It is important to note that the Pachmarhi Formation is completely devoid of carbonaceous matter, but the layers of clay sometimes contain the leaf impressions are also present. The sandstones of the formation are coarse-grained, good quality and tinted with

various shades of red (Krishnan, 1949; Mukherjee, 1997). Hence, it is extensively used as a building material. A Lower Triassic age has been inferred for the formation.

**Maleri Formation:** The Maleri Formation overlying the Pachmarhi Formation is about 330 m thick. The formation is named after the village of Marweli in the Tandur as it is well developed in the Tandur coalfield of the Pranhita-Godavari basin in Asifabad area of Telangana. Lithologically, it consists of red clayey beds, siltstones, argillaceous sandstones and lime-pellet rocks. The rocks of this formation are known to contain abundant remains of fishes and reptiles as well as coprolites (fossil dung/animal dropping). In addition, some fresh water unionids (gastropods) and large tree trunks were also known. This formation is considered to be deposited during the Upper Triassic.

**Kota Formation:** It lies above the Maleri Formation in the Pranhita-Godavari basin. It is about 600 m thick and dominantly composed of large-scale cross-bedded sandstones, grits with red clay bands and some bands of limestone. It also contains carbonaceous clays and a few thin seams of coal. The formation yielded remains of plants, for example, *Ptilophyllum* flora, fishes, dinosaurs and mammals. The Kota Formation is considered to be of Middle Jurassic age.

**Rajmahal Formation:** The Rajmahal Formation is well developed in the Rajmahal Hills, which is located in the northeastern Jharkhand. The formation is about 600 m thick, primarily made up of the Rajmahal volcanics (basaltic lava flows) with intercalated sedimentary beds known as intertrappean beds. Lithologically, intertrappean beds are made up of sandstones, siltstones, arenaceous clays, white and grey colour baked shales, carbonaceous shales, tuffite and chert beds and yield well preserved remains of plants. These intertrappean beds were deposited in freshwater conditions probably in the locally formed isolated lakes. The Rajmahal Formation lies above the Dubrajpur Formation in the Rajmahal basin. The Dubrajpur Formation is more or less equivalent to the Maleri formation of the Pranhita-Godavari basin. The Rajmahal Formation is considered to be of Lower Cretaceous age. The plant fossil-yielding intertrappean beds of the formation are informally known as Rajmahal plant beds. These plant beds have yielded one of the richest floral assemblages of the world. Numerous plant fossils belonging to the ferns, cycads and conifers are known from the formation. Among them *Ptilophyllum*, *Pterophyllum*, *Dictyozamites*, *Taeniopteris*, *Williamsonia*, *Brachyllum*, *Thinnfeldia* and *Cladophlebis* are the most common genera of plant fossils.

**Jabalpur Formation:** The Jabalpur Formation is well developed in the Jabalpur area of Madhya Pradesh. It unconformably lies above the Mahadeva Group of Central India. It consists of massive sandstones, jasper-yielding sandy conglomerates, white and light-coloured soft clays and carbonaceous shales and with a few coal seams. The formation is considered to be of Lower Cretaceous age. It yields *Ptilophyllum*, *Pagiophyllum*, *Brachyphyllum*, *Taeniopteris*, *Nilssonina*, *Dictyozamites*, *Otozamites* and other plant fossils.

#### **7.2.4 Economic Significance**

Significantly, the Gondwana Supergroup is a major repository of coal deposits in India. It is accounting for more than 98% of country's coal resources, whereas

remaining 2% of coal is coming from the Tertiary basins of the country. The Lower Gondwana sequences are the main coal producing sequences of the Gondwana Supergroup. The Karharbari, Barakar and Raniganj formations of the Lower Gondwana sequences are main coal producing formations. Among them, the Barakar Formation alone hosts a vast majority of coal resources of the country. Apart from this, Gondwana sandstones are used for building and construction purposes whereas clays are used in refractory industries. Some iron-ore deposits occur in the Barren Measure Formation. Finally, it should be understood that coal deposits of the Gondwana Supergroup reflect main economic importance of the supergroup.

Learners, you have learnt about the distribution, classification, description of formations and economic significance of Gondwana Supergroup. Before discussing about the Deccan Traps, spend few minutes to perform an exercise to check your progress.

### SAQ 1

- The Gondwana sediments are of ----- origin.
- Name the two classification schemes of the Gondwana Supergroup.
- What is the age range of the Gondwana Supergroup?
- List the main lithology of the Gondwana Supergroup.
- Where does the sediments of the Lower Gondwana Sequence are well developed?
- Match the following:
 

a. Lower Gondwana Sequence	i. Iron ore
b. Upper Gondwana Sequence	ii. Damuda basin
c. Raniganj Formation	iii. <i>Ptilophyllum</i> flora
d. Barren Measures Formation	iv. <i>Glossopteris</i> flora

## 7.3 DECCAN TRAPS

At the close of the Cretaceous period, the peninsular India was witnessed by the major phase of volcanic activity. It was a remarkable event in the geology of India, where numerous lava flows were poured out mainly through fissure-type of volcanic eruption and covered a vast area of the Deccan Plateau in the western and central India. These lava flows formed as one of the Large Igneous Provinces in the world, which are known as the Deccan Traps or Deccan Volcanic Province. The term “Deccan Traps” was given by W. H. Sykes in 1833. The word “Deccan” is derived from a Sanskrit word “Dakshin” referring south or southern whereas the word “Traps” derived from a Scandinavian word “Traps/Trappa” referring a step-like appearance. Hence, Deccan Traps refers to the step-like appearance of the basaltic terrain of the Deccan Plateau. Moreover, the lava flows of the Deccan Traps formed the flat-topped plateau-like topography of the terrain with step-like terraces. The lava flows are dominantly basaltic in composition. Hence, these flows are generally, called

traps rocks. The basalts of the Deccan Traps are also known as Flood Basalts, because they cover a large area of the country.

The enormous lava flows of the Deccan Traps were erupted on the surface at parts of peninsular India formed by the rocks of the Precambrian to Mesozoic age. These rocks belong to the Dharwar, Aravalli, Bastar and Bundelkhand groups of the Precambrian age and the Bagh Beds, Lameta Formation and Dharangadhara Group of the Upper Cretaceous age. The Deccan Traps are made up of several lava flows with the thickness of individual flow varying from a few meters to as much as 40 m. A total of 48 lava flows have been identified within the Deccan Traps. Among them, majority of lava flows occur in the form of horizontal sheets with an individual lava flow covering an area of about 1000 km². The Deccan Traps have a maximum thickness of about 2.5 km in the western side of the plateau (near Mumbai, Western Ghats) and thinnest on the eastern side.

### 7.3.1 Distribution

Deccan Traps, that hosts one of the large igneous provinces of the globe, occupy an area of about 500,000 km² mainly in the western and central India. It covers parts of Maharashtra, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Telangana, Karnataka, Gujarat, Rajasthan, Goa and Daman and Diu in peninsular India (Fig. 7.4).

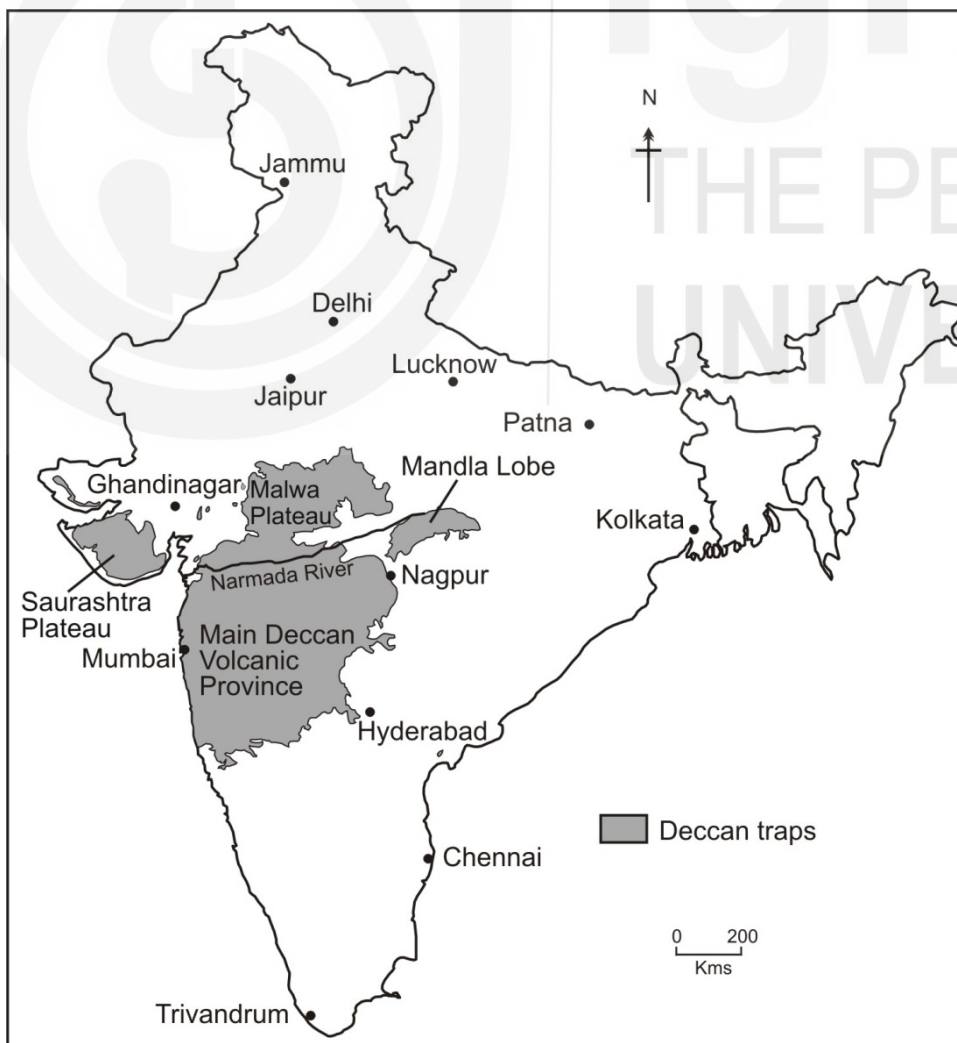


Fig. 7.4: Map of India showing spatial distribution of the Deccan Traps.

### 7.3.2 Classification

Lithologically, the Deccan Traps are made up of fine to medium grained, black to dark grey coloured basaltic rocks. The tholeiitic basalts are the main constituents of the traps. However, other types of igneous rocks such as alkali-olivine basalts, rhyolites, trachytes, nepheline syenites, nephelinites, carbonatites, lamprophyres and picrites are also present. The lava flows of the traps are separated by the intervening thin sedimentary and volcanic ash beds. It is interesting to know that beds of volcanic ash associated with the lava flows are a very common feature of the traps. The sedimentary beds sandwiched between two successive lava flows are known as **intertrappean beds** whereas the sedimentary beds that lie just below the first or oldest lava flows are called **infratrappean** or **Lameta beds**. The infratrappean and intertrappean beds contain abundant remains of plants and animals. The Deccan Traps are classified into three stratigraphic units based on intertrappean beds and their fossil content as shown in Table 7.2.

**Table 7.2: Stratigraphy of the Deccan Traps.**

Traps	Distribution	Lithology
Nummulitics of Surat and Broach; Eocene of Kutch; laterite ~~~~~ Unconformity ~~~~~		
Upper Traps (450 m thick)	Bombay and Saurashtra	Lava flows with numerous volcanic ash-beds and sedimentary intertrappean beds. Intertrappean beds contain numerous remains of vertebrates and molluscan shells
Middle Traps (1200 m thick)	Malwa and Central India	Lava flows and ash-beds forming the thickest part of the traps. Numerous ash-beds occur in the upper part of the traps, but intertrappean beds are rare.
Lower Traps (150 m thick)	Madhya Pradesh	Lava flows with few ash-beds and numerous fossiliferous intertrappean beds
~~~~~ Slight unconformity ~~~~~ Lameta or Infratrappean beds, Bagh beds and older rocks		

The Deccan Traps are divided into following sub-provinces:

- **Western Deccan Volcanic Province:**

It represents the Main Deccan Volcanic Province and lies south of the Narmada river comprising western, central and south eastern parts of the Deccan Traps. It largely occurs in Maharashtra. Its western part consists of Western Ghats, ranging from Mumbai to Ratnagiri, where the traps are well exposed and have maximum thickness. The central part includes area around Aurangabad and south eastern part covers area around Gulbarga and Nanded (Vaidyanadhan

and Ramakrishnan, 2010). It covers larger area of the country, as a result, it is also known as **Main Deccan Plateau**.

- **Malwa Plateau:**

It lies north of the Narmada river and covers the areas around Indore, Bhopal and Sagar in Madhya Pradesh. The Satpura hills separate the Western Deccan Volcanic Province from the Malwa Plateau.

- **Eastern Deccan Volcanic Province:**

It is an isolated lava pile, located on the eastern part of the Main Deccan Volcanic Province in the Central India. It covers areas around Chhindwara, Seoni and Jabalpur in Madhya Pradesh. This lava pile occurs as an outlier near Mandla and hence, commonly known as **Mandla lobe**.

- **Saurashtra Plateau:**

It represents the square shaped trap, located between the Khambhat graben in the east and Son-Narmada fault in the south of Gujarat.

It may be noted that the Deccan Traps are best studied in the Western/Main Deccan Volcanic Province. Based on the nature of lava flows, the Western Deccan Volcanic Province is classified into a number of subgroups and formations as shown in Table 7.3.

Table 7.3: Lithostratigraphy of the Western Deccan Volcanic Province of the Deccan Traps. (Source: simplified after Vaidyanadhan and Ramakrishnan, 2010)

Group	Subgroup	Formation	Characteristic feature
Western Deccan Volcanic Province	-----	Mahabaleshwar	Simple and aa phyric flows
	Wai	Purandhargad	Simple and aa type flows
		Diveghat	Aphyric aa type flows
	Lonavala	Karla	Compound pahoehoe flows
		Indrayani	Simple flows of columnar jointed and aphyric types
		Ratangad	Compound flows of phyric type
	Kalsubai	Salher	Simple pahoehoe flows of phyric type

7.3.3 Age and Duration

The lava flows of the Deccan Traps were erupted near the Cretaceous-Palaeogene (K-Pg) boundary [66 million years (Ma) ago]. The K-Pg boundary represents an important time frame in geological history of the Earth because this time interval is marked by a massive mass extinction, when all dinosaurs became extinct on the surface of the Earth. Therefore, this mass extinction is termed as **K-Pg mass extinction** as it was held at K-Pg boundary. It has been

proposed that K-Pg mass extinction is linked with voluminous eruptions of the Deccan Traps. As a result, the age and duration of the Deccan Traps have received global attention during last two decades. The age and duration of the Deccan Traps is mainly determined based on the fossils present in the intertrappean and infratrappean beds as well as by the radiometric dating of the trap rocks.

It has been proposed that lava flows of the Deccan Traps were erupted in three phases. The first phase is marked by the beginning of eruption of lava flows of the Deccan Traps at 67.5 Ma ago, which followed by a quieter period of 2 million years. At the close of K-Pg boundary, the second phase of volcanic eruption took place. It is considered as the main event of lava flows because 80% of the total lava flows of the Deccan Traps were erupted during this phase. The last and third phase began after the K-Pg boundary around 64 Ma ago and about 14% of lava flows of the total Deccan Traps were erupted. A total duration of about 4 million years, from 68 to 64 Ma ago, for volcanic eruptions has been estimated for the Deccan Traps. Out of which, a major portion of the Deccan Traps was formed with duration of less than 1 million years during the second phase of volcanic eruption at K-Pg boundary and this phase is considered to be linked with K-Pg mass extinction. In addition, based on the fossils especially foraminifers, ostracods and plants discovered from the infratrappean and intertrappean beds associated with the Deccan Traps, a Maastrichtian to Danian (Upper Cretaceous to Lower Palaeocene) age has also been proposed for the Deccan Traps.

The Lameta Formation (Infratrappean beds) underlies the Deccan traps, having an aerial extent of more than 10,000 km² and occurs as detached outcrops in Madhya Pradesh, Gujarat and Maharashtra. Lithologically, it consists of red and green clays, green sandstone, limestone, gray marls and yellow laminated clays interbedded with marlites and mottled nodular bed and is well known for its dinosaur fauna. Important dinosaurian fauna of the formation is consisted of titanosaurids (*Jainosaurus septentrionalis*, *Isisaurus colberti*) and theropods (*Indosuchus raptorius*, *Indosuchus matleyi*, *Laevisuchus indicus*, *Lametasaurus indicus*, *Rajasaurus narmadensis*, *Rahiolisaurus gujaratensis*).

7.3.4 Economic Significance

The rocks of the Deccan Traps are hard, dense and durable, hence, they are extensively used as road metals and building material. The monumental site "Gateway of India" which is located in Mumbai is built by using these rocks. The weathering of the Deccan Traps formed many workable deposits of high-grade bauxite, which is an ore of aluminium ore. These deposits occur in Jabalpur, Katni, Mandla, Belgaum, Kolhapur and Gujarat. The rocks of traps also yield many semi-precious stones such as agate, chalcedony, amethyst and others. Black soil, also known as regur, formed due to the weathering of the traps, is highly suitable for the cultivation of cotton.

Learners, you have learnt the distribution, classification, age and duration and economic significance of Deccan Traps. Now, spend few minutes to perform an exercise to check your progress.

SAQ 2

- The Deccan Traps are of ----- origin.
- What are intertrappean and infratrappean beds?
- Name the rocks that form the Deccan Traps.
- Describe the geographical distribution of the Deccan Traps.

7.4 ACTIVITY

Study Table 7.4 carefully and write the lithology and age of various formations of the Gondwana Supergroup at their respective places.

Table 7.4: Stratigraphic classification of the Gondwana Supergroup.

Super group	Formation	Lithology	Age
Gondwana Supergroup	Jabalpur Formation		
	Rajmahal Formation		
	Kota Formation		
	Maleri Formation		
	Pachmarhi Formation		
	~~~~~ Unconformity ~~~~~		
	Panchet Formation		
	Raniganj Formation		
	Barren Measures Formation		
	Barakar Formation		
	Karharbari Formation		
	Talchir Formation		

## 7.5 SUMMARY

In this unit, you have learnt about the following:

- Gondwana Supergroup comprises a thick sequence of fluviatile and lacustrine sediments having a cumulative thickness of about 6 to 7 km.
- The deposition of the sequence began in the Upper Carboniferous and continued up to the Lower Cretaceous.
- The rocks of the Gondwana Supergroup in peninsular India mainly occur in the four isolated patches: Koel-Damodar, Son-Mahanadi, Satpura and Pranhita-Godavari basins. Small outcrops are also present in the Himalayan region.
- Two-fold classification scheme divided the supergroup into two subdivisions: Lower Gondwana Sequence and Upper Gondwana Sequence. The Lower Gondwana Sequence is characterised by the dominance of *Glossopteris*

flora whereas the Upper Gondwana Sequence is characterised by appearance of *Ptilophyllum* flora.

- Three-fold classification divided the supergroup into three sequences such as Lower, Middle and Upper Gondwana, corresponding roughly to the Permo-Carboniferous, Triassic and Jurassic, respectively, rock systems of Europe.
- Two-fold classification scheme is generally followed by most of the workers. Talchir, Karharbari, Barakar, Barren Measures, Raniganj and Panchet are the main formations of the Lower Gondwana Sequence, whereas Pachmarhi, Maleri, Kota, Rajmahal and Jabalpur are the major formations of the Upper Gondwana Sequence.
- Coal-deposits of the Gondwana Supergroup are the main source of coal for the country.
- The Deccan Traps are a large igneous province of volcanic origin in the world.
- It is Upper Cretaceous to Lower Palaeocene in age and occurs in Maharashtra, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Telangana, Karnataka, Gujarat, Rajasthan, Goa and Daman and Diu in Peninsular India.
- The Deccan Traps are mainly composed of tholeiitic basalts. It also consists of intratrappean and intertrappean beds of sedimentary origin.
- The Deccan Traps have a maximum thickness of about 2.5 km in its western side and total 48 lava flows have been identified.
- The Western Deccan volcanic province, Malwa plateau, eastern Deccan volcanic province and Saurashtra plateau are the main sub-provinces of the Deccan Traps.
- The lava flows of the Deccan Traps were erupted near the Cretaceous-Palaeogene (K-Pg) boundary (66 Ma ago) with a total duration of about 4 million years, from 68 to 64 Ma ago.
- The rocks of the traps are used as building material and road metal. The black soil derived from weathering of the traps is most suitable for growing cotton. Trap rocks also yield semi-precious gemstones.

## 7.6 TERMINAL QUESTIONS

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1. Give an account of the classification of the Gondwana Supergroup of peninsular India.
2. List the economic importance of the Gondwana Supergroup.
3. What are Deccan Traps? Discuss the stratigraphy of the Deccan Traps.
4. List the economic importance of the Deccan Traps.

## 7.7 REFERENCES

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- Krishnan, M.S. (1949) Geology of India and Burma. The Madras Law Journal Office, Madras.
- Kumar, R. (1988) Fundamentals of Historical Geology and Stratigraphy of India. New Age International Publishers, New Delhi.
- Mukerjee, P. K. (1997) A Textbook of Geology. The world Press Pvt Ltd, Calcutta.

- Vaidyanadhan, R. and Ramakrishnan, M. (2010) Geology of India. Geological Society of India, Bangalore.

## 7.8 FURTHER/SUGGESTED READINGS

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- Naqvi, S.M. (2005) Geology and Evolution of the Indian Plate (From Hadean to Holocene – 4 Ga to 4 Ka). Capital Publishing Company, New Delhi.
- Shah, S.K. (2018) Historical Geology of India. Scientific Publishers, Jodhpur.
- Wadia D.N. (1966) Geology of India. McMillan Press, London.

## 7.9 ANSWERS

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### Self Assessment Questions

- 1 a) Fluvial and lacustrine.
  - b) The two schemes of the Gondwana Supergroup classification are two-fold and three-fold. The two-fold scheme classifies the Gondwana sequences into two sequences such as Lower and Upper Gondwana sequences. The three-fold scheme classifies it into three sequences namely Lower, Middle and Upper Gondwana sequences.
  - c) Upper Carboniferous to Lower Cretaceous.
  - d) The Gondwana Supergroup is dominantly composed of sandstones, shales and clays with rich coal seams as well as fossil remains of plants and animals.
  - e) The sediments of the Lower Gondwana Sequence are well developed in the Damuda basin.
  - f) Match the following: -
    - a. - iv
    - b. - iii.
    - c. - ii.
    - d. - i.
- 2a) Volcanic origin.
  - b) The intertrappean beds are those which are sandwiched between two successive volcanic lava flows of traps. The intratrappian beds include those sedimentary beds which lie just below the first or oldest lava flow of the traps.
  - c) The Deccan Traps are dominantly composed of fine to medium grained, black to dark grey coloured basaltic rocks. The tholeiitic basalts are the main constituents of the traps. However, other types of igneous rocks such as alkali-olivine basalts, rhyolites, trachytes, nepheline syenites, nephelinites, carbonatites, lamprophyres and picrites are present within the traps.
  - d) Geographically, the Deccan Traps occur in peninsular India covering the parts of Maharashtra, Madhya Pradesh, Chhattisgarh, Andhra Pradesh, Telangana, Karnataka, Gujarat, Rajasthan, Goa and Daman and Diu.

**Terminal Questions**

1. Refer to subsection 7.2.2.
2. Refer to subsection 7.2.4.
3. Refer to introductory part of section 7.3 for general description of the Deccan Traps and subsection 7.3.2 for its classification.
4. Refer to subsection 7.3.4.



# CENOZOIC OF HIMALAYA |

## Structure

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### 8.1 Introduction

Expected Learning Outcome

### 8.2 Palaeogene–Neogene Sequences of Northwest Himalaya

Palaeogene–Neogene Sequences of ITSZ

Palaeogene Sequences of the Sub-Himalaya

Neogene Sequences of the Sub-Himalaya

### 8.3 Palaeogene–Neogene Sequences of Assam

Palaeogene Sequences of Assam

Neogene Sequences of Assam

### 8.4 Activity

### 8.5 Summary

### 8.6 Terminal Questions

### 8.7 References

### 8.8 Further/Suggested Readings

### 8.9 Answers

## 8.1 INTRODUCTION

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In Unit 7, you have studied about the Gondwana Supergroup and the Deccan Traps, which are well developed in Peninsular India. The Gondwana Supergroup, ranging in age from the Upper Carboniferous to Lower Cretaceous, contains huge coal deposits and fossils. The Upper Cretaceous to Lower Palaeocene aged Deccan Traps, on the other hand, is marked by the end of the Mesozoic sedimentation in Peninsular India. The beginning of the Cenozoic era in the Himalayan region represents a distinct phase in the tectonic and sedimentation history of India. From the Precambrian to Mesozoic time, the Himalayan region dominantly witnessed the marine sedimentation whereas freshwater sedimentation in this region largely commenced during the Cenozoic era.

During the Cenozoic, the Himalayan region witnessed two major geological events; first, India-Asia collision and second, Himalayan orogeny. In Unit 6, you have studied that India separated from

Gondwanan landmasses during the Middle Jurassic and subsequently, it started drifting north towards Asia. The India-Asia collision, which took place in the Early Cenozoic, formed 2500 km long northwest to southeast trending Himalayan ranges in the form of an arc. The convex side of the Himalayan arc lies towards India. The southernmost range of this arc, known as Outer or Sub-Himalaya, comprises Cenozoic successions of the Himalaya. These successions occur both in the northwest and northeast parts of the Himalayan region of India. In addition, some Palaeogene–Neogene sediments also occur within the northernmost boundary of the Indian plate, marked by the Indus Tsangpo Suture Zone (ITSZ). This Palaeogene–Neogene succession is well exposed in Ladakh region of Jammu and Kashmir.

In this unit, we will discuss the lithology, classification, age and distribution of various Palaeogene–Neogene successions exposed in the northwest and northeast Himalayan regions of India.

### Expected Learning Outcomes

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After reading this unit, you should be able to:

- ❖ outline the various Palaeogene–Neogene successions of the northwest and northeast Himalaya;
- ❖ define and classify the main Palaeogene–Neogene successions of the Himalayan region;
- ❖ discuss the lithology of important Palaeogene–Neogene groups/formations; and
- ❖ enlighten the stratigraphy of Palaeogene–Neogene successions of the northwest Himalaya and Assam.

## 8.2 PALAEOGENE–NEOGENE SEQUENCES OF NORTHWEST HIMALAYA

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Himalaya comprises a chain of parallel mountain ranges. Topographically, the Himalaya can be linearly divided into five parallel ranges from north to south such as Trans Himalaya, Tethys Himalaya, Greater or Higher Himalaya, Lesser or Lower Himalaya and Outer or Sub-Himalaya (Fig. 8.1). These divisions are separated by distinctive fault or thrust zones. For example, Indus Tsangpo Suture Zone (ITSZ), which represents the northern boundary of the Indian plate and zone of collision between India and Asia, lies between Trans and Tethys Himalaya. The necessity to highlight these divisions and ITSZ is that the Outer or Sub-Himalaya as well as ITSZ contain well preserved successions of the Palaeogene–Neogene age.

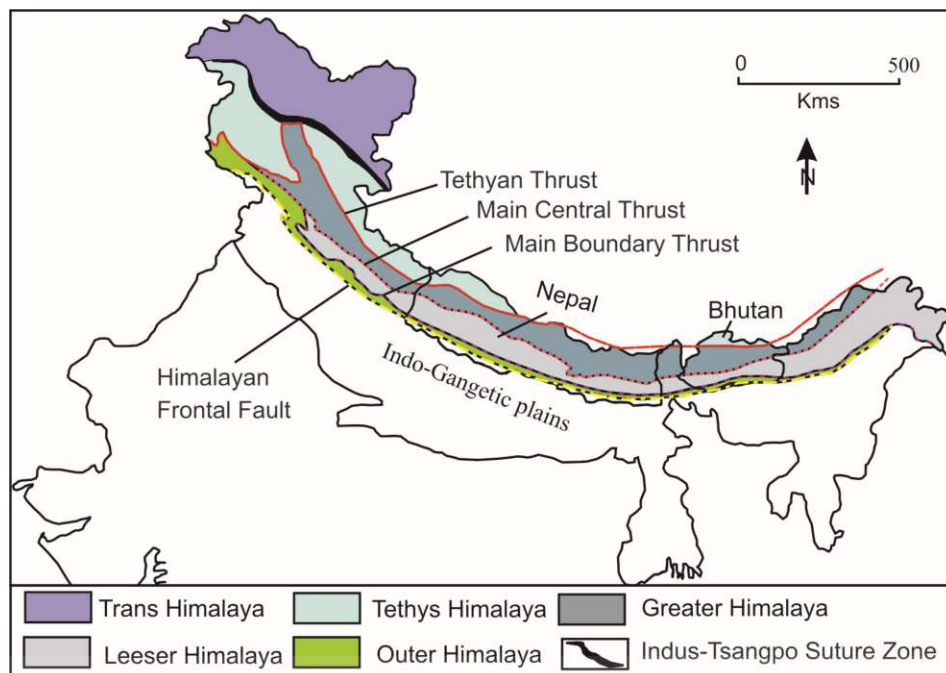


**Fig. 8.1: Geologic map of Himalaya showing different tectonic units.** (Source: simplified after Kumar, 1988).

### 8.2.1 Palaeogene–Neogene Sequences of ITSZ

Indus Tsangpo Suture Zone (ITSZ) is well exposed in the Ladakh area of Jammu and Kashmir state. The Cenozoic rocks of ITSZ have been termed as Indus Basin Sedimentary Rocks (IBSR) that have been divided into two groups, namely the Tar Group of Middle Cretaceous to Lower Eocene age and the Indus Group of Middle Eocene to Miocene age. The Tar Group deposited under marine conditions, comprises three formations such as Jurutze, Sumda and Chogdo in ascending order and mostly consists of black shales, siltstones, nummulitic limestone, etc. The Indus Group represents predominantly a continental sedimentary succession that comprises four formations such as Nurla, Choksti, Lower Nimu and Upper Nimu in ascending order. Lithologically, the group is made up of mudstones, sandstones, shales, siltstones and conglomerates.

### 8.2.2 Palaeogene Sequences of the Sub-Himalaya

The Outer or Sub-Himalaya is the main zone of the Cenozoic sedimentation. The Palaeogene–Neogene sequences of the Sub-Himalaya occur in the northern states of India comprising Jammu and Kashmir, Punjab, Himachal Pradesh and Uttarakhand. It is important to note that Subathu, Murree and Dharamsala are the main Palaeogene groups of rocks whereas Siwalik is a major Neogene group of Cenozoic sequences of the Sub-Himalaya. Let us discuss the Palaeogene groups of the Northwest Himalaya.

#### • Subathu Group

The Subathu Group gets its name from the town of Subathu in the Solan District of Himachal Pradesh where it is well exposed. The Subathu Group consists of a thick succession of conformable strata comprising of dark green and red shales interbedded with nummulitic limestones, carbonaceous shales and bands of sandstones. The group occurs in Jammu and Kashmir, Punjab,

Himachal Pradesh and Uttarakhand and overlies the Precambrian-Cambrian slates and limestones. The rocks of the Subathu Group are richly fossiliferous, yielding remains of larger foraminifers such as *Nummulites*, *Ranikothalia*, etc. ostracods, molluscs and fish remains, indicating a marine environment of deposition for the group. It is divided into two formations: Kakara and Subathu in ascending order (Table 8.1). An Upper Palaeocene to Eocene age is proposed for this group.

**Table 8.1: Palaeogene successions of the northwest Himalaya**

Group	Formation	Lithology	Age
~~~~~ Neogene Siwalik Group ~~~~~			
Murree (= Dharamsala)	Upper Murree (= Kasauli)	Red, maroon and purple sandstones, mudstones and shales. Conglomerates at the base.	Upper/Middle Eocene to Lower Miocene
	Lower Murree (= Dagshai)		
Subathu	Subathu	Dark green and red shales interbedded with nummulitic limestones, carbonaceous shales and bands of sandstones	Upper Palaeocene to Eocene
	Kakara		
~~~~~ Precambrian and Cambrian slates and limestones ~~~~~			

#### • Murree Group

The Subathu Group is followed by Murree and Dharamsala groups. These two groups have almost the same age range, but occur at two different areas and thus named differently. The Murree Group occurs in Jammu and Kashmir and its coeval Dharamsala Group in Himachal Pradesh (Table 8.1). Firstly, let us discuss the Murree Group. Type locality of the Murree Group occurs in the Murree township of Pakistan. The rocks of the Murree Group consist of red, maroon and purple sandstones, mudstones and shales. The base of the group, which is well exposed in Kohat-Potwar area of Pakistan, consists of conglomerates, which indicate the end of marine sedimentation and beginning of freshwater deposition in the Himalayan region (Naqvi, 2005). The Murree Group is divided into two formations namely the Lower Murree Formation and the Upper Murree Formation based on lithological changes (Table 8.1). A Middle Eocene to Lower Miocene age is generally assigned to the Murree Group.

#### • Dharamsala Group

The Dharamsala Group of Himachal Pradesh, coeval of the Murree Group of Jammu and Kashmir is divided into the lower Dagshai Formation and the upper Kasauli Formation (Table 8.1). The **Dagshai Formation** equivalent to the Lower Murree Formation of Jammu and Kashmir overlies the Subathu

Formation. It is named after the Dagshai town that lies close to Subathu in Himachal Pradesh. The formation comprises alternating sequence of red, grey and purple clays with hard, green-grey coloured sandstones and red mudstones. The formation was deposited under shallow marine to terrestrial environment (Vaidyanadhan and Ramakrishanan, 2010). The gradationally overlying **Kasauli Formation** consists of brownish yellow and greyish green medium to coarse grained sandstones with subordinate yellowish green, greyish green and purple shales. The formation is named after Kasauli town of Himachal Pradesh that lies close to Dagshai. The floral elements of the Kasauli Formation indicate moist to dry tropical environment. An Upper Eocene to Lower Miocene age has been assigned to the Dharamsala Group (Kumar, 1998; Vaidyanadhan and Ramakrishanan, 2010).

### **8.2.3 Neogene Sequences of the Sub-Himalaya**

In Himalaya, the Neogene successions are developed in two geographically separated areas: Sub-Himalaya and Lesser Himalaya. The Neogene rocks of the Sub-Himalaya are termed as the Siwalik Group. In the Lesser Himalaya, the Neogene sediments are known as Karewa Formation that occurs in the Kashmir valley, Srinagar, Jammu and Kashmir. The Siwalik Group is one of the dominant groups of the Neogene rocks in the northwest Himalaya and hence, it is described in a greater detail.

- **Siwalik Group**

The Neogene Siwalik Group is exposed throughout a linear belt along the Himalayan foothills between the river Indus in the west and the Brahmaputra gorge in the east except for a small break near Sikkim where the Lesser Himalaya comes in direct contact with the Indo-Gangetic plain. The group is well developed in Haritalyanagar area of Himachal Pradesh and Tawi valley in Jammu province of Jammu and Kashmir. Generally, the group consists of alternate beds of muddy and maroon sandstones, shales, silts, clays with occasional pebbly conglomerate layers coarsening upward. The sediments of the Siwalik Group are thought to be derived from the ranges of the Himalaya located towards the north of the group and rivers flowing across these ranges brought the sediments down into the Siwalik basin that gave rise to the Siwalik Group.

- **Classification**

The Siwalik Group is a rich store house of fossils. Among them the vertebrates are more dominant than invertebrates and plant fossils. The whole succession of the group shows a frequent repetition in the lithology, as consequence, the characteristics of rocks are not useful to classify the group. The Siwalik Group, which ranges from the Lower Miocene to Lower Pleistocene in age, is made up of three subgroups: Lower Siwalik, Middle Siwalik and Upper Siwalik in the order of ascendance (Table 8.2). Each subgroup is further divisible into two or three formations (Table 8.2). Let us discuss these subgroups and formations of the group in detail in ascending order.

Table 8.2: Stratigraphy of the Siwalik Group.

Group	Subgroup	Formation	Lithology	Age
~~~~~ Older alluvium ~~~~~				
Siwalik	Upper	Boulder conglomerate	Conglomerates, sandstones, siltstones and clays	Pliocene - Pleistocene
		Pinjor	Sandstones, siltstones, conglomerates and clays	
		Tatrot	Conglomerates, soft sandstones and clays	
	Middle	Dhok Pathan	Sandstones, shales, claystones, conglomerates.	Miocene - Pliocene
		Nagri	Massive sandstones, with subordinate red clays, shales and conglomerates	
	Lower	Chinji	Sandstones, claystones and red shales.	Miocene
		Kamlial	Hard and soft sandstones, clays, purple shales and pseudo-conglomerates.	
~~~~~ Middle Eocene to Lower Miocene Murree/Dharamsalagroups ~~~~~				

**Lower Siwalik Subgroup** comprises dominantly of sandstone and claystone units that were deposited under the fluvio-lacustrine environment. It is divided into Kamlial and Chinji formations.

- **Kamlial Formation** represents lowermost unit of the group and is named after the village Kamlial in Potwar Plateau, Pakistan. This unit lies above the Murree Group and comprises fine to medium grained grey to greenish grey coloured hard sandstones with occasional well indurated to soft brown sandstones, purple shales and pseudo-conglomerates. It has yielded numerous mammalian remains. A Lower to Middle Miocene age has been proposed to this formation.
- The overlying **Chinji Formation** also derives its name from a village in Potwar Plateau named Chinji. The Chinji Formation is relatively more clayey, comprising brown and yellow claystones, subordinate grey and brown sandstones and red shales. This formation contains a wealth of fossils. It has yielded remains of mammals, reptiles and bivalves. The Chinji Formation has been assigned a Middle Miocene to Upper Miocene age.

**Middle Siwalik Subgroup** is dominated by multistoried sandstones with occasional claystones, which were deposited in flood plain environment. It comprises the Nagri and Dhok Pathan formations.

- The **Nagri Formation** is named after Nagri village in Potwar Plateau. It overlies Chinji Formation of the Lower Siwalik subgroup. It consists of massive sandstones with subordinate red clays, shales and conglomerates. This formation is poor in fossils as compared with the underlying Chinji Formation. It has yielded remains of horse, cattle, primates, etc. This formation is dated as Upper Miocene.
- The overlying **Dhok Pathan Formation** gets its name from a village of the same name in the Potwar Plateau. The formation is relatively dominant in shales. In addition, it also contains sandstones, claystones with occasional conglomerates. The Dhok Pathan Formation is an important fossil-yielding unit of the Siwalik Group. It has yielded diverse mammalian assemblages. An Upper Miocene to Lower Pliocene age has been assigned to this formation.

**Upper Siwalik Subgroup** largely consists of sandstone, clay and conglomerate horizons deposited under fluvial environment. This group is divided into three formations viz. Tatrot, Pinjor and Boulder Conglomerate.

- The **Tatrot Formation** is named after the village Tatrot in the Potwar Plateau. It is the basal most unit of the Upper Siwalik that lies above the Dhok Pathan Formation and consists of conglomerates, soft sandstones and orange and brown clays. The conglomerate bed is found at the base of the formation and indicates a physical break in sedimentation after the deposition of the Middle Siwalik (Krishnan, 1949). The formation has yielded remains of elephant, horse, cattle, etc. A Pliocene age has been assigned to the formation.
- The overlying **Pinjor Formation** derives its name from Pinjor town in Haryana, in the Indian Siwalik. It consists of light grey to white coarse sandstones and light pink siltstones, conglomerates and clays. It contains a rich assemblage of mammals, which are regarded as probable ancestors of many of the modern mammals. The formation is dated from Pliocene to Lowermost Pleistocene in age.
- The topmost **Boulder Conglomerate Formation** lies above the Pinjor Formation and is the youngest unit of the Siwalik Group. It dominantly consists of conglomerates, but sandstones, siltstones and clays are also present. The sediments of this formation are coarse in nature, deposited under glacial regime and almost unfossiliferous. It ranges from Middle to Upper Pleistocene in age.

Siwaliks are unique in the world of geology, as they present an almost continuous depositional record of a Neogene terrestrial sequence with only minor hiatuses and many fossiliferous levels, although the quality of fossil record varies. For the last 150 years, Siwalik is well known for its rich repository of vertebrate fauna along with significant invertebrate and plant fossils. Over the years focused research work by several workers in India have brought to light important fossil localities, in the Siwaliks of India viz. the Lower Siwaliks of Ramnagar (Jammu and Kashmir), the Middle Siwaliks of Haritalyanagar and

Nurpur (Himachal Pradesh), the Upper Siwaliks north and east of Chandigarh, and Markanda valley (Himachal Pradesh) and the Middle - Upper Siwaliks of Haridwar (Uttarakhand). Other than fossil remains of elephant, horse, giraffe etc., remains of apes have also been discovered from the Siwalik Group.

Learners, you have learnt about the Palaeogene-Neogene sequences of northwest Himalaya. Before discussing about the Palaeogene-Neogene sequences of Assam, spend few minutes to perform an exercise to check your progress.

## SAQ 1

- a) What are main groups of Palaeogene–Neogene rocks in the northwest Himalaya?
- b) List the name of the formations of the Siwalik Group in ascending order.
- c) Match the following:
 

a. Subathu Group	i. Chinji Formation
b. Lower Siwalik Subgroup	ii. Pinjor Formation
c. Indus Group	iii. Kakara Formation
d. Upper Siwalik Subgroup	iv. ITSZ

## 8.3 PALAEOGENE–NEOGENE SEQUENCES OF ASSAM

Assam is a northeastern state of India. The Palaeogene–Neogene sequences of rocks are well developed in Assam and adjoining areas like Meghalaya, Naga Hills, Shillong Hills, Chittagong Hills, Surma Valley etc. in the northeastern Himalaya. These sequences were deposited under a range of environments from marine to terrestrial or freshwater.

### 8.3.1 Palaeogene Sequences of Assam

The Palaeogene succession of Assam is made up of the Langpar Formation, and Jaintia and Barail groups as shown in Table 8.3. Let us discuss the Langpar Formation, which is the oldest formation of the Palaeogene Sequences of Assam.

#### • Langpar Formation

The Langpar Formation has been considered to be the base of the Cenozoic succession in Assam and Meghalaya. The Langpar Formation overlies the Upper Cretaceous Mahadeo Formation, which is well exposed in the Shillong Plateau, Meghalaya. The Langpur Formation consists of shale with bands of limestone and argillaceous sandstone, yellowish brown impure limestone and sandstone, and sandy shale with sandy limestone in the ascending sequence. It is considered to be of a Lower Palaeocene age.

#### • Jaintia Group

The Jaintia Group conformably overlies Langpar Formation and is divisible into three formations namely, Tura sandstone, Sylhet limestone and Kopili in

ascending order (Table 8.3). An Upper Palaeocene to Upper Eocene age has been assigned to the group.

**Table 8.3: Stratigraphy of Palaeogene Sequences of Assam.**

Group	Formation	Lithology	Age
Miocene Surma Group			
Barail	Renji	Sandstones with some shales	Oligocene
	Jenam	Carbonaceous shales, shales and sandstones	
	Laisong	Sandstones with some shales	
Jaintia	Kopili	Alternating beds shales and sandstones	Upper Palaeocene to Upper Eocene
	Sylhet limestone	Limestones with alternating bands of sugary sandstones	
	Therria/Tura sandstone	Coarse to medium grained, current bedded sandstones and clays with limestones, shales and coal.	
~~~~~ Unconformity ~~~~~			
---	Langpar	Limestones, sandstones, sandy shales with sandy limestones	Lower Palaeocene
Upper Cretaceous Mahadeo Formation			

The basal **Tura Sandstone Formation** of the group is composed of coarse to medium grained, current bedded, non-feldspathic, coal-bearing sandstones and clays with limestones, grayish-white shales, carbonaceous shales and coal.

Three coal seams occur in the Tura Sandstone of which, the middle one is workable. Some invertebrate fossils have been recovered from the upper strata of the Tura Formation and a near-shore shallow marine environment with continental influence has been proposed to the formation.

The overlying **Sylhet Limestone Formation** consists of limestones with alternating bands of sugary sandstones and coal seams. The limestone beds have yielded characteristic remains of foraminifers such as *Nummulites*, *Discocyclina*, *Miscellanea*, *Orbitolites* etc. The microfaunal assemblages suggest a shallow marine environment of deposition to the formation.

The topmost **Kopili Formation** of the group lies above the Sylhet Limestone Formation. It comprises mainly of alternating beds shales and sandstones with streaks of limestones, phosphatic nodules, marls and coals with leaf impression. A variety of environments of deposition from shallow and open marine, warm water to near shore coastal environment have been inferred to this formation. The formation grades upward into the Barail Group.

• Barail Group

The Jaintia Group conformably underlies a thick succession of arenaceous sedimentary rocks that mainly consists of alternating band of hard sandstones and shales with coal-seams termed as **Barail Group**. The group is well

developed in both Upper and Lower Assam. The Barail Group contains workable coal seams and many productive petroliferous beds in Upper Assam. The thickness of the group increases from northwest to southwest. In Lower Assam, the Barail Group is divided into three formations namely, Laisong, Jenam and Renji in ascending order (Table 8.3).

The **Laisong Formation** is basal most unit of the group that lies above the Kopili Formation of the Jaintia Group. This formation occurs in Central and Lower Assam and is dominantly composed of sandstones with some shales. The overlying **Jenam Formation** consists of carbonaceous shales, shales and sandstones. The **Renji Formation** is youngest formation of the group and lies above the Jenam Formation and below the Surma Group. It is mainly made up of sandstones with a few horizons of shale.

It may be noted that Barail Group in Upper Assam is also divided into three formations such as Naogaon, Baragoloi and Tikak Parat. The group has yielded only a few fossils and is considered to be of Oligocene age. The sediments of the Barail Group were deposited under swampy and marshy environmental conditions.

8.3.2 Neogene Sequences of Assam

The Neogene sequences consist of the Surma and Tipam groups of rocks. In Assam and its vicinity, the Neogene sequence occurs in Shillong-Mikir Hills, Dhansiri, Upper Assam valley, Manipur and Kohima. The Surma and the Tipam groups made up of different lithologies vary in their thickness spatially. The Neogene sequence of Assam is bounded by two regional unconformities, one lies at its base between the top of Barail and bottom of Surma groups and other at top between the boundaries of Tipam and post Tipam sediments (Table 8.4).

Table 8.4: Stratigraphy of Neogene sequences of Assam.

Group	Formation	Lithology	Age
~~~~~ Unconformity ~~~~~			
Tipam	Girujan Clays	Variegated clays with patchy variable sand content or occasional thin bands of sandstone and lignite	Miocene to Pliocene
	Tipam Sandstones	Massive ferruginous sandstones with some thin bands of shales, clays, conglomerates and lignite	
Surma	Bokabil	Silty shales, shales with siltstones and sandstones	Middle to Upper Miocene
	Bhuban	Sandstones, mudstones, conglomerates and shales	
~~~~~ Unconformity ~~~~~			
Oligocene Barail Group			

• Surma Group

The Surma Group is a thick sequence of Middle-Upper Miocene clastic sediments consisting of alternation of sandstones, shales and siltstones. It

overlies the Oligocene aged Barail Group with a distinct unconformity and underlies the sandstones dominating Tipam Group of Miocene to Pliocene age. The Surma Group contains marine and brackish water microfauna reflecting basinal deposition under deltaic to estuarine condition. The lower part of the group is well developed in the Surma Valley, especially in the Bhuban Hills and upper part at the Bokabil near Masimpur. The Surma Group is divided into a lower, Bhuban Formation and an upper, Bokabil Formation (Table 8.4). Let us discuss about these formations.

Bhuban Formation is the basal unit of the group that lies above the Renji Formation of the Barail Group. The Formation is made up of an alternating sequence of bedded sandstones, mudstones, conglomerates and shales and has yielded fragmentary remains of shells.

The **Bokabil Formation** conformably overlies the Bhuban Formation and is overlain by the Tipam Sandstone Formation of the Tipam Group. It is primarily an argillaceous sequence. It chiefly consists of silty shales, shales with siltstones and sandstones. It has yielded remains of molluscs especially bivalves and gastropods.

• Tipam Group

The Tipam Group that overlies the Surma Group consists dominantly of massive sandstones with subordinate clay and shales. The Tipam Group is considered to be of Miocene to Pliocene age and is well developed along the Tipam river in Assam. It is divided into two formations, namely the Tipam Sandstone and Girujan Clay (Table 8.4).

The lowermost **Tipam Sandstone Formation** overlies the Bokabil Formation and underlies the Girujan Clay. It comprises massive ferruginous sandstones with some thin bands of shales, clays, conglomerates and lignite. The sandstones are rich in heavy minerals like enstatite, kyanite, sillimanite, andalusite, hornblende and epidote. The formation contains a few oil-bearing beds and fossil wood.

The **Girujan Clay Formation** lies above the Tipam Sandstone Formation and comprises soft variegated clays with patchy variable sand content or occasional thin bands of sandstone and thin streaks of lignite. The formation also contains bluish-grey mottled clay. The Girujan Clay has yielded some plant fossils.

Learners, you have learnt about the Palaeogene-Neogene sequences of Assam. Now, spend few minutes to perform an exercise to check your progress.

SAQ 2

- a) What are the main groups of Palaeogene rocks in the northeast Himalaya?
- b) List the name of the formations of the Tipam Group in ascending order.
- c) Match the following:

a. Surma Group	i. Renji Formation
b. Barail Group	ii. Upper Palaeocene to Upper Eocene
c. Jaintia Group	iii. Lower Palaeocene
d. Langpar Formation	iv. Boka Bil Formation

8.4 ACTIVITY

Figure 8.2 is showing the outline of different divisions of the Himalaya. Find and demarcate the ITSZ and Sub-Himalaya. List the name of groups that occur in these areas.

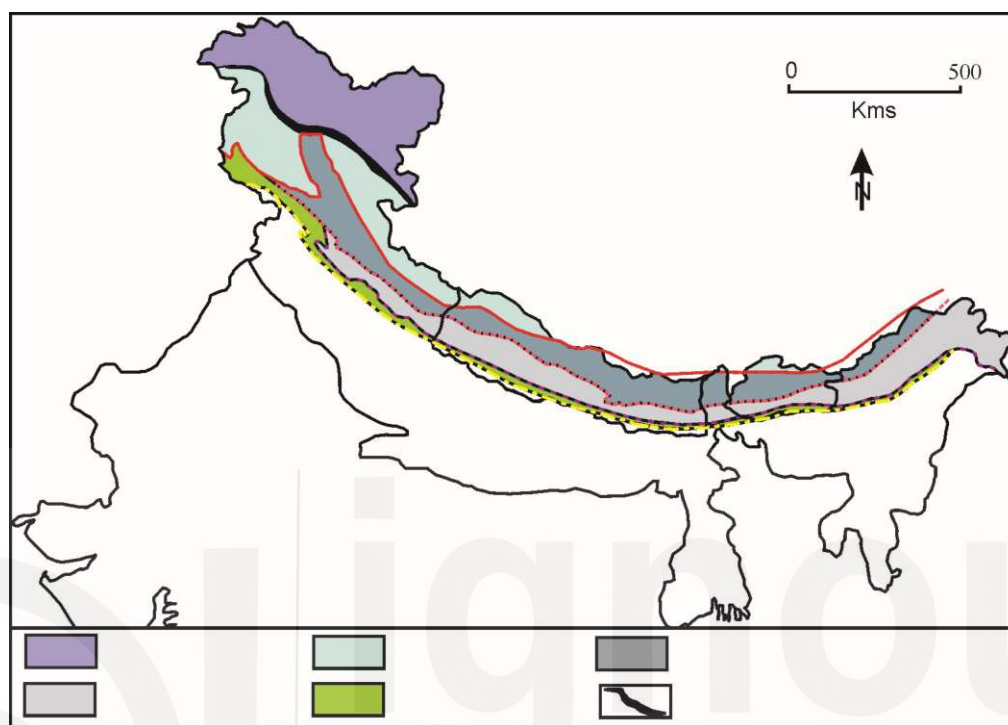


Fig. 8.2: Map showing the outline of various divisions of the Himalaya.

8.5 SUMMARY

In this unit, you have learnt about the following:

- Cenozoic successions are well developed in the northwest and northeast parts of the Himalayan region of India. In northwest Himalaya, these occur in ITSZ, Lesser Himalaya and Sub-Himalaya comprising the states of Jammu and Kashmir, Punjab, Himachal Pradesh and Uttarakhand. Whereas in northeastern part, the Cenozoic successions are present in Assam and adjoining areas.
- Tar Group, ranging in age from Middle Cretaceous to Lower Eocene and the Indus Group ranging in age from Middle Eocene to Miocene represent the Palaeogene-Neogene successions of ITSZ.
- The Subathu, Murree and Dharamsala are the main Palaeogene groups of Sub-Himalayan region of the northwest Himalaya. The Subathu consists of dark green and red shales interbedded with nummulitic limestones, carbonaceous shales and bands of sandstones. The group is an Upper Palaeocene to Eocene in age.
- The Murree Group consists of red, maroon and purple sandstones, mudstones and shales and is Middle Eocene to Lower Miocene in age.
- The coeval of the Murree Group of Jammu and Kashmir in Himachal Himalaya is the Dharamsala Group, which is divided into Dagshai Formation and Kasauli Formation.

- The Siwalik Group is a Neogene group of rocks in the northwest Sub-Himalaya. It is divided into three subgroups: Lower, Middle and Upper. The Siwalik Group is made up of alternate beds of muddy and maroon sandstones, shales, silts, clays with occasional pebbly conglomerate layers coarsening upward. It ranges from Lower Miocene to Pleistocene in age and has yielded diverse mammalian assemblages.
- The Palaeogene–Neogene rock sequences of the northeastern Himalaya are well developed in Assam and adjoining areas like Meghalaya, Naga hills, Shillong hills, Chittagong hills, Surma valley etc.
- The Palaeogene succession of Assam is made up of the Langpar Formation, and Jaintia and Barail groups. The Surma and Tipam are the main groups of the Neogene sequences of Assam and adjoining areas in the northeast Himalaya.

8.6 TERMINAL QUESTIONS

1. Discuss the Palaeogene stratigraphy of northwest Himalaya.
2. Describe the Siwalik Group.
3. Explain the Palaeogene groups of Assam.
4. Discuss the stratigraphy and age of the Surma and Tipam groups.

8.7 REFERENCES

- Krishnan, M.S. (1949) Geology of India and Burma. The Madras Law Journal Office, Madras.
- Kumar, R. (1988) Fundamentals of Historical Geology and Stratigraphy of India. Fourth Reprint, New Age International Publishers, New Delhi.
- Naqvi, S.M. (2005) Geology and Evolution of the Indian Plate (From Hadean to Holocene – 4 Ga to 4 Ka). Capital Publishing Company, New Delhi.
- Vaidyanadhan, R. and Ramakrishnan, M. (2010) Geology of India. Volume II, Geological Society of India, Bangalore.

8.8 FURTHER/SUGGESTED READINGS

- Mukerjee, P. K. (1997) A Textbook of Geology. The world Press Pvt Ltd, Calcutta.
- Shah, S.K. (2018) Historical Geology of India. Scientific Publishers, Jodhpur.

8.9 ANSWERS

Self Assessment Questions

- 1 a) Palaeogene–Neogene rocks in the northwest Himalaya occur in three different parts such as at ITSZ, Lesser and Sub-Himalaya. The Tar Group of the Middle Cretaceous to Lower Eocene age and the Indus Group of the Middle Eocene to Miocene age are main successions of ITSZ. The Subathu, Murree, Dharamsala and Siwalik groups are the main Palaeogene–Neogene successions of the Sub-Himalaya. Whereas,

the Karewa Formation constitutes a Neogene succession of the Lesser Himalaya.

- b) The Neogene Siwalik Group is divided into three subgroups and seven formations. These are the Lower, Middle and Upper Siwalik Subgroups in ascending order. The Lower Siwalik includes two formations such as Kamlial and Chinji, the Middle Siwalik also comprises two formations namely Nagri and Dhok Pathan and the Upper Siwalik is made up of three formations, which are Tatrot, Pinjor and Boulder Conglomerate.
 - c) Match the following: -
 - a. iii.
 - b. i.
 - c. iv.
 - d. ii
- 2 a) The Langpar Formation, and Jaintia and Barail groups are the main Palaeogene successions of Assam and adjoining areas in northeast Himalaya. The Jaintia Group conformably overlies the Langpar Formation and is divided into three formations: Tura sandstone, Sylhet limestone and Kopili in ascending order. The overlying Barail Group is divided into three formations such as Laisong, Jenam and Renji in ascending order.
- b) The Tipam Group that overlies the Surma Group consists dominantly of massive sandstones with subordinate clay and shales. The Tipam Group is considered to be of Miocene to Pliocene age and well developed along the Tipam river in Assam. It is divided in to two formations such as the Tipam Sandstone and Girujan Clay.
 - c) Match the following: -
 - a. iv.
 - b. i.
 - c. ii.
 - d. iii.

Terminal Questions

1. Refer to subsection 8.2.2.
2. Refer to subsection 8.2.3.
3. Refer to subsection 8.3.1.
4. Refer to subsection 8.3.2.

Glossary

- Archaean** : Eon defined as the time between 4 billion years ago to 2.5 billion years ago. Most of the oldest rocks on Earth, including large portions of the continents, formed at this time.
- Batholith** : A large intrusion of igneous rock, usually granite, formed deep beneath the surface of Earth so the rock cooled very slowly.
- Beach** : An accumulation of sediment found along the landward margin of the ocean or a lake.
- Bedding Plane:** : Individual layer of a sedimentary rock is called bed. Each bed is separated from the adjacent bed by a plane called bedding plane
- Biostratigraphic Unit** : It is a body or layer of rock sequence characterised by its content of fossils. Range zone, interval zone, assemblage zone and abundance zones are the common biostratigraphic units.
- Cambrian** : A division of geological time in the Palaeozoic era between 542 and 488 million years.
- Carboniferous** : A division of geologic period and system that spans 60 million years from the end of the Devonian Period 358 Mya to the beginning of the Permian Period, 298 Mya.
- Conglomerate** : A sedimentary rock with rounded, larger (≥ 2 mm) clasts.
- Craton** : The name is derived from a Greek word meaning "strength". It is used to distinguish those portions of continental crust that are stabilised after a series of cycles of orogeny (mountain building) and are composed of crystalline rocks. The term craton is used against mobile belts, which are still unstable. The term shield is often used to denote a region composed of cratons and associated mobile belts.
- Cretaceous** : A division of geological time in the Mesozoic Era between 145 and 65 million years ago.
- Deccan Plateau** : Deccan plateau is a large plateau in India, located between the mountain ranges of the Western Ghats and the Eastern Ghats.
- Deformation** : It is a general term that encompasses change in shape, size or both in a body. In geological studies deformation in the rocks is generally observed in the form of folding, faulting, and shearing.

- Disconformity** : A type of unconformity. It is the surface of a division between parallel rock strata, indicating interruption of sedimentation.
- Fossil** : A fossil is the remains of a plant or organism which are preserved in rocks either fully or in parts through some process.
- Himalaya** : The word Himalaya is derived from Sanskrit word *Him-alaya*. *Him* means snow and *alaya* means covered range, which refers to the snow-covered mountain range. Most western writers pluralise it as “Himalayas”, which is incorrect because the Sanskrit word itself is pluralised.
- Inliers** : Inlier refers ‘to older bed inside’. In the field or on a geological map when the older rock is completely surrounded by younger rocks it is known as inlier. Inliers may be produced by erosion, folding, faulting or combination of more than one of these phenomena.
- Incrop** : When a portion of the rocks which are not exposed at the surface are referred to as incrop.
- Joints** : Joints are quite common and important structures found in the rocks. Joint is in fact, a kind of fracture without any observable movement along it.
- Jurassic** : A division of geological time in the Mesozoic Era between 200 and 145 million years ago.
- Limestone** : It is a sedimentary rock composed mainly of calcium carbonate (CaCO_3), deposited usually under marine conditions, and composed of chemically derived lime muds or fossilised shells, or both.
- Lithostratigraphic Units:** : They comprise bed, member, formation, group and supergroup, and are classified on the basis of lithology.
- Lithospheric Plates:** : Earth is constituted of many different segments of lithosphere known as lithospheric plates. These lithospheric plates are also known as tectonic plates or simply plates.
- Mesozoic** : An Era, a division of geological time between 251 and 65 million years ago.
- Mountain Range** : Mountain range exists in a linear system of mountains and hills having several ridges, peaks, summits and valleys.
- Offlap** : Offlap shows reverse relation of older and younger beds. Here the successively younger beds of the younger series

get deposited short of the older sequence of beds. In case of offlap the lowest bed of an upper series extends further over the older series than the younger one of the same series. This phenomenon occurs because of marine regression (i.e. receding of sea).

- Ophiolites** : They are pieces of oceanic plate that have been thrust (obducted) onto the edge of continental plates. They are an assemblage of mafic to ultramafic lavas and hypabyssal rocks found in association with sedimentary rocks like greywackes (hard compact sandstone with high quartz and feldspar and) radiolarian cherts.
- Outlier** : Outlier refers to 'older bed outside' The terms indicate special relation between older and younger rocks. In the field or on a geological map when a limited area of younger rock is completely surrounded by older rocks, the structure is called as outlier. Outlier may be produced by erosion, folding, faulting or combination of more than one of these phenomena.
- Outcrop** : The term outcrop means 'what emerges out'. Thus, an outcrop denotes the area on Earth's surface over which rock mass crops out and is visible on the surface, which provides the basic source of information for a geologist.
- Overlap** : The term overlap is used to describe the relationship of beds in an unconformity where progressively younger member of an upper series rests upon an older series by overlapping it and extends beyond the previous one just below. This occurs because of marine transgression.
- Permian** : A division of geological time in the Palaeozoic Era between 299 and 251 million years ago.
- Physiography** : It deals with the physical processes and patterns of the Earth.
- Precambrian Orogeny** : Precambrian orogeny (before 550 million years ago) comprising several orogenic periods dating from 3800 to 550 million years ago for example, Rodinian orogeny at 1100 ma;
- Pyroclastic** : Rocks or rock textures that are formed from explosive volcanism.
- Sandstone** : It is a sedimentary rock composed of sand sized grains of minerals, rock or organic material. It also contains a cementing material that binds the grains together.

- Shale** : It is a fine grained clastic sedimentary rock composed of mud mixed with clay minerals along with silt size particles and other minerals like quartz and calcite.
- Suture zone** : A linear belt of strong deformation, where distinct terranes, or tectonic units with different plate tectonic, metamorphic, and paleogeographic histories join together.
- Terrigenous** : Sediments derived from the erosion of rocks on land.
- Unconformity** : Unconformity is defined as a plane of non-deposition in the rock sequence. It marks the hiatus or break in deposition.
- Weathering** : The disintegration and decomposition of rock at or near the surface of the Earth.



NOTES



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Dear Learner,

While studying the theory course BGYCT-137 (Stratigraphy and Palaeontology), you may have found certain portions of the text difficult to comprehend. We wish to know your difficulties and suggestions, in order to improve the course. Therefore, we request you to please fill out and send us the following questionnaire, which pertains to this course (i.e., BGYCT-137). If you find the space provided is insufficient, kindly use a separate sheet.

Please mail to:

Course Coordinator BGYCT-137

Discipline of Geology

School of Sciences

IGNOU, Maidan Garhi

New Delhi – 110068 (India)

Questionnaire

1. Name: _____

2. Enrolment No.

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3. Regional centre code and name: _____

4. Study centre code and name: _____

5. How many hours did you spend for studying the each unit?

Course	BGYCT-137: Stratigraphy and Palaeontology															
Unit no.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
No. of hours																

6. Please give your reactions (by '√' mark) to the following items based on your reading of the theory course:

Items	Excellent	Very Good	Good	Poor	Give specific examples, if poor
Presentation Quality					
Language and Style					
Illustrations used (Diagrams, Tables etc.)					
Conceptual Clarity					
Self Assessment Questions (SAQ)					
Feedback to SAQ					

7. Your specific comments on the course BGYCT:137

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