



36th International Geological Congress

GEO TOURISM

HOTSPOTS OF INDIAN SUBCONTINENT





Published in 2016 by

36th International Geological Congress (IGC)

Secretariat

C/o Geological Survey of India

C-II Pushpa Bhawan, New Delhi 110062, INDIA

Tel: + 91 11 29965750, + 91 11 26057035

Email: igc.delhi2020@nic.in

Website: www.36igc.org

© 36th International Geological Congress, New Delhi

All rights reserved. No part of this publication may be reproduced in any form without prior permission of the publisher.

Published under the overall supervision of:

1. M.Raju, Director General, Geological Survey of India and Co-President, 36th IGC
2. Dr. Niranjana K Singh, Joint Secretary, Ministry of Mines and Secretary General, 36th IGC

Compilation, scrutiny and processing of manuscript:

Dr. PR Golani, Dr. K P Bandopadhyay, Mervin J D'Souza, Dr. Joyesh Bagchi, Dr. Santanu Bhattacharjee,
Dr. Snigdha Ghatak, Dr. V V Sessa Sai, Mriganka Ghatak, Dr. Sreemati Gupta, Akhouri Bishwapriya, Dr. ML Dora,
Debasish Rout

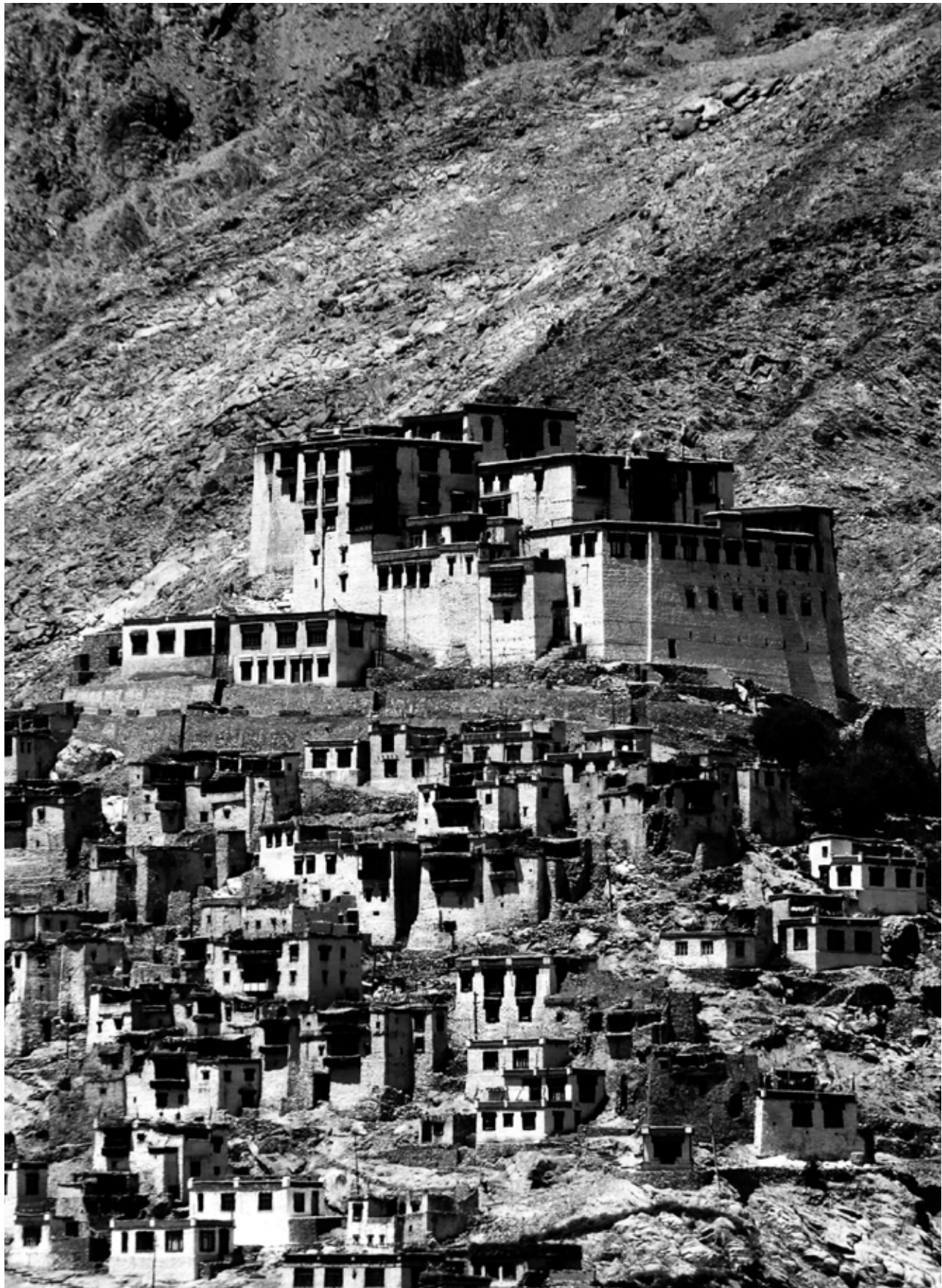
Cover photographs courtesy: Anshu Bhatnagar

Design & Printed by: designmill.in

TABLE OF CONTENTS

Message from Minister, Ministry of Mines, Government of India	i
Foreword	ii
Introduction	iii
Location of Geotourism hotspots in Indian Subcontinent	
Geotourism in India - Geology of India	1-3
1. Ajanta Caves, Maharashtra	4-5
2. Akal Fossil Wood Park, Rajasthan	6-7
3. Angadipuram Laterite, Kerala	8-9
4. Arwah- Lumshynna Cave, Meghalaya	10-11
5. Barr Conglomerate, Rajasthan	12-13
6. Bedded Barytes, Andhra Pradesh	14-15
7. Charnockite, St. Thomas Mount, Tamil Nadu	16-17
8. Columar Volcanics, St.Mary's Islands, Karnataka	18-19
9. Deccan Traps, Maharashtra	20-21
10. Dhala Impact Structure, Madhya Pradesh	22-23
11. Dinosaur Fossil Park, Gujarat	24-25
12. Ellora Caves, Maharashtra	26-27
13. Erra Matti Dibbalu, Andhra Pradesh	28-29
14. Eparchaeon Unconformity/Natural Arch, Andhra Pradesh	30-31
15. Fossils of Rajmahal Hills, Jharkhand	32-33
16. Gossan, Rajasthan	34-35
17. Karai Badlands, Tamil Nadu	36-37
18. Kerala Backwaters, Kerala	38-39
19. Lonar Lake, Maharashtra	40-41
20. Malani Igneous Suite - Jodhpur Group Contact, Rajasthan	42-43
21. Marine Gondwana Fossil Park, Chhattisgarh	44-45
22. Mardihalli Pillow Lava, Karnataka	46-47
23. Naga Hill Ophiolite, Nagaland	48-49
24. Nepheline Syenite, Rajasthan	50-51
25. Nomira Pillow Lava, Odisha	52-53

26. Panjal Traps, Jammu & Kashmir	54-55
27. Peninsular Gneisses, Karnataka	56-57
28. Pyroclastic Rocks, Karnataka	58-59
29. Salkhan Fossil Park, Uttar Pradesh	60-61
30. Sattanur Fossil Wood Park, Tamil Nadu	62-63
31. Sendra Granite, Rajasthan	64-65
32. Sela Pass, Arunachal Pradesh	66-67
33. Shyok-Nubra Valley, Jammu & Kashmir	68-69
34. Siwalik Fossil Park, Himachal Pradesh	70-71
35. Stromatolite bearing carbonate, Sikkim	72-73
36. Stromatolite Park, Rajasthan	74-75
37. Sundarban – The Mangrove Forest, West Bengal	76-77
38. Thar Desert of India, Rajasthan	78-79
39. Tiruvakkarai Fossil Wood Park, Tamil Nadu	80-81
40. Varkala Cliff, Kerala	82-83
Geotourism in Bangladesh - Geology of Bangladesh	85-91
41 - 43. Salient Geotourist Hotspots in Bangladesh	
Geotourism in Nepal- Geology of Nepal	93-95
44 - 48. Salient Geotourist Hotspots in Nepal	
Geotourism in Pakistan- Geology of Pakistan	97
49 - 52. Salient Geotourist Hotspots in Pakistan	
Geotourism in Sri Lanka- Geology of Sri Lanka	99-101
53 - 64. Salient Geotourist Hotspots in Sri Lanka	





पीयूष गोयल
PIYUSH GOYAL



विद्युत, कोयला, नवीन और नवीकरणीय ऊर्जा एवं खान
राज्य मंत्री (स्वतंत्र प्रभार)
भारत सरकार

Minister of State (Independent Charge) for Power,
Coal, New & Renewable Energy and Mines
Government of India



Message

It gives me immense pleasure to know that the Geological Survey of India is publishing this compiled volume on the Geotourism Hotspots of the Indian sub-continent on the occasion of the 35th International Geological Congress being held at Cape Town, South Africa.

The Indian sub-continent, by virtue of its enormous expanse and fascinating geological and geographical melange, is a storehouse of delightful geographical marvels. What stands out in these sites is their mystifying diversity, geoscientific uniqueness and the protracted span of time they represent. Interestingly, these sites are spread out across the entire sub-continental landscape and have regional as well as international significance. Not only are these sites appealing to the scientific community but also to the layman for their natural and pristine beauty.

The geological monuments not only help in creating an awareness of preserving our natural heritage, but also give a sense of pride to the local community. Coupled with all other aspects of the area's natural and cultural heritage, these have immense potential for geotourism and creation of innovative local enterprise.

Witnessing these works of nature, which have been created over millions of years, is a truly humbling experience. I am confident that the compilation of geotourism hotspots would help attract focus of the national and international geo-scientific community.

Piyush Goyal



Foreward



India is well known for its rich endowment of well preserved geoheritage sites of a variety of geological features. Many of the locations display spectacularly preserved geological wonders that are aptly given status of National Geological Monuments in India. Several of such sites have become most favoured tourist destinations. The Geological Survey of India-a premiere geoscience organization is instrumental in identifying such geological marvels.

The geoheritage sites are distributed from the southern shores of the country to mighty Himalayas in north, the desertic terrain in west to mangrove forest in the east and the magnificent Deccan Trap in Central India. Several of the sites are associated with cultural activities and religious beliefs of the country that make them more popular. These monumental sites of geological significance cover a time span from Archaean to Recent.

This publication is brought out in the backdrop of hosting of 36th IGC by India and cohost nations- Bangladesh, Nepal, Pakistan and Sri Lanka in the year 2020 at New Delhi. The geoheritage sites covered in this volume showcase only a small spectrum of the geoscientific endowment of India. Some of the sites are planned to be covered in geological excursions while others may find reference in scientific texts and discussions during the proceedings of the 36th IGC. I believe that this pictorial write up shall ignite interest of readers in geological studies of the Indian subcontinent and motivate them to catch up the forthcoming ICG at New Delhi.

(M. RAJU)
Director General
Geological Survey of India
27, Jawaharlal Nehru Road
Kolkata - 700 016



Introduction

Nature is an exquisite sculptor. Many artefact of nature and landscapes are illustrative of geological processes that were operative not only on the surface but also deep inside the Earth. The best landscapes, illustrating the evolutionary history of the Earth is an invaluable legacy that not only needs to be conserved as Geoheritage sites, but also publicized amongst the masses so that their significance and the need to protect them from the natural degradation and anthropogenic interference is understood by the geoscientific community and people at large. Conservation and protection of such marvels of nature which silently speak volumes about the journey of our planet through time is vital for posterity, because once lost it can never be retrieved.

The optimal and sustainable approach for conservation of Geological Heritage Sites being long practiced in the world is to establish Geoparks (a nationally protected area containing one or a group of geological heritage sites of particular importance, rarity or aesthetic appeal) and to make them special landscapes for protecting the Earth's legacy. The development of Geoparks is done through a three pronged approach involving Conservation, Education and Geotourism.

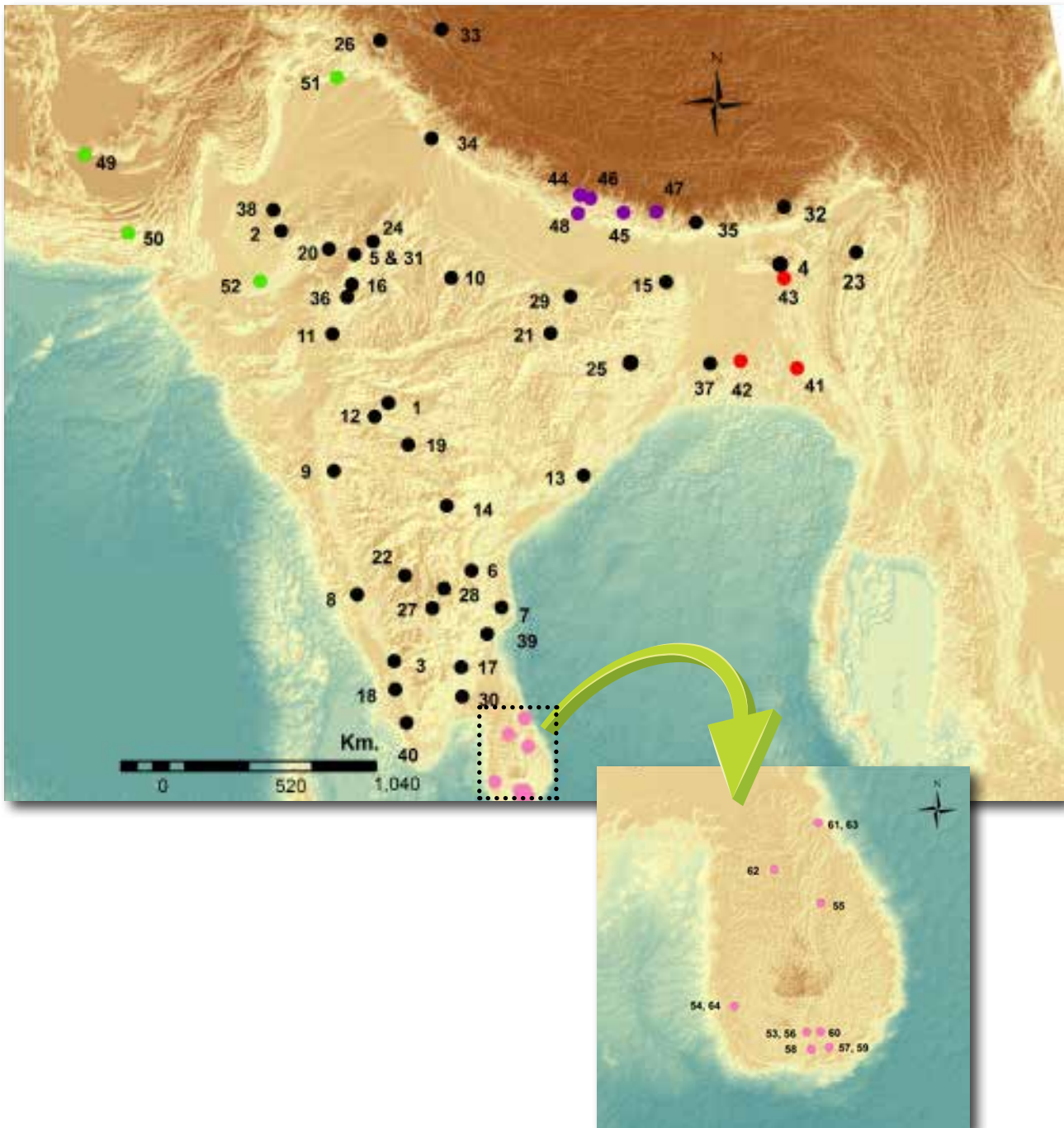
Under 'Conservation', the custodians of Geopark need to ensure adequate protection measures in consultation with collaborating geological surveys, academic institutions and/ or relevant statutory bodies in accordance with local traditions and legislative obligations. Within the realm of 'Education', these sites need to be used as research bases for important geoscientific issues, educational field bases for Earth Science students and scientific popularization bases for the general public. In the sphere of 'Geotourism', Geological

Heritage Sites can support local economies and promote employment that would further sensitize local governments as well as local inhabitants through the development of the feeling of ownership amongst them. The Geotourism can help generate revenues for conservation and maintenance of the Geoheritage sites and provide the sustainable source of livelihood to the local population.

In India, Geological Survey of India (GSI) has the mandate to identify and delineate areas of such unique geological significance. It has identified many sites of geological importance and exceptional geomorphic expression/ landscapes, some of which have been dealt with through this publication. Till date, GSI has declared 32 sites as National Geological Monument.

Recently, a legislation on "Geological Heritage Site (Declaration, Conservation, Protection and Maintenance): Act 2014" has been prepared, which once enacted would accord and legally recognize the status of "Geological Heritage Sites" as sites of Geoscientific importance.

LOCATION OF GEOTOURISM HOTSPOTS IN INDIAN SUBCONTINENT



LEGEND

● India

1. Ajanta Caves, Maharashtra
2. Akal Fossil Wood Park, Rajasthan
3. Angadipuram Laterite, Kerala
4. Arwah- Lumshynna Cave, Meghalaya
5. Barr Conglomerate, Rajasthan
6. Bedded Barytes, Andhra Pradesh
7. Charnockite, St. Thomas Mount, Tamil Nadu
8. Columnar Volcanics, St. Mary's Islands, Karnataka
9. Deccan Traps, Maharashtra
10. Dhala Impact Structure, Madhya Pradesh
11. Dinosaur Fossil Park, Gujarat
12. Ellora Caves, Maharashtra
13. Erra Matti Dibbalu, Andhra Pradesh
14. Eparchaean Unconformity/ Natural arch, Andhra Pradesh
15. Fossils of Rajmahal Hills, Jharkhand
16. Gossan, Rajasthan
17. Karai Badlands, Tamil Nadu
18. Kerala Backwaters, Kerala
19. Lonar Lake, Maharashtra
20. Malani Igneous Suite-Jodhpur Group contact, Rajasthan
21. Marine Gondwana Fossil Park, Chattisgarh
22. Mardihalli Pillow Lava, Karnataka
23. Naga hill Ophiolite, Nagaland
24. Nepheline Syenite, Rajasthan
25. Nomira Pillow Lava, Odisha
26. Panjal Traps, Jammu & Kashmir
27. Peninsular Gneisses, Karnataka
28. Pyroclastic Rocks, Karnataka
29. Salkhan Fossil Park, Uttar Pradesh
30. Sattanur Fossil Wood Park, Tamil Nadu
31. Sendra Granite, Rajasthan
32. SeLa Pass, Arunachal Pradesh
33. Shyok-Nubra Valley, Jammu & Kashmir
34. Siwalik Fossil Park, Himachal Pradesh
35. Stromatolite bearing Carbonate, Sikkim
36. Stromatolite Park, Rajasthan
37. Sundarban – The Mangrove Forest, West Bengal
38. Thar Desert of India, Rajasthan
39. Tiruvakkarai Fossil Wood Park, Tamil Nadu
40. Varkala Cliff, Kerala

● Bangladesh

41. Cox's Bazar, Teknaf, St. Martin's Limestone, Chittagong
42. Sundarban – The Mangrove Forest, Khulna & Barisal
43. Sylhet Limestone, Sylhet

● Nepal

44. Kaligandaki River Section
45. Kathmandu valley
46. Pokhara Valley, Western Nepal
47. Salleri - Lukla - Namche Corridor
48. Tinau River Corridor

● Pakistan

49. Copper deposit, Reko Diq
50. Lead and zinc mine, Duddar
51. Salt Range
52. Thar Coal Field

● Sri Lanka

53. Akarella
54. Eppawala
55. Gal Viharaya
56. Ginigalpelassa
57. Hambantota
58. Kalametiya
59. Madunagala
60. Mahapelassa
61. Panirendawa
62. Polwatta
63. Pulmoddai
64. Rambuka



GEOTOURISM IN INDIA

Geology of India

India extends for about 3200 km from north to south and 2900 km from west to east and is bound between latitudes 8°4' North to 37°6' North and longitudes 68°7' East to 97°25' East. India has a diverse geology with different rock types representing the complete spectrum ranging in age from some of the oldest Archaean metamorphites/granitoids to the youngest Quaternary alluvium. Indian subcontinent is tectonically and physiographically divided into three broad domains i.e. the Peninsular India, the Extra-Peninsular India and the intervening Indo-Gangetic Plains.

PENINSULAR INDIA

Peninsular India, the main repository of economic minerals, exposes rock units of almost the entire spectrum of geological era. Remnants of Archaean crust, preserved only in small isolated patches along with the oldest supracrustals are recorded from south, east, central and western parts of the country. These Archaean nuclei have later been accreted with the fold belt sequence, which transgresses well within the Proterozoic, and display some tectono-magmatic episodes. The middle to upper part of the Proterozoic era (Meso- to Neo-proterozoic) is mainly characterised by the development of major intracratonic basins (namely Cuddapah, Godavari, Indravati, Chhattisgarh, Vindhyan etc.). The Gondwana rocks, spanning between Late Paleozoic and Mesozoic period, are developed in faulted grabens. The evidences of marine transgression during Mesozoic era are well documented both in the East and West Coasts. However, the spectacular event of this era is the Deccan volcanism which covers vast tracts of western, central and southern India. Temporally comparable volcanic events, viz. Rajmahal and Sylhet Traps along with the oldest volcanic event (Panjal Traps) are recorded from the eastern and northern part respectively. Compared to the earlier geological periods, Tertiary era is not well represented in India and is preserved only in small isolated basins in southern, eastern, western and north-eastern parts of the Peninsula. However, both temporal and spatial development of Quaternary sequences is well documented throughout the country including its coastal tracts.



INDO-GANGETIC PLAIN

The tectonic trough (foreland basin) sandwiched between peninsular shield in the south and Himalayan mountains in the north formed due to upliftment of the latter; has been filled up by sediments derived from both sides, especially from the Himalaya, by rivers like Ganga, Brahmaputra and Indus and has been termed as Indo-Gangetic Brahmaputra alluvial plain and stretches across northern India from Assam and Bengal in the east through Bihar and Uttar Pradesh to Punjab in the west.

EXTRA PENINSULAR REGION

The Himalayan Mountain Chain occurring all along northern part of India can be divided into four contrasting longitudinal litho-cum-morphotectonic belts from south to north, viz. i) Foot hill belt ii) Main Himalayan belt iii) Indus-Shyok belt and iv) Karakoram belt.

The foothill Himalaya is a 10-50 km wide Miocene to Recent Molasse sequence represented by Siwalik, Murree and Subathu Group of rocks. The belt is a domain of active tectonics having participated in the terminal phase of the Himalayan Orogeny. This is followed to the north by the Lesser and Higher Himalaya, represented by geological sequences of Proterozoic age with Phanerozoic cover of varying thickness in different parts. The foothill Himalaya is overlain by alluvium and separated from the Lesser Himalaya by the north-dipping fault commonly known as the Main Boundary Fault (MBF) or the Main Boundary Thrust (MBT) in Garhwal, Kumaon, Nepal, Darjeeling, Bhutan and Arunachal Pradesh Himalaya. This belt is involved in western syntaxial bend of the Himalaya. The Main Frontal Thrust (MFT) limits the margins of the Siwalik Zone against the Ganga Plains.



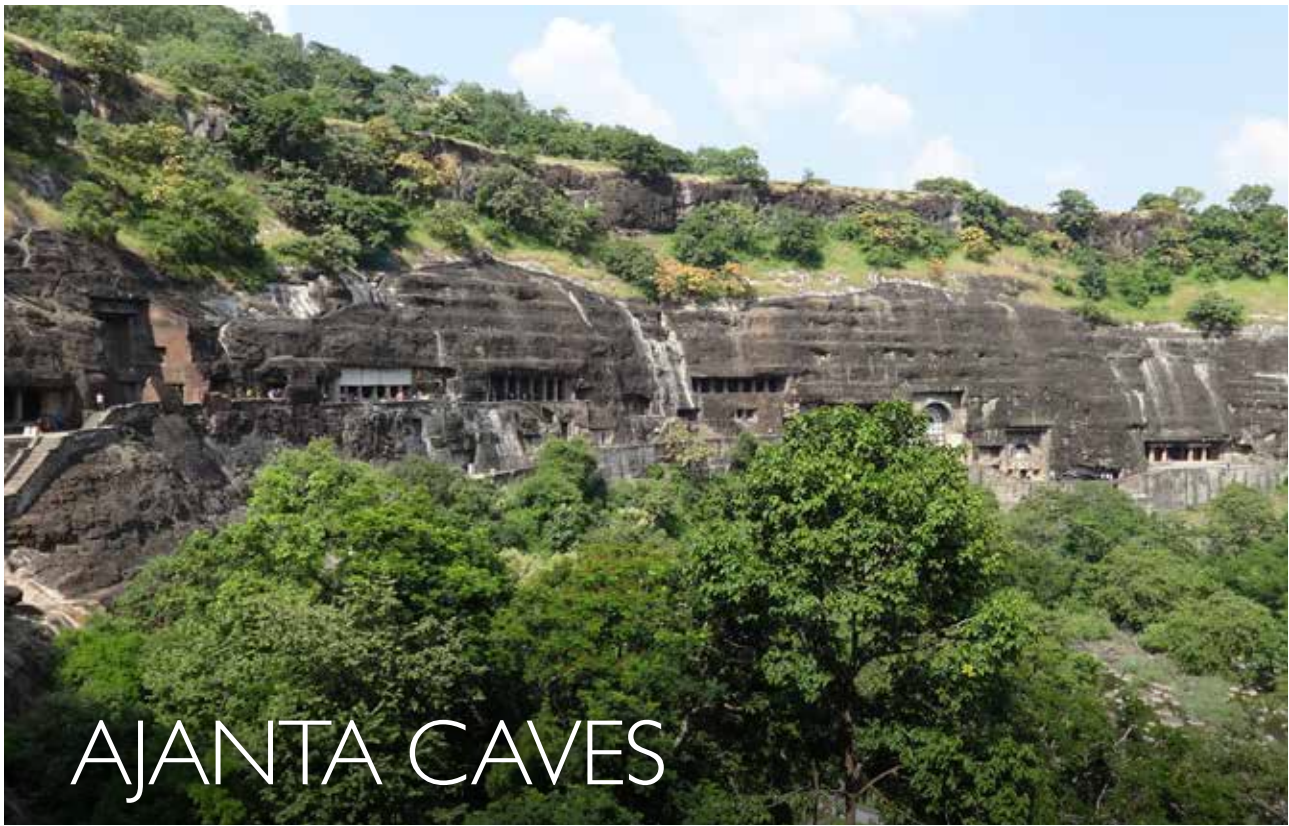
The Lesser Himalaya is 60-80 km wide and is a discontinuous belt stretching between the MBT in the south and the Main Central Thrust (MCT) in the north. It consists of autochthonous late Proterozoic sediments, thrust over by three vast nappes that are built up successively of Palaeozoic sediments, Precambrian epi-metamorphics and mesograde metasediments. The epi-metamorphic and meso-metamorphic nappes throughout their extent are characterised by Early Proterozoic and Early Palaeozoic granitic bodies of large dimension.

The MCT separates the Lesser Himalaya from the Higher Himalaya to its north. The Higher Himalaya marks the region of the highest peaks of the Himalaya (Nunkun, Leopargial, Kedarnath, Badrinath, Nanda Devi, Api, Dhaulagiri, Mt. Everest, Kanchanjunga), made up of 10-15 km thick Precambrian crystallines exhumed up and intruded by granites, some of which are Tertiary in age.

The Indus Shyok Belt / the Tethys Himalaya extends to the south of the Trans-Himalayan Karakoram belt and comprises ophiolite mélangé (Indus ophiolite and associated formation) and plutonic rocks (Ladakh Granitoid Complex) of the Indus Shyok belt. These predominantly fossiliferous sediments range in age from Late Proterozoic to Eocene. Sporadic occurrences of chromite have been reported from the ultrabasic rocks associated with Dras volcanics from Ophiolite-Mélange zone.

Karakoram Belt, the northern most zone, comprises Palaeozoic and Mesozoic sedimentary sequences on a metamorphic basement of unknown age. This Trans-Himalayan belt lies to the north of the Indus Suture Zone in Ladakh region and extends eastward into Tibet.





AJANTA CAVES

Maharashtra

The rock cut caves of Ajanta belonging to Deccan trap basalts of Late Cretaceous affinity in district Aurangabad, Maharashtra are the finest surviving examples of Indian art. The figures of Buddha and other wisdom tales are mainly depicted through paintings and are masterpieces of Buddhist religious art. Built in two phases, the site is a protected monument under the care of the Archaeological Survey of India and is a UNESCO World Heritage Site, since 1983.

The 30 basic caves are excavated in a 76 m high semicircular escarpment carved out of a compound pahoehoe lava flow by the Waghur River that descends in a waterfall beyond the last cave. The waterfall popularly known as "Waterfall of Seven Kettles" (Saptkund) derives its name from the seven large potholes along with numerous smaller ones. The falling water having high energy, has carved out a large amphitheatre.





The compound pahoehoe flow made of 16–19 flow lobes is sandwiched between two aa flows. The individual flow lobes display various features such as reddened flow unit contacts, pipe vesicles, crack infilling structure (inflation cleft) and ropy structure. A variety of cavity minerals including different species of zeolites can be seen in small vugs or veins in the vesicular crust of many lobes.

The core of the upper aa flow forms a vertical scarp with well-developed vertical columns, many a times having pentagonal or hexagonal geometry. The lower aa flow is exposed in the Waghur riverbed, marked by a prominent clinker zone at the top.

Belonging to the period from 2nd century BC to the 6th century AD, the Ajanta caves were accidentally discovered in 1819 by a British officer on a hunting party. They are Buddhist monastic buildings, apparently representing a number of distinct “monasteries” or colleges.



- NEAREST AIRPORT: AURANGABAD (100 KM)
- NEAREST RAILWAY STATION: JALGAON (60 KM)





AKAL FOSSIL WOOD PARK

Rajasthan

The Akal Fossil Wood Park in district Jaisalmer, Rajasthan is a wonder for those who know that Jaisalmer, now being a part of the Great Thar Desert once hosted luxuriant forests in a warm and humid climate, bordering the sea. The park is famous for its fossil remains of trees of Lower Jurassic period i.e. 180 million years ago, petrified and preserved in the sedimentary basin to yield useful fossils that give a clue to the palaeoenvironment of those times.

The sedimentary basin of the Jurassic Period, consists of a fluvial sequence of conglomerate



and sandstone known as Lathi Formation that unconformably overlies the basement rocks. The Lathi Sandstones, contain a large number of gymnosperm fossil wood logs belonging to dicotyledonous stem. They comprise fossils of petrophyllum, ptylophyllum, equisetites species, silicified dicotyledonous wood and gastropod shells. The fossil wood, lying horizontal, are in random orientation. The longest specimen has a dimension 13.4 m x 0.9 m.

The Akal Fossil Wood Park was declared as a National Geological Monument in 1977. The park occupies an area of 21 hectares and is located on Jaisalmer-Barmer State Highway.



- NEAREST AIRPORT: JAISALMER (18 KM)
- NEAREST RAILWAY STATION: JAISALMER (18 KM)
- SE OF JAISALMER ON THE NH-15



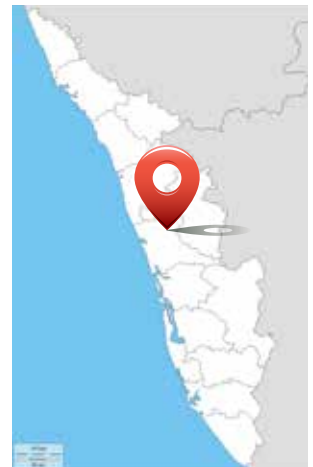


ANGADIPURAM LATERITE

Kerala

Laterite is a secondary residual product, resulting from the chemical weathering of widely varied rock types and does not fall in the usual classification of igneous, metamorphic or sedimentary rocks. The term laterite was, in fact, christened in India, for the highly weathered red subsoil found around Angadipuram, district Malappuram, Kerala in the year 1800 by Francis Hamilton Buchanan, a surgeon from Scotland.

The residual laterite of Angadipuram has been derived from acid charnockite. The crystalline rocks of this region are an admixture of pyroxene granulite, charnockite and migmatite. It is scoracious and the scoriae are big in size. The alumina in the

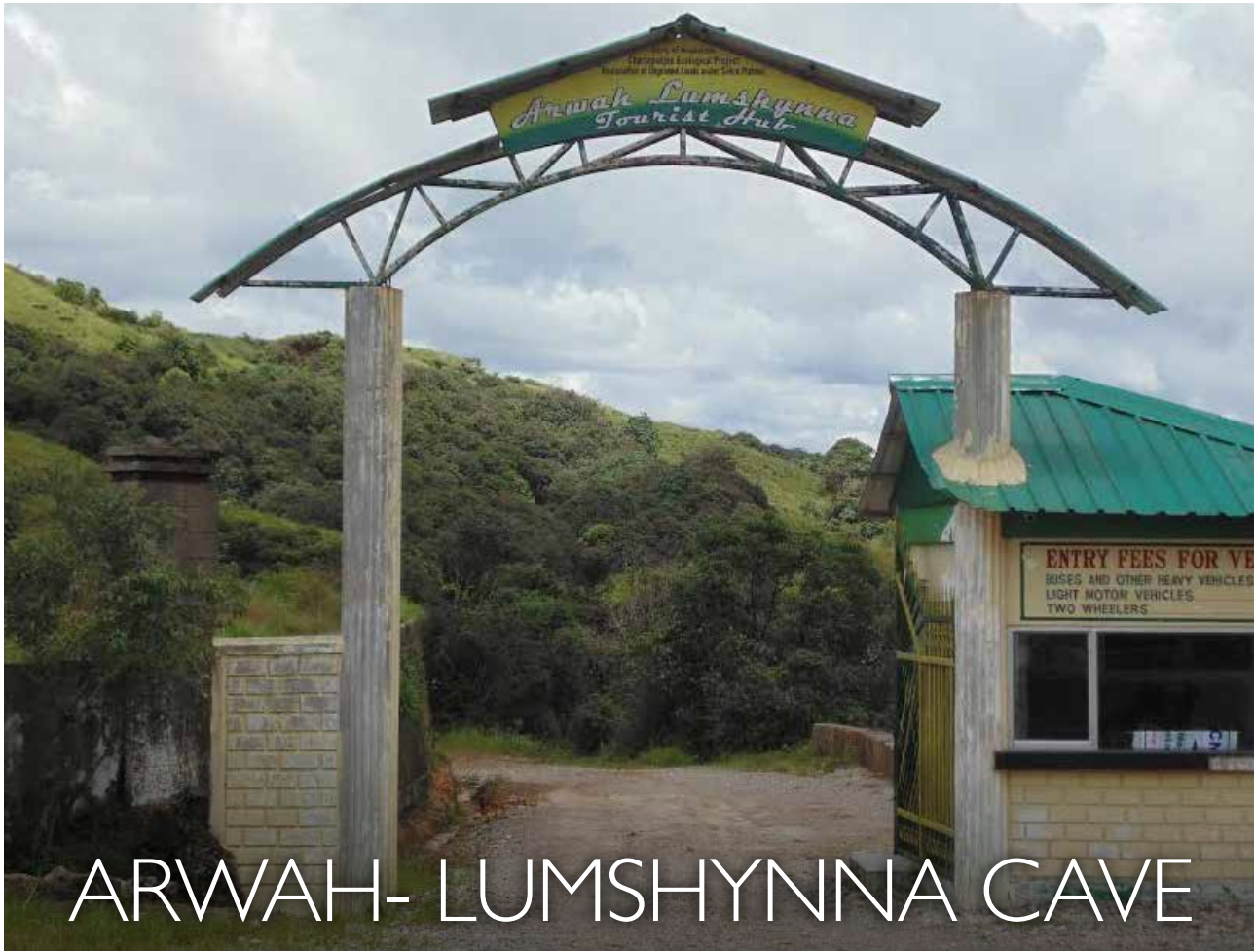


laterite mainly comes from clays (kaolinite and sepiolite) and the ferric oxide from goethite. The relatively high silica in the laterites reflects the presence of clay minerals and free quartz, indicating inadequate leaching effect. The copious rainfall of Kerala during the southwest monsoons and the high temperature together with its lush vegetation has been responsible for the rapid chemical weathering of the host rocks. Studies indicate that the palaeoclimate dating back to several million years too influenced the formation of laterite.

The site was declared as a National Geological Monument in 1979.

- NEAREST AIRPORT: CALICUT (53 KM)
- NEAREST RAILWAY STATION: ANGADIPURAM
- LOCATED WITHIN THE PREMISES OF THE PWD REST HOUSE, ABOUT 26 KM FROM MALAPPURAM ON ROAD TO PALGHAT.





ARWAH- LUMSHYNNNA CAVE

Meghalaya

Arwah- Lumshynna cave, district East Khasi Hills, Meghalaya is known for both recreational and scientific reasons. This cave lies in the slope of U Lum Lawshynna Hill. It is approximately one kilometre in length. It is adorned with different types of carving and formation designed by nature itself which adds lot of beauty to the place.



Lumshynna cave has been formed within Fossiliferous Limestone of Shella Formation of Jaintia Group. This limestone belonging to Lower Tertiary period (Palaeocene epoch) is overlain by sandstone, shale, thin discontinuous coal band (exposed above the cave) and underlain by medium to coarse grained sandstone bed exposed along the floor of the

cave. A stream flows continuously through the cave, along a particular channel.

The most interesting aspect of the cave is the occurrence of both mega and microfossils (mainly foraminifera) along wall and roof of the cave. The prolific occurrences of the Gastropoda, mainly *Turritella* species and other closely linked genera is recorded throughout the limestone. The gastropod shells are of very large dimension, their height varying from 2-10 cm.

The assemblage of fossils are generally concentrated near the base of the Limestone band along a particular horizon. Along the wall of the cave, sometimes outline of the fossils are so beautifully preserved that at ease, one can visualize it as a nature's spectacular drawing. In the outer part of the cave there are rhythmic wavy crenulation features developed due to the prolonged weathering and erosion (solution activity) of limestone.



- NEAREST AIRPORT: GUWAHATI (~130 KM)
- NEAREST RAILWAY STATION: GUWAHATI (132 KM)





BARR CONGLOMERATE

Rajasthan

The Barr Conglomerate is named after the village Barr, in district Pali, Rajasthan. It rests unconformably upon the Basement Gneissic Complex (BGC) and extends over 50 km in length in a NE-SW direction with a variable width of 300 m. This conglomerate horizon is mainly composed of pebbles of quartzite and rarely of granite gneiss set up in a fine grained pelitic matrix. The pebbles are stretched to an extraordinary extent such that their longest dimension are as much as 20 to 30 times their least dimension, simulating the shape of cuttle bones.

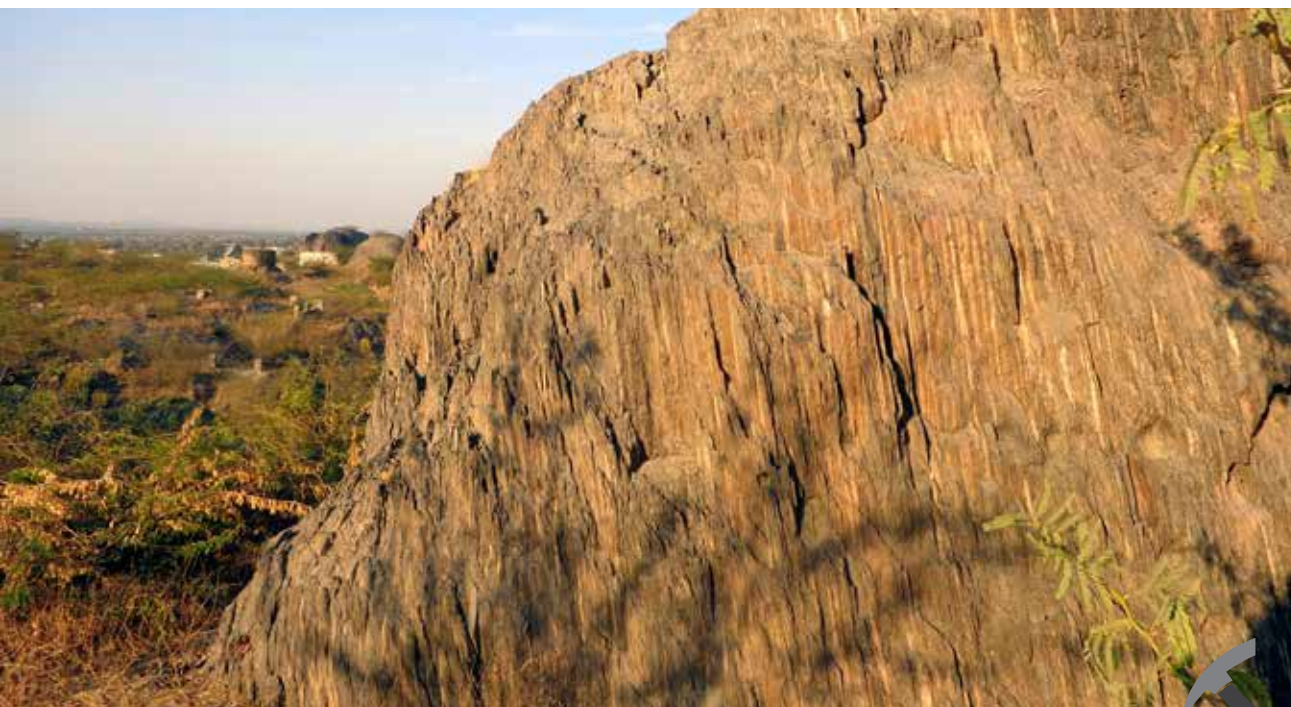
Recent workers have considered the conglomerate to be autoclastic in origin on the basis of the uniform composition of pebbles, constant stretching ratio and absence of sedimentary structures. The highly elongated shape of the pebbles has been ascribed to the shearing of alternating psammatic and pelitic layers.

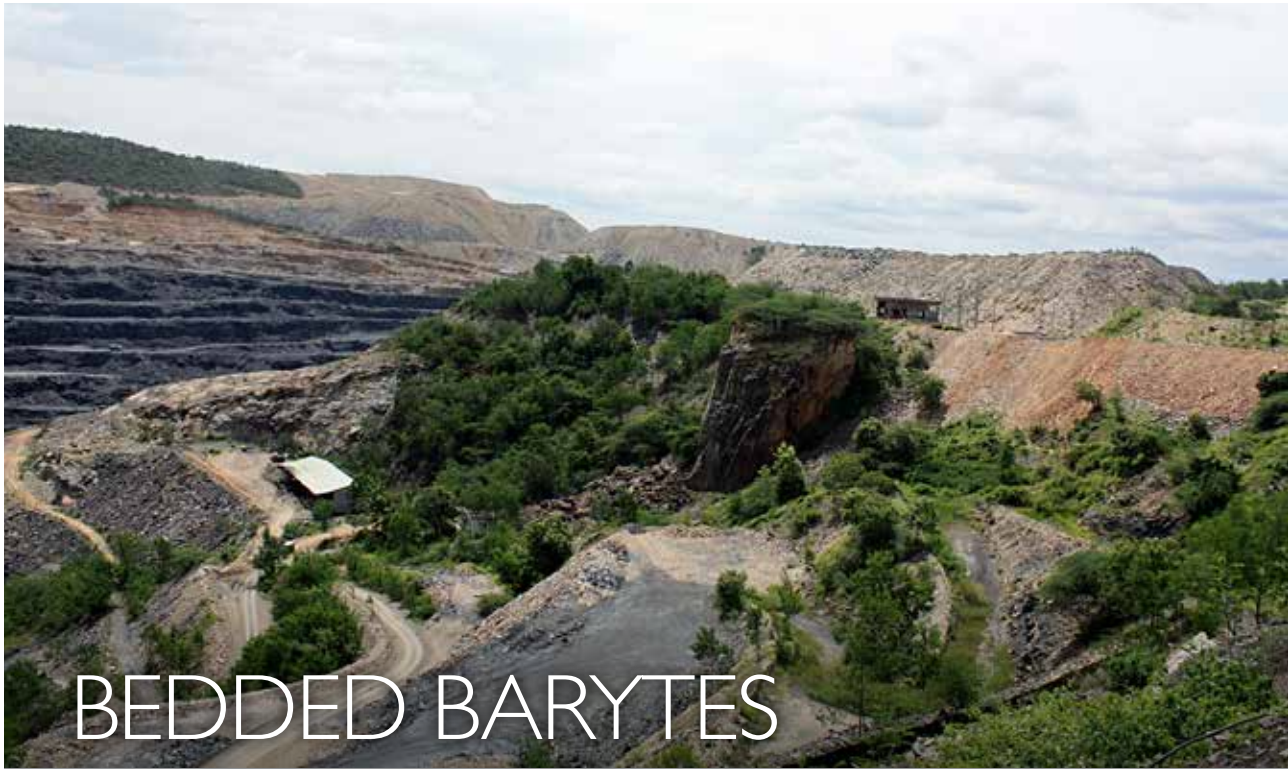


The Barr Conglomerate was declared as a National Geological Monument in 1977.



- NEAREST AIRPORT: JODHPUR (75 KM).
- NEAREST RAILWAY STATION: PALI
- BEST EXPOSED ON EITHER SIDE OF THE BEAWAR-SENDRA-BARR-PALI ROAD AND IS LOCATED JUST BEFORE BARR-PALI CROSS ROAD TOWARDS SENDRA.





BEDDED BARYTES

Andhra Pradesh

The Mangampeta bedded barytes deposit, district Cuddapah, Andhra Pradesh is the largest among the known baryte deposits of the world. The deposit occurs in the form of two discontinuous (lensoid) bodies i.e. the northern and the southern, separated from one another by a distance of 700m. Of the two, the northern body is larger in extent and thickness and hosts almost all the barytes reserves. The barytes occurs as distinct layers separated by shale/phyllite, indicating that the barytes was formed in several phases in the depositional basin.

Precipitation from volcanic vapours under submarine conditions and subaerial showering of ash and molten barytes lapilli resulted in high concentration of barium that led to formation of reserve of over 74 million tonnes in this deposit. Extraordinary physical and chemical properties like high specific gravity, low hardness, chemical inertness and stability etc., collectively makes baryte a valuable mineral.





- NEAREST AIRPORT: TIRUPATI (95 KM)
- NEAREST RAILWAY STATION: NANDALUR (11 KM)
- LOCATED ON THE KURNOOL-RENIGUNTA STATE HIGHWAY

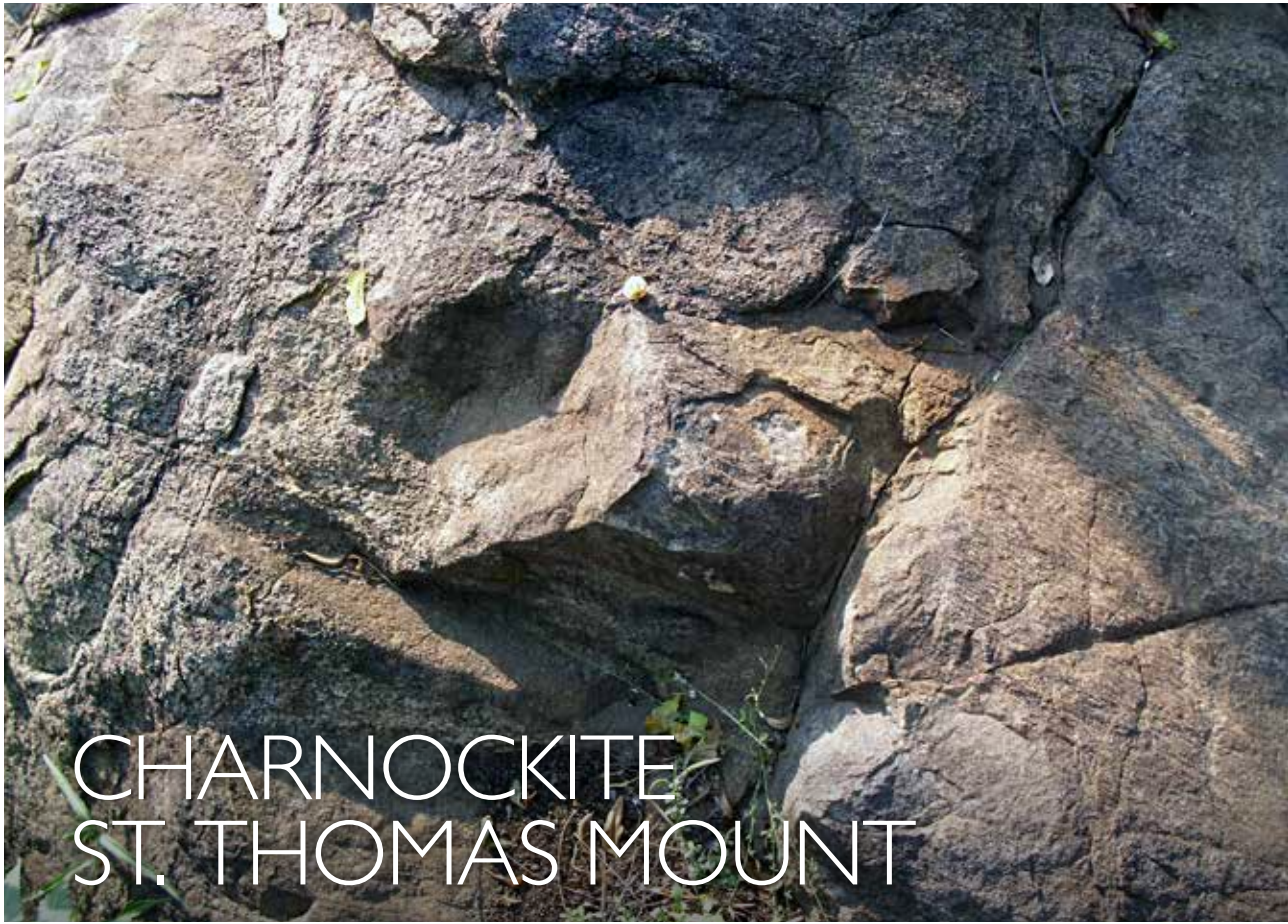


Mangampeta barytes being grey in colour is used mostly in drilling of oil wells and in chemical industries. The Mangampeta Barytes Deposit occurs in the Pullampet Formation of the Nallamalai Group within the Cuddapah Supergroup. Shale/phyllite (tuff) interbedded with dolomite and quartzite (quartz crystal tuff) are the major rock units of the Pullampet Formation.

The lower beds of the Mangampeta deposit are of the highest grade, and often occur as pure barium sulphate, readily marketable, or even fit to serve as "sweetener" for low grade ore. The upper beds containing lower grade ore are not readily suitable for industrial purposes though the percentage of barium sulphate is as high as 70 to 90 percent.

With the huge reserves at Mangampeta alone, India occupies the top position among the baryte producing countries of the world. The mine area has been declared as a National Geological Monument in 1982. The Kurnool-Renigunta state highway passes through the Mangampeta mines area.





CHARNOCKITE ST. THOMAS MOUNT

Tamil Nadu

The occurrence of Charnockite, which is a hypersthene granite was referred in 1892 by Sir Thomas Oldham, the then Director of the Geological Survey of India. The term Charnockite for this hypersthene granite rock was coined in honour of Job Charnock, the founder of Kolkata who's tombstone at St. John's Churchyard was fashioned from this rock. The Charnockite at St. Thomas Mount, has been declared as National Geological Monument.

Charnockites have received worldwide attention as unique rocks characteristic of two pyroxene facies metamorphism and evoked considerable interest among Earth scientists engaged in the study of Precambrians. The two important characters of the rock type are presence of highly pleochroic variety of hypersthene and a common granulitic texture.

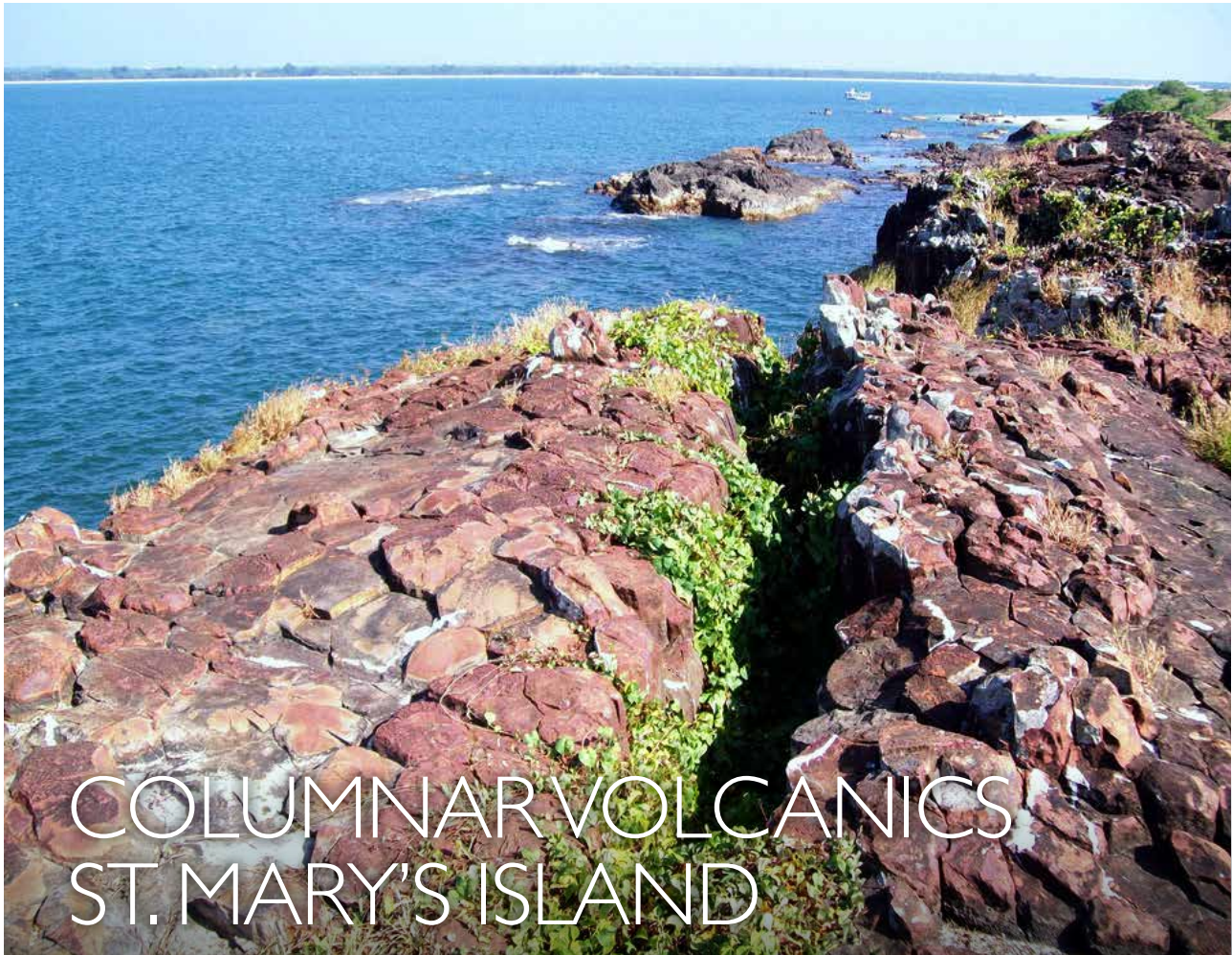


The mineral facies of highest P-T condition comprising hypersthene, with or without garnet and spinel as mafic minerals, plagioclase, K- feldspar and quartz and corresponding to granulitic facies, suggests that the charnockites have originated under particularly dry and high temperature conditions and have an important bearing in elucidating primordial crustal evolution. Their position has been assigned in the upper division of the Archaeans. The recent radiometric age data on the charnockites ranging up to 3500 Ma in some cases has indeed great significance in bringing out the metamorphic and tectonic history of the Earth's crust.

St. Thomas Mount is also of historical importance as St. Thomas, an apostle of Jesus Christ fell prey to the opponent's spear while praying before a cross, carved in stone, popularly called the 'Bleeding Stone'. The hill south of the Powder Magazine near St. Thomas Mount and the Mosque Hill at Pallavaram which also show extensive development of charnockite rocks are also included in this monument.

- NEAREST AIRPORT: CHENNAI (3 KM).
- NEAREST RAILWAY STATION: CHENNAI (3 KM).
- LOCATED IN THE SOUTHERN PART OF CHENNAI, AT THE JUNCTION OF BANGALORE- CHENNAI HIGHWAY AND CHENNAI- KANNYAKUMARI (NH-45).





COLUMNAR VOLCANICS ST. MARY'S ISLAND

Karnataka

St. Mary's Islands, a tiny group of four picturesque islands with lush coconut palms are situated off the west coast of India near Malpe, a small coastal hamlet about 6 km west of district Udupi, Karnataka. This group of islands exhibit excellent example of nature's handiwork in form of columnar joints. The geometrical form of the rock mosaic looks deceptively man-made, as if a sculptor has delicately chiselled them from rough-hewn rocks.

The rhyolitic rocks in the St. Mary's Island are the lava flows in the vast Deccan Plateau, issued through long narrow fissures or cracks in the Earth's crust when the Indian subcontinent moved over a hotspot in the Earth's mantle around 60





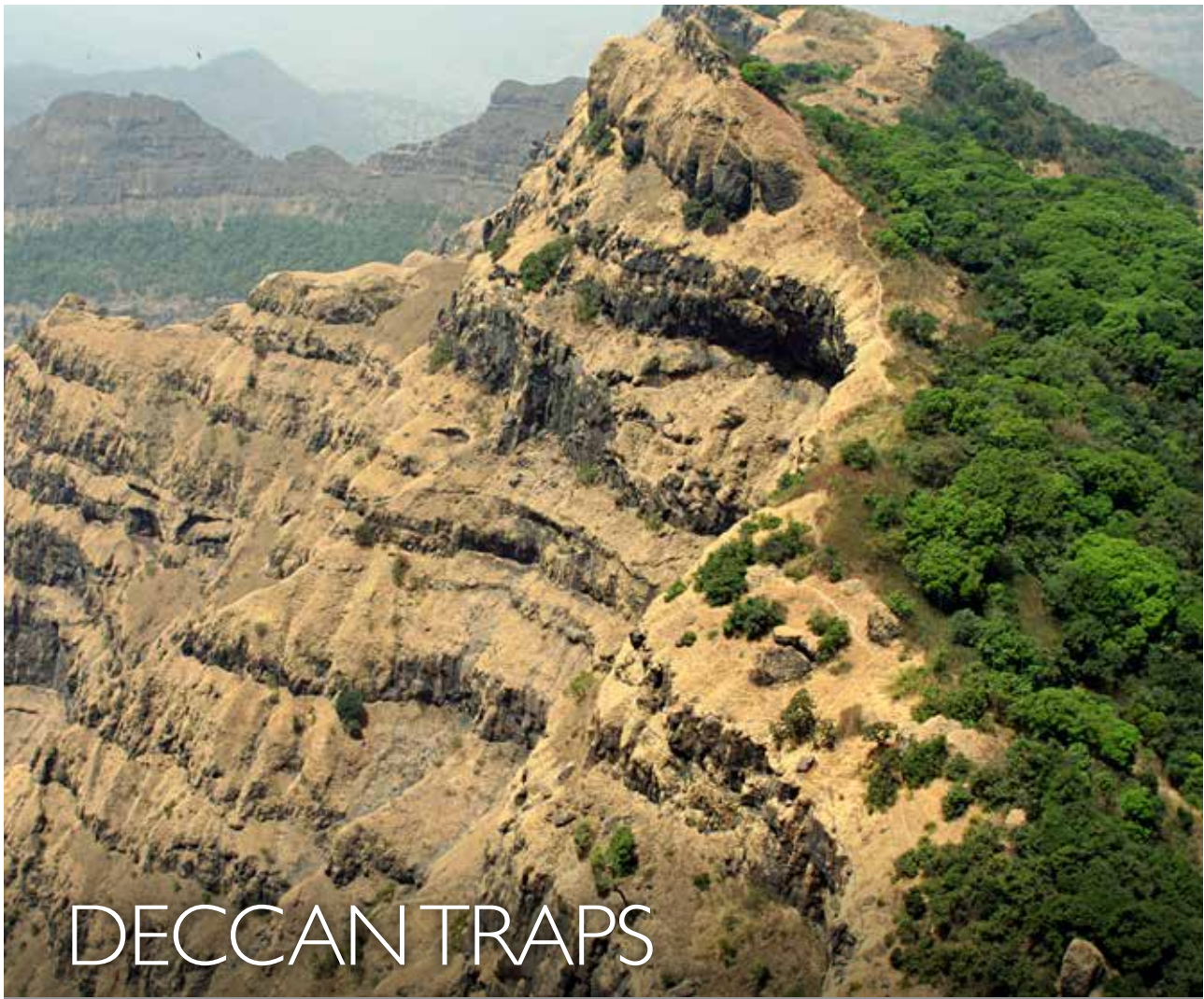
- NEAREST AIRPORT: MANGALORE (65 KM)
- NEAREST RAILWAY STATION: UDUPI (6 KM)
- ST. MARY'S ISLAND IS WELL CONNECTED BY ROAD.



million years ago, in the Cretaceous-Eocene times. The vertical columnar joints developed by contraction during slow cooling of a large volume of hot mobile lava.

Of the four islands, the northern Coconut Island, and the middle Bhadurgarh Island with its prominent lighthouse are approachable by boat from Malpe. These little islands, declared as National Geological Monument in 1979, are set against the backdrop of the emerald waters of the Arabian Sea and the towering, forest clad Western Ghats, with immense scenic beauty that has attracted visitors through centuries.





Maharashtra

The Panchgani – Mahabaleshwar corridor exposes a thick lava pile of the Deccan Traps. The Deccan Traps are a large igneous province that form the Deccan Plateau in west-central India and constitute one of the largest volcanic provinces on the Earth. They occupy about half a million km² of Indian Peninsula. They consist of multiple layers of continental flood basalt that together are more than 2,000 m thick.



It is postulated that the Deccan Traps eruption was associated with a deep mantle plume. The area of long-term eruption, known as the Réunion hotspot, is suspected of both causing the Deccan Traps eruption and opening the rift that once separated the Seychelles Plateau from India. Seafloor spreading at the boundary between the Indian and African Plates subsequently pushed India north over the plume, which now lies under Réunion Island in the Indian Ocean, southwest of India.



- NEAREST AIRPORT: PUNE (120 KM)
- NEAREST RAILWAY STATION: SATARA (~50 KM)
- LOCATED 285 KM FROM MUMBAI AND CAN BE APPROACHED VIA NH -66 AND SH -72





DHALA IMPACT STRUCTURE

Madhya Pradesh

The Dhala impact structure is one of the confirmed terrestrial meteoritic impact structures on Earth. It is so far recognized as the largest, oldest and the only complex impact structure in South East Asia.

The impact structure covers an area of 64 km² and is located in the eastern fringe of Dhala village, district Shivpuri, Madhya Pradesh. The impact origin of Dhala structure was confirmed on the basis of the presence of diagnostic evidences of shock metamorphism, specifically the occurrence of multiple sets of Planar Deformation Features (PDF) in mineral clasts (quartz and feldspar), ballen quartz, checkerboard feldspar, granular zircon, feather features and shock melted lithic clasts in





- NEAREST AIRPORT: KHAJURAHO (53 KM)
- NEAREST RAILWAY STATION: JHANSI (25 KM)
- IT IS WELL CONNECTED WITH DELHI-AGRA YAMUNA EXPRESSWAY.

melt breccia. The pressure estimate suggests a shock pressure in the excess of 20 GPa (200 Kbar).

The structure occurs entirely in an Archean crystalline basement of the Bundelkhand Craton, mainly composed of granitoids of 2563 ± 6 Ma age. It is overlain by sediments of the Semri Group of Vindhyan Supergroup whose age of sedimentation is constrained between 1.6 and 1.7 Ga.

The impact event is estimated to have taken place between 1700 and 2570 Ma ago and currently listed as seventh oldest in the world. The impact melt rock has anomalous uranium content (up to 6000 ppm).





DINOSAUR FOSSIL PARK

Gujarat

Raiyoli-Balasinor in Gujarat is home to one of the largest dinosaur fossil sites in the world. This dinosaur site discovered in the year 1981, has drawn a world wide attention of academicians and public. No single site in the world has so far produced dinosaur



nest and skeletal remains of such an abundance and diversity as found in Kheda area.

Dinosaur remains including fossilized eggs occur in the Maestrichtian (Upper Cretaceous) calcretised sandstone and limestone of the Lameta Formation. More than 1200 dinosaur eggs have been found and some of them are unhatched. Both herbivore and carnivore dinosaur eggs have been identified on the basis of morphology, ornamentation and shell structure. More than ten dinosaur species have been identified on the basis of classification.

To conserve the dinosaurian remains, the site has been developed as Geopark with a spread of over 70 acres. This site has rich palaeontological value and offers most potential area for researchers on dinosaurs.



- NEAREST AIRPORT: AHMEDABAD (94 KM)
- NEAREST RAILWAY STATION: MANINAGAR (85 KM)
- LOCATED ON AHMEDABAD-JALOD HIGHWAY.





ELLORA CAVES

Maharashtra

Ellora which occupies a relatively flat region of the Western Ghats, is an UNESCO World Heritage Site and forms one of the major tourist attractions of India. The Ellora caves are a group of Hindu, Buddhist and Jain caves built between the 5th century and 10th century A.D. The presence of Hindu, Buddhist and Jain caves adjoining each other demonstrate the religious harmony prevalent during this period of Indian history. It consists of 34 caves excavated out of a thick basalt vertical scarp belonging to Deccan Traps, a large Igneous Province consisting of multiple layers of solidified flood basalt of about 66 Ma. The vertical face made access to many layers of basalt easier, enabling architects to pick the fine grained one for more detailed sculpting. The Cave 16, also known as the Kailasa Temple, is considered one of the most remarkable cave temples in India because of its size, architecture and sculptural treatment.





The natural processes of weathering, environmental pollution and biotic interference are the main reasons for the destruction of sculptures and paintings in the caves and their environment. Besides these the caves face some geotechnical problems which includes slope stability and water seepage problems.

- **NEAREST AIRPORT: AURANGABAD (37 KM)**
- **NEAREST RAILWAY STATION: JALGAON (53 KM)**
- **IT CAN BE APPROACHED THROUGH NH-52 VIA KHULDABAD.**





ERRA MATTI DIBBALU

Andhra Pradesh

Erra Matti Dibbalu (Red sand dunes) are the dissected and stabilized coastal red sediments. The Erra Matti Dibbalu consists of fragile unconsolidated reddish brown to brick red sand dunes. The light yellowish colored sand with calcrete at different elevations is underlined by semi-consolidated, poorly sorted Quaternary pebble beds, gritty sand stone and red clay resting over the Precambrian Khondalite suite of rocks. It appears to be controlled by aeolian, fluvial and marine agencies and presents varied landforms such as sand dunes, gullies, buried channels, beach



ridges, valley in valley, paired terraces and also records events of paleo-environmental/ climatic changes and ancient human activity.

The Erra Matti Dibbalu has been declared as one of the geoheritage sites in India. It is rare and unique as it is amongst the only three remaining gullied red dune formation in South East Asia. The geoheritage site measures 1.083 Km².



- NEAREST AIRPORT: VISHAKHAPATNAM (35 KM).
- NEAREST RAILWAY STATION: VISHAKHAPATNAM (35 KM).
- SITUATED 20 KM NE OF VISHAKHAPATNAM AND 4 KM SW OF BHEEMUNIPATNAM.





EPARCHAEAN UNCONFORMITY/ NATURAL ARCH

Andhra Pradesh

The Tirumala Hills of Andhra Pradesh, is an important location where the Nagari Quartzite unconformably overlies the Archaean granite basement. The Nagari Quartzite forms the lower part of the Nallamalai Group in the Cuddapah Supergroup of the Proterozoic Cuddapah basin. The contact between the Nagari Quartzite and the Archaean granite is exposed in the ghat section on the way to the sacred Tirumala hills. The Nagari Quartzite is around 1600 million years; this unconformity represents a significant hiatus in sedimentation in Eastern Dharwar craton.



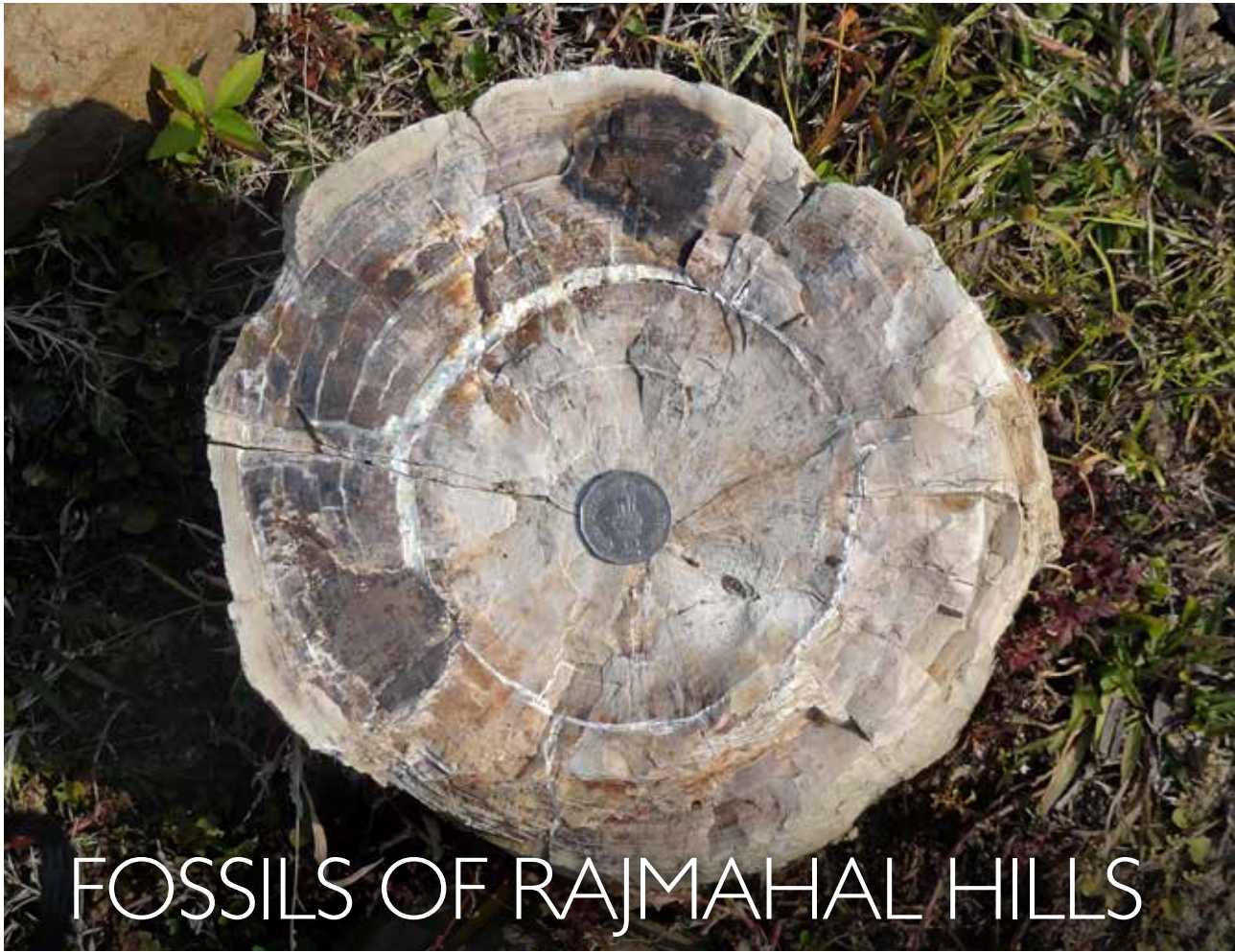


In addition to this, the natural arch at Tirumala, is a unique geological marvel formed as a result of wind and water erosion formed over a long period of time. It measures about 8m wide and is 3m high. It has been carved out of quartzites by the collective action of weathering agents like water and wind over a long period of several thousand years.

The Tirumala Hill hosts the famous temple of Lord Venkateshwara. It is situated about 10 km northwest of Tirupati town on the Srikalahasti-Chittoor State Highway. The Tirupati town is well connected by rail, road and air.

- **NEAREST AIRPORT -TIRUPATI (~10 KM)**
- **NEAREST RAILWAY STATION: TIRUPATI (~10 KM)**
- **THE TIRUPATI-RENIGUNTA LOOP LINE CONNECTS IT TO THE CHENNAI-VIJAYAWADA MAIN LINE OF SOUTH CENTRAL RAILWAY.**





FOSSILS OF RAJMAHAL HILLS

Jharkhand

The Rajmahal Hills of district Sahibganj, Jharkhand, covering an area of nearly 4300 km² comprises a series of volcanic lava flow of basalt and associated intertrappean sedimentary beds. The individual intertrappean beds (Rajmahal Formation) varying in thickness from 0.5 m to 11 m has a great significance regarding the preservation of prolific Ptilophyllum flora that are also referred to as "Rajmahal Plant Beds".



Well preserved plant fossils and fossil wood of immense stratigraphic significance are found in the intertrappean bed of Rajmahal Formation in localized areas. These fossils belong mainly to the fern, cycads and conifers. The most common plant genera are Ptilophyllum, Taeniopteris, Dictyozamites, Pterophyllum and Cladophlebis. These are preserved in the exposed lower three or four intertrappean beds in the northern, central and southern parts of the Rajmahal Hills. Fossils in the form of either petrification or impression are extremely well preserved - a rarity for remnants of that age. The richest assemblage of fossils is found in Mandro. Petrified wood has preserved the original structure of the stem in details, down to the microscopic level.



- NEAREST AIRPORT: PATNA (250 KM).
- NEAREST RAILWAY STATION: MIRZA CHOWKI (14 KM)
- RAJMAHAL HILLS ARE ~100KM AND MANDRO BLOCK IS ~ 32 KM FROM SAHIBGANJ, JHARKHAND.





GOSSAN

Rajasthan

Gossans are signboards that point to what lies beneath the surface. It is formed by the oxidation of sulphur and host metals, leaving hydrated iron oxides and rare sulphates. Gossans sometimes indicate presence of richer ore deposits at depth.

Location of the ancient mines near and within gossan zones at Rajpura-Dariba, indicate that the ancient miners and prospectors had already realized the importance of gossans and utilized them as a tool





- NEAREST AIRPORT: UDAIPUR (100 KM)
- NEAREST RAILWAY STATION: FATEHNAGAR (60 KM)

to locate and mine out the concealed metalliferous deposit. These gossans led to the rediscovery of the Rajpura-Dariba mineralized zone. The gossan is formed due to extensive chemical weathering and pervasive oxidation of the mineralized sulphides-sulphosalts ore bodies through prolonged geological periods under favourable climatic conditions.

The Rajpura-Dariba gossan is found capping the ridge near Dariba village in Rajsamand district over a strike length of 4.5 km with width ranging from 2-40 m. Considering its unique nature and academic importance to Earth sciences, this exposure of gossan in the southern part of the Dariba Belt was declared as a National Geological Monument in 1977.





KARAI BADLANDS

Tamil Nadu

The Cretaceous sedimentary rock succession of the Cauvery Basin of Tamil Nadu is famous for preserving excellent fossil record of marine invertebrates of Mid and Late Cretaceous age. During that period, marine transgression engulfed a large area of Cauvery Basin in parts of Tiruchchirappalli, Ariyalur and Perambalur districts of Tamil Nadu.

The badlands of Karai occur along a length of 4 km (Karai-Kulakkalnattam) in district Perambalur, Tamil Nadu. It is close to Chennai-Tiruchchirappalli National Highway 45. The section



is well exposed, on either side of Alattur-Ariyalur road and the fossils marking the lower part of marine Cretaceous are well preserved in it. It consists of clay and sandstone of Karai Formation. A variety of easily extractable marine fossils like ammonites, nautiloids, belemnites, worm tubes, pelecypods, gastropods and oysters occur in abundance. Presence of a number of extinct megafossils species make the section interesting for searching variety of spectacular fossils.



- NEAREST AIRPORT: TIRUCHIRAPALLI (61 KM)
- NEAREST RAILWAY STATION: ARIYALUR (22 KM)
- IT IS IN CLOSE PROXIMITY TO CHENNAI-TIRUCHCHIRAPPALLI NH-45.





KERALA BACKWATERS

Kerala

The Kerala backwaters are a network of brackish lagoons and lakes lying parallel to the western coast of India. The network includes five large lakes linked by canals, both manmade and natural, fed by 38 rivers, and extending across almost half the length of Kerala state.

The backwaters are a result of marine transgression-regression aided by fluvio-marine interactive process, creating low barrier beaches across the mouths of the many rivers flowing down from the Western Ghats range. In the midst of this landscape there are a number of towns and cities, which serve as the starting and





- NEAREST AIRPORT: KOCHI (61 KM)
- NEAREST RAILWAY STATION: ALLEPPEY

end points of backwater cruises. The backwaters are also host to a rich assemblage of flora and fauna.

National Waterway 3 from Kollam to Kottapuram, covers a distance of 205 km and runs parallel to the Kerala coastline. It is a much visited route for backwater tourism. Ashtamudi lake having an area of nearly 200 km² is one of the major destinations.





LONAR LAKE

Maharashtra

The Lonar Crater, formed in the basaltic rocks of Deccan Traps (Cretaceous – Eocene age), is a circular depression cradling a saline water lake in its central portion. The crater is 1830 m in diameter and is 137 m deep from the highest point on the rim crest to the water level. It is about 1200 m in diameter at water level. The 20 m high crater rim gently slopes away and has an undulating topography. A shallow but prominent nearly circular depression with a raised rim, having a diameter of about 300 m, is situated on the rim flank, half a kilometer north of the main crater.





Geological studies have revealed shock ejecta including black glassy material characteristic of intensely shocked basalt. Shock ejecta was found as far as 610 m away from the rim of the crater. Drilling investigations have yielded fractured and brecciated basalt at a depth of even 335 m. Cores of shock breccias showing evidence of shock in the form of veins, light and dark structures, pseudo flow structures, shatter cones and the mineral maskelynite (so far known to occur in meteorites and artificially shock loaded basalts) have been obtained. These evidences have conclusively established that the Lonar Crater is of impact origin.

The Lonar Crater was declared a National Geological Monument in 1975.

- NEAREST AIRPORT: LATUR (233 KM).
- NEAREST RAILWAY STATION: PARBHANI (100KM)
- THE LONAR CRATER IS ADJACENT TO LONAR TOWN, LINKED BY ROAD TO MEHKAR AND BULDANA WHICH IS ABOUT 90 KM SE.





MALANI IGNEOUS SUITE- JODHPUR GROUP CONTACT

Rajasthan

The rocks of Malani Igneous Suite representing the last phase of igneous activity of Precambrian age in the Indian subcontinent have been dated up to 700 ± 50 m.y. Its aerial extent is about $44,500 \text{ km}^2$ in parts of Thar Desert and a substantial expanse remains underlain with Phanerozoic Formations. The three phases of igneous cycles manifested are volcanic, hypabyssal and plutonic and, the eruption appears to be of fissure type. The pyroclastics with an exposed thickness of 40-50 m occur towards the



base, followed by rhyolite flows of 50- 60 m thickness. The contact between Malani Igneous Suite and overlying Jodhpur Group is erosional in nature. The basal part of the Jodhpur Group comprises Pokaran Boulder Bed and is followed upwards by arenaceous facies of Sonia Formation and Girbhakar Formation. The Malani-Jodhpur contact is best exposed in Mehrangarh Fort located within Jodhpur city.

- NEAREST AIRPORT: JODHPUR
- NEAREST RAILWAY STATION: JODHPUR
- LOCATED SW OF JAIPUR AND IS WELL CONNECTED BY STATE HIGHWAYS.





MARINE GONDWANA FOSSIL PARK

Chhattisgarh

The marine Gondwana fossil park developed on the banks of Hasdeo River displays a 5 m thick shale and conglomerate unit with marine fauna. This forms a part of Lower Talchir Formation (Permo- Carboniferous) belonging to Gondwana Supergroup. The sedimentary structures preserved in the lithounits of Gondwana Supergroup indicate fluvial environment of deposition. The fossils which are mainly marine shells in the lower part of Gondwana's indicate a period of marine transgression. The fossils exposed here are of Permian geological period (around 250 Ma).

The Fossil Park is located on the right bank of Hasdeo River, near the railway bridge between milestone 937 and 938 of the Annupur- Chirmiri branch of Southeastern Railway.





- NEAREST AIRPORT: BILASPUR (181 KM)
- NEAREST RAILWAY STATION: MANENDRAGARH (2.5 KM)
- IT IS 650 KM FROM NAGPUR, CAN BE APPROACHED BY ROAD FROM NAGPUR (NH-7 AND SH-14).





MARDIHALLI PILLOW LAVA

Karnataka

The Pillow structures in ancient lava flows exposed at Mardihalli, Karnataka belong to the Archaean Chitradurga Group (2500 Ma) of Dharwar Supergroup. The presence of these pillow structures has been of great value in terms of their sub-aqueous flows and in their utility in determining their temporal relationship with the strata that physically lie above and below them. Thus, the top of 'Y' points towards the direction of younging and is very useful in determining the order of superposition in deformed strata. All these features are displayed at Mardihalli exposure and have been duly protected as a National Geological Monument.

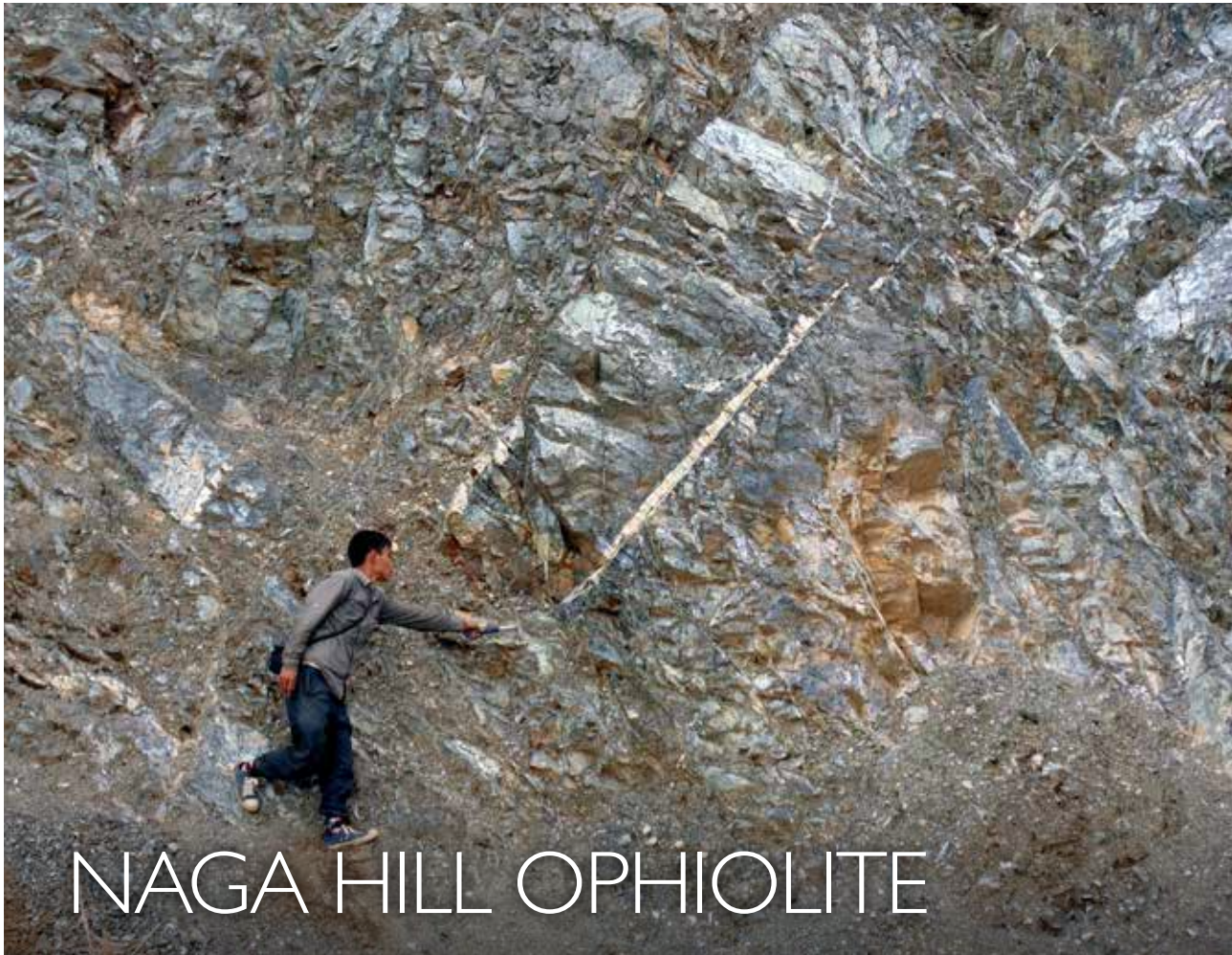




- NEAREST AIRPORT : BENGALURU (165 KM).
- NEAREST RAILWAY STATION: CHIKJAJUR (~ 30 KM).
- ~ 16 KM SE OF CHITRADURGA TOWN, LOCATED ON THE NH-4 (BENGALURU- PUNE ROAD).

The pillows are bun shaped with flat bottom and rounded top. Volcanic glass, resulting from the rapid cooling, forms a rind on many pillows. Inside each such pillow, the escape of occluded gas from the molten rock forms radial, elliptical and tubular structures. In cross-section, the pillows show a thin chilled glassy margin and radial cracks and vesicles.





NAGA HILL OPHIOLITE

Nagaland

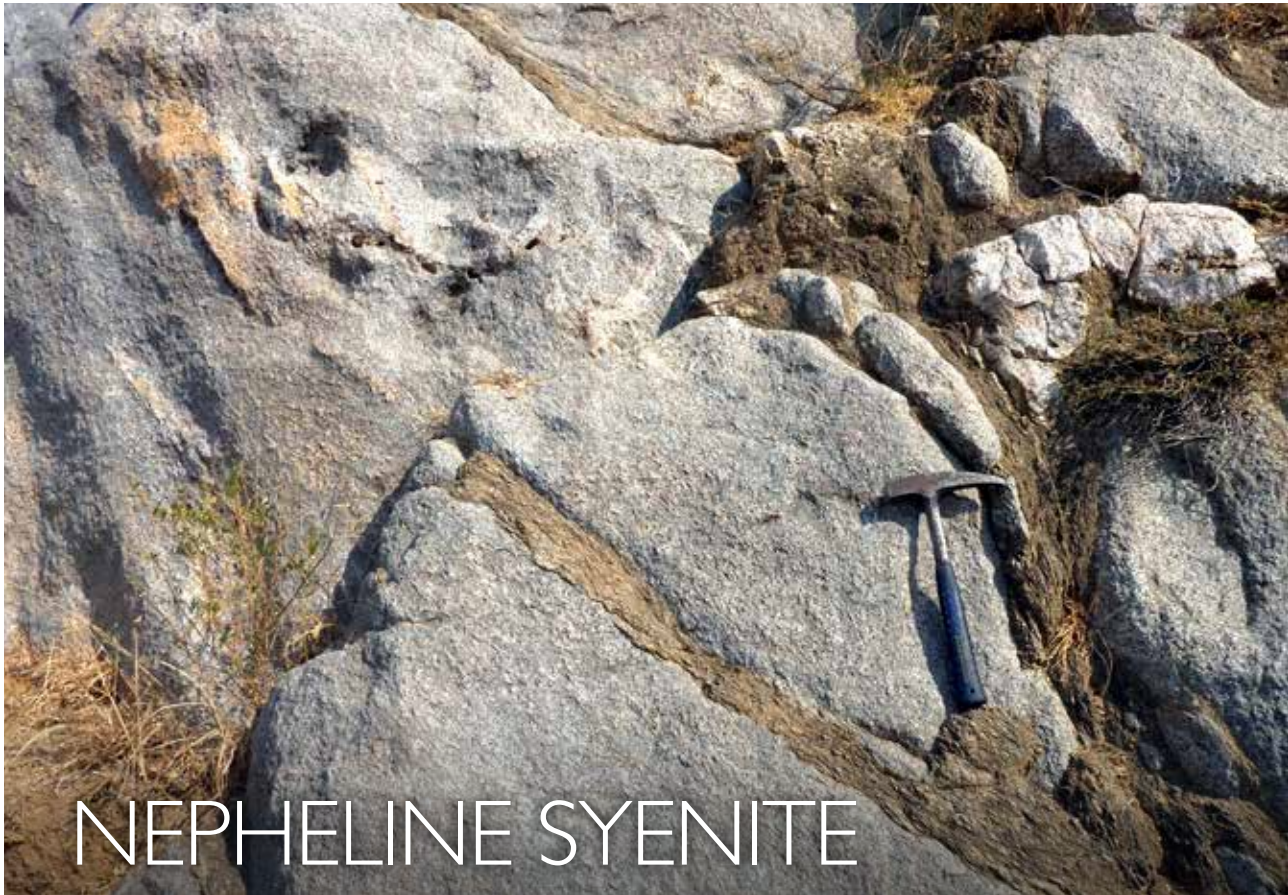
The eastern part of the India-Eurasia collision zone preserves a segment of the oceanic lithosphere that originated under the NeoTethys Ocean in Late Jurassic period and emplaced within the accretionary wedge of the supra-subduction zone where the Indian plate subducted under the Burma microplate. This fragment of oceanic lithosphere designated as Naga Hill Ophiolites (NHO) is exposed discontinuously for over 200 km in the northern part of Indo-Myanmar Range in the Indian States of Nagaland and Manipur. The exposures are fresh and are easily approachable.



The Naga Hill Ophiolite belt is characterized by the presence of dismembered thrust sheets of ultramafics, mafic to intermediate volcanics (often with pyroclastic components), ocean pelagic sediments and high grade metamorphics such as glaucophane bearing metabasalt, meta-pelites and cherts. The whole of the ophiolite suite of rocks occur as disconnected lenses sandwiched between Nimi Formation to the east and Disang flysch sediments to the west. The ultramafic component of the ophiolite is highly tectonised and composed of peridotite with dominance of harzburgite, and minor pods of dunite, wherlite and anorthosite. Most of the peridotites are altered to serpentinites up to 90%. Gabbros and plagiogranite occur as integral parts of this suite.

- NEAREST AIRPORT: DIMAPUR
- DIMAPUR IS CONNECTED BY ROAD WITH PUNGRO AND WAZIHO VIA KOHIMA.





NEPHELINE SYENITE

Rajasthan

Nepheline syenite is a plutonic rock composed essentially of alkali feldspars and nepheline. The occurrence of nepheline syenite (1590 m.y to 1910 m.y) at Kishangarh is unique since there is no other known occurrence in this part of the Aravalli Craton. Hence the site located near Kishangarh was declared as a National Geological Monument in 1976. The alkaline suite comprises nepheline syenite, theralite and camptonite. Theralite occurs as inclusions within the nepheline syenite while camptonite occurs as dykes cutting across the banding of the nepheline syenite. The textural varieties include the granitoid, the foliated and the banded types. The first type forms the central part of the pluton, flanked by the foliated variety and the margins showing the banded variety. The main outcrops of nepheline syenite form a hook shaped antiformal dome. A few



outcrops occur along the eastern margin of the Delhi Fold Belt. The syenite is grayish white and is pitted due to the leaching of feldspathoids.

Kishangarh syenite is a pluton emplaced along the core of an antiform of the metamorphites. The nepheline syenite does not have a sharp contact with the country rock. There is one large and four small outcrops located to the north and northeast of Kishangarh town. The trace of the boundary between the Delhi Supergroup in the west and the pre-Delhi rocks in the east marks an important lineament in the tectonic framework of the Aravalli Craton. Deep seated nature of this lineament is inferred by the occurrence of ultramafic bodies hosting emerald deposits along its trace. In the area around Kishangarh, besides the presence of deep seated lineaments, the occurrence of the interesting suite of nepheline syenite bearing alkaline rocks is an important feature. The nepheline syenite body has been interpreted as a diapirically emplaced pluton in the Delhi Supergroup of rocks. The emplacement was at the katazonal depth, presumably during the opening of the Delhi rift basins in the west.



- NEAREST AIRPORT: JAIPUR (107 KM)
- NEAREST RAILWAY STATION: KISHANGARH
- LOCATED ~500 M AFTER THE BYPASS BIFURCATION OF KISHANGARH TOWARDS JAIPUR ON NH-8.





NOMIRA PILLOW LAVA

Odisha

Pillow structures have been reported from basaltic and andesitic volcanic rocks from many parts of the world. In Odisha, well preserved pillow structures have been reported from Nomira and Unchabali areas of Jamda-Koira Iron Ore basin and from several other places in the Gorumahisani Belt.

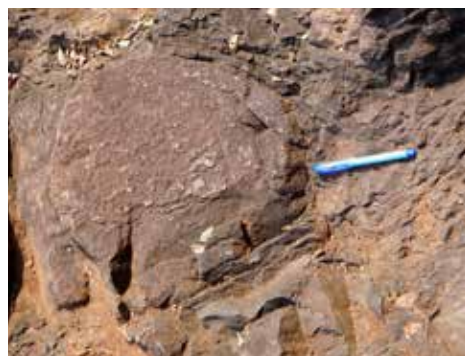
The individual pillows are roughly ellipsoidal and have a maximum size of 2m x 0.6m. The pillows are closely packed with the convexity of one fitting the concavity of the other. Grain size within the pillows is found to decrease towards the margin. The pillows generally exhibit a chilled margin and concentric compositional layers. The escaping occluded gas from the molten lava has resulted in radial, elliptical and tubular structures. Occasionally, individual pillows are surrounded by hyaloclastite.



Thick piles of volcanic rocks are exposed on the eastern, southern, and western fringes of the Jamda-Koria Iron Ore Syncline. The pillow lavas of Nomira and the associated tuff are underlain by quartzite towards east and overlain by shale, chert-shale and banded hematite jasper to the west. The basic lava is fine to medium grained, green to bluish green in colour with abundant vesicles filled with quartz. The volcanics of Nomira, occurring below the Banded Iron Formation of Jamda-Koira belt and containing pillow structures, indicate the sub-aqueous nature of the flow. The association of pyroclastics and tuffs with the pillow lava suggests a shallow submarine volcanic activity.

These pillow lavas were declared as a National Geological Monument in December, 1976.

- NEAREST AIRPORT: BHUBANESHWAR (269KM)
- NEAREST RAILWAY STATION: JODA (~22 KM)
- ABOUT 18 KM SOUTH OF JODA TOWN ON THE KEONJHAR-BARBIL-LAHUNIPADA SH.
- CAN ALSO BE APPROACHED FROM JODA VIA JODA -NAYAGAR ROAD.





PANJAL TRAPS

Jammu & Kashmir

Panjal volcanic, in district Srinagar, Jammu and Kashmir comprises greenish lava flows mostly of basaltic to andesitic composition and are amygdaloidal in nature, the vesicles being filled with quartz, calcite and zeolite. Acidic variety of Panjal volcanic is rhyolitic in composition. Epidotisation and chloritisation have imparted green colour to the rock. The glomeroporphyritic texture, formed due to clustering of crystals, renders Panjal Traps a picturesque look.



The Panjal Traps were first documented in 1824 and were eventually named by British Geologist Richard Lydekker in 1883. They were dated to 289 Ma in 2011. Dacites and rhyolites are found within the lower flows of the Panjal Traps. The silicic Panjal traps are derived by partial melting of ancient sialic crust. The silicic rocks are compositionally similar to peraluminous 'A-type' granites.

The Shankaracharya Temple dedicated to Lord Shiva and thought to be the oldest shrine in the Kashmir valley, is situated on the rocks of Panjal Traps.



- NEAREST AIRPORT: SRINAGAR
- NEAREST RAILWAY STATION : JAMMU (330 KM)





PENINSULAR GNEISSES

Karnataka

Peninsular Gneiss, coined by W.F. Smeth of the Mysore Geological Department, India, refers to a highly heterogeneous association of polyphase grey gneisses ranging in composition from Tonalite-Trondhjemite-Granodiorite (TTG Suite) to light coloured rocks such as granite gneiss and granites. The name was chosen to emphasize its extensive distribution throughout the Indian peninsula. Gneisses form the major lithology of the Dharwar Craton and range in age from 2.9 Ga to 3.4 Ga.

Albargh located in the city of Bengaluru, has been declared as a National Geological Monument in March, 1975. It is not only a storehouse of botanical and horticultural research, but also has stone quarries which expose excellent sections of Peninsular Gneisses.



The major rock type exposed in the hill and its quarries is dark biotite gneiss of granitic to granodioritic composition containing streaks of biotite mica. Vestiges of older rocks are seen in the form of enclaves within the gneiss. Amphibolite comprising plagioclase feldspar and hornblende form common enclaves. Due to interactions with granitic fluids, these enclaves have developed a border rich in biotite mica. Later magmatic activity represented by grey porphyritic granite followed by pink massive granite is also seen at several places. The gneisses and granites have been profusely invaded by still younger veins of coarse grained pegmatite which have dissected the gneisses into several irregular and lenticular shapes.

Recent geochronological data suggest that the gneisses were accreted in three major episodes.



- NEAREST AIRPORT: BENGALURU (40 KM).
- NEAREST RAILWAY STATION: BENGALURU (6 KM)





PYROCLASTIC ROCKS

Karnataka

The pyroclastic rocks of Pedapalli, district Kolar, Karnataka, consists of large fragments of granite, granite gneiss, basalt and banded ferruginous quartzite set in a matrix of ignimbrite. While many rock fragments are angular, some of them appear to be well rounded. Some rock fragments of granite gneiss measure up to 80 cm in diameter. Eutaxitic structure is quite prominent and fiamme structure is also seen.

Quartz, feldspar and biotite are seen in the fiamme structure when observed under the microscope. Many quartz and feldspar crystals occur as phenocrysts in the rock - a feature characteristic of ignimbritic pyro magma, and is regarded





as one of the factors contributing to the glowing avalanche type of volcanic eruption. Under thin section, the rock reveals the presence of micrographic intergrowths that could represent spherulitic and axiolitic structures which recrystallized. The matrix of the rock is composed of quartz, potash feldspar, abundant biotite and a few crystals of hornblende. Mineralogically, the rock ranges in composition from rhyodacite to dacite.

In addition to the pyroclastic rocks of Peddapalli, there are a few occurrences of pillow lava and pyroclastic rocks in the Kolar Gold Field. These are within the Yerrakonda Formation of Kolar Group.

The outcrop is best approached by following the Bangarpet- Betmangala road and taking the southerly diversion near the 10 km stone for about 1 km.

- NEAREST AIRPORT: BENGALURU (50 KM)
- NEAREST RAILWAY STATION: PEDDAPALLI
- PEDDAPALLI LIES 700 M TO THE EAST OF THE ROAD CONNECTING KOLAR GOLD FIELD(KGF) WITH THE BANGARPET- BETMANGALA ROAD.





SALKHAN FOSSIL PARK

Uttar Pradesh

Stromatolite exposures at Salkhan area in district Sonbhadra, Uttar Pradesh presents rare sites of geological interest. Salkhan area has also been developed as "Salkhan Fossil Park".

Here, two stromatolite outcrops of dimension– 110 m (E-W) X 25 m (N-S) and 30 m (E-W) X 12 m (N-S) are well exposed on the slopes of the hillock. These are columnar/cylindrical in form and are mostly Conophyton. The size of colonies attains maximum height of 110 cm and diameter 30 cm. The colonies



make right angle with bedding plane with lime mud as filling material. Salkhan limestone belongs to Semri Group of Lower Vindhyan sequence.

Stromatolites are the most ancient records of life on Earth and dates back to Achaean elsewhere in the world. These are layered bio-chemical accretionary structures formed in shallow marine water by trapping and cementing of sediment grains by cyanobacteria (a unicellular photosynthesizing microbe). Morphologically, the cyanobacteria appear in conical, stratiform, branched, domal, and columnar forms.



- NEAREST AIRPORT: VARANASI (128KM)
- NEAREST RAILWAY STATION: AGTHORI (~5 KM), ROBERTSGANJ (~16 KM)
- SALKHAN AREA LIES 2 KM WEST OF VARANASI - OBRA NH, ~ 25 KM FROM CHOPAN ON CHATWARA ROAD IN SONBHADRA DISTRICT.



நந்தனகரீ, ஁ரீய அதீகாரீ
ள் தண்டனீக்குள்ளாவாரீகள்
எம்எஸ். பாலசுந்தரம்
டைரக்டர் டீனரல்
தீதீய புவீயியல் தீவாக்தாரீ.

28காடிதீண்டுகள் பழகையான
கஸ்மரம். இடம்: தீருவக்கரை,
வீழ்ப்புரம் மாவட்டம்.
20 Million Year Old
FOSSIL WOOD From
THIRUVAKKARAI, VILUPPURAM DL.

SATTANUR FOSSIL WOOD PARK

Tamil Nadu

The Sattanur village located within the Ariyalur area of the Cauvery Basin, district Perambalur, Tamil Nadu is known for its exceptionally shallow marine sequences with very rich faunal assemblage of Albian-Maestrichtian age. It has been globally recognised as a reference sequence for the Upper Cretaceous. The profusion of fauna in the sediments has earned it the epithet 'Mecca of fossils' and is a veritable field museum of Cretaceous Palaeozoology.

The Sattanur fossil tree i.e. conifers (non-flowering plants) is a testimony to the geological history that prevailed during the Cretaceous Period. Owing to its immense geological



importance, the place has been declared as a National Geological Monument.

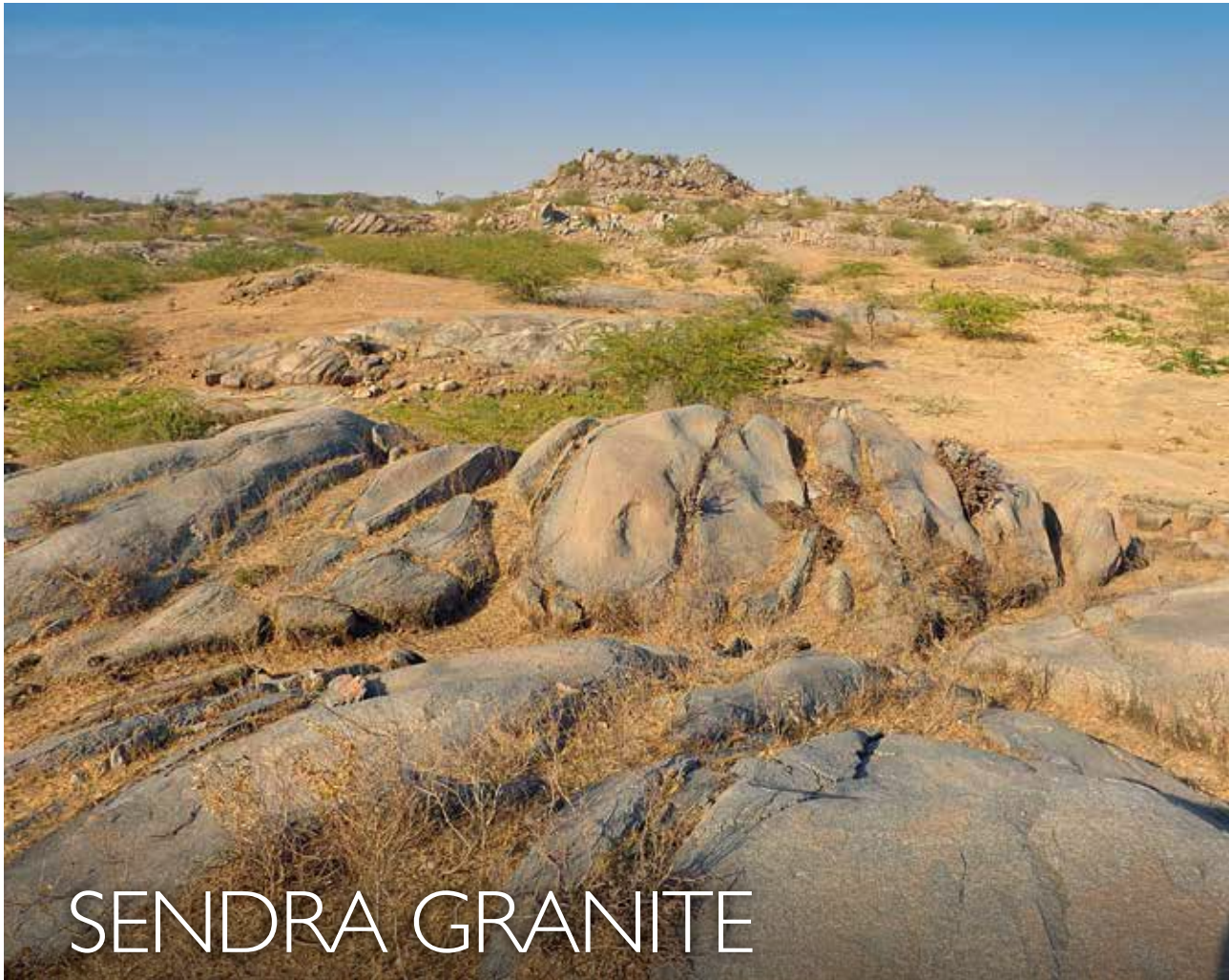
Geological study indicate that during Cretaceous times the sea, (which in present times, lies about 100 km east of Sattanur) had transgressed as far as 8 -10 km west of Sattanur. During this period the sea had a variety of marine animals similar to those found in the present day. The sea animals after death sank to the bottom and were buried under the sands and clays brought down by the rivers. Along with them, some trees which thrived near the shore were also buried after transport by flooded streams with the passage of time.

The large trunk of petrified tree at Sattanur within the Trichinopoly Group of Rocks is about 100 million years old. This tree belongs to conifers (the non-flowering plants) that, dominated the land vegetation prior to the, advent of angiosperms (the flowering plants of the present day). The petrified tree trunk at Sattanur measures over 18m in length.



- NEAREST AIRPORT: MADURAI (100 KM)
- NEAREST RAILWAY STATION: ARIYALUR, ON THE TIRUCHCHIRAPPALLI - CHENNAI SECTION OF THE SOUTHERN RAILWAY.
- ~ 700M NORTH OF SATTANUR VILLAGE. APPROACH FROM NH-45, CONNECTING CHENNAI WITH TIRUCHCHIRAPPALLI, UP TO SIRUVACHCHUR VILLAGE.



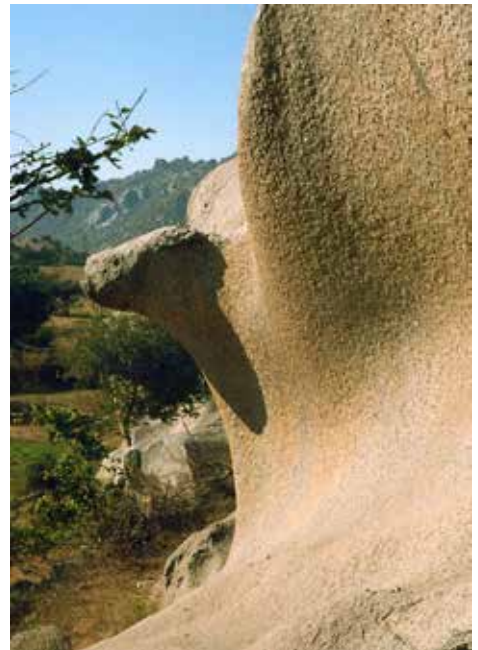


SENDRA GRANITE

Rajasthan

Sendra Granite is a unique example of nature's capacity as a sculptor. It is approximately 900 m.y. old and intrudes into the Delhi Supergroup of metasedimentary rocks of Proterozoic age. Large bosses are concordantly emplaced in the calc gneiss while small bodies are distributed in and around the hornblende schists.





It extends from south of Ambaji in Gujarat to north of Ajmer in Rajasthan over a distance of 350 km. The Sendra Granite is exposed in all forms and sizes. Huge bosses are exposed to the east of Sendra and around Borwar, and are called Chang and Borwar boss respectively. Small sized bodies are exposed to the east of Dholia. Weathering of these has resulted in alluring landforms viz., huge tors, pillars, caves and natural arches.

- NEAREST AIRPORT: JODHPUR (77 KM)
- NEAREST RAILWAY STATION: SENDRA (~1 KM)
- LOCATED ON THE SENDRA-PALI ROAD AND IS EXPOSED ON EITHER SIDE OF NH-8.





SELA PASS

Arunachal Pradesh

The Sela Pass is a high-altitude mountain pass located in district Tawang, Arunachal Pradesh . It is at an elevation of 4170 m (13,700 ft) above msl. It exposes lithounits of higher Himalayan crystallines and leucogranite. It remains snow bound for most part of the year and is known for its pristine beauty.





- NEAREST AIRPORT: TEZPUR (259 KM)
- NEAREST RAILWAY STATION: DEKARGAON (~270 KM)
- 78 KM FROM TAWANG; 340 KM FROM GUWAHATI.

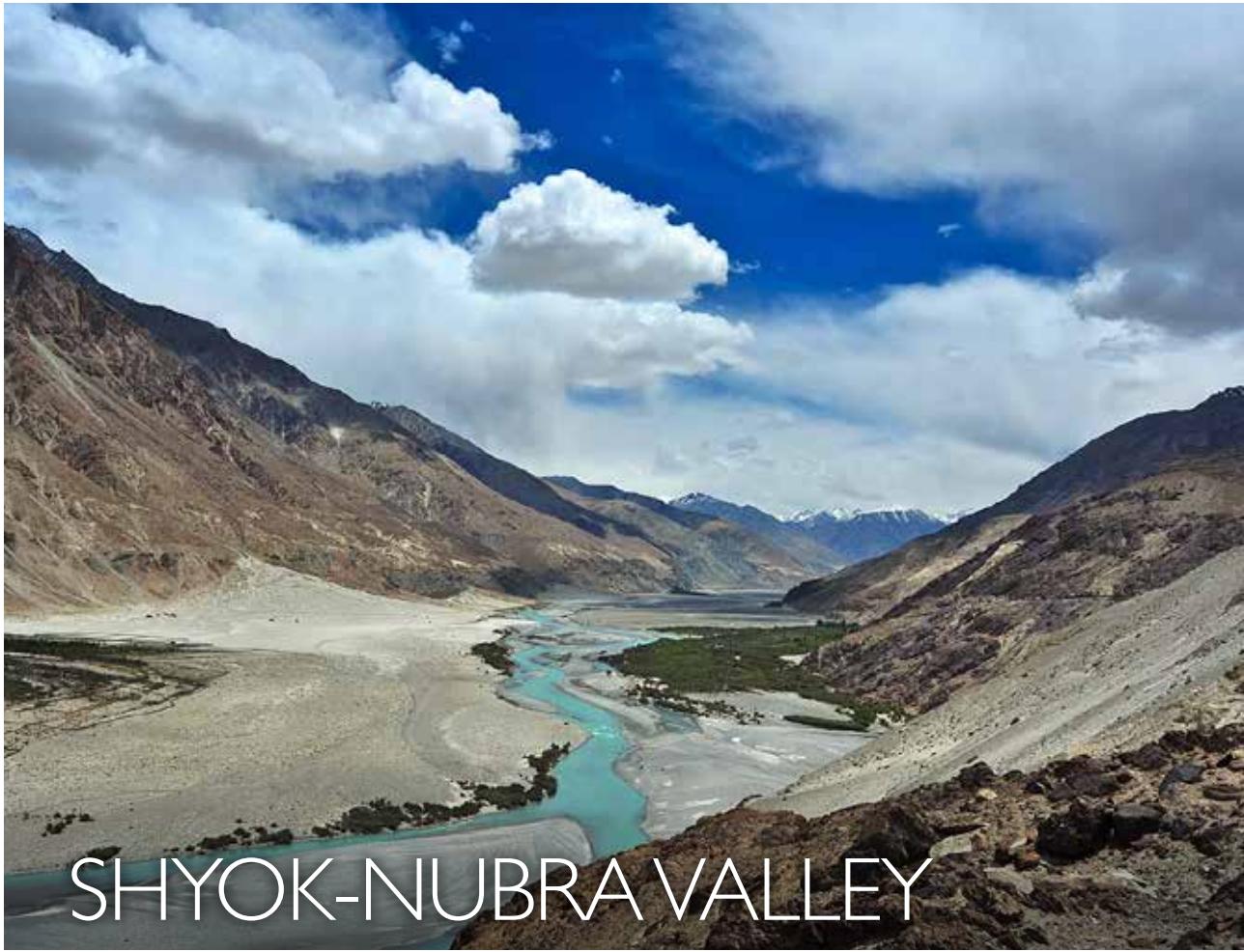


Nearly 101 lakes exist in and around Sela Pass and each of these lakes has a huge religious significance for the Buddhist community. Amongst these, the beautiful Sela Lake also called Paradise Lake stands out for its majestic scenic beauty.

Some spectacular geomorphological features can also be seen around the pass which includes, water falls along fault cliffs and hot water springs etc.

It connects the Buddhist city of Tawang to Tezpur and Guwahati and is the main road connecting Tawang with the rest of India.





Jammu & Kashmir

The Shyok-Nubra valley at the confluence of Shyok-Nubra rivers near Diskit is unique due to the presence of sand dunes as observed in desert of Rajasthan. This is the main attraction for the tourist as they can experience this by a double hump camel ride. These sand dunes are of great importance for geologists which suggest climatic variability in high altitude terrain. These dunes are situated at the banks of these rivers which offer new approach towards Quaternary geological studies. The Shyok-Nubra valley is also important in context of geology as it marks a suture zone. The areas to the south of Shyok are part of Indian plate while those to the north are a part of the Eurasian plate.



The topography of the region is dominated by three parallel mountain ranges constituting the Trans-Himalaya viz: the Zaskar, the Ladakh and the Karakoram. The altitude ranges from 2300 m to over 8000 m above mean sea level. Most of the habitation is concentrated along floor of the narrow and steep river valleys.



- NEAREST AIRPORT: LEH (~140 KM)
- NEAREST RAILWAY STATION: JAMMU (~845 KM)
- THE SHYOK-NUBRA VALLEY CAN BE APPROACHED AFTER CROSSING THE HIGHEST (18360FT) MOTORABLE ROAD OF THE WORLD- THE Khardungla Pass.





SIWALIK FOSSIL PARK

Himachal Pradesh

The Siwalik Fossil Park at Saketi spreads over an area of about 1.5 Km² and displays life-size fiberglass models of six of the prehistoric animals that thrived in the area about 1 to 1.5 million years ago, their fossilized remains being recovered from Saketi and neighbouring regions.

A large and rare collection of vertebrate fossils (about 250 specimens) recovered from Siwalik hills in Saketi and adjacent areas have been displayed in a field museum within the park. The fossil specimens include skulls, teeth, jaws, horn cores, limb bone fragments and vertebrae of various animal groups mainly mammalian, reptilian and fish. Among mammals, the fossils of proboscids (elephants), equids (horses), hippopotamids, rhinoceroses, bovids (cattle), cervids (deer), suids (pigs), giraffids and carnivores are the





common exhibits. A large collection of stone artifacts used by Early Palaeolithic Man recovered from the vicinity of Saketi are also displayed in the museum.

Presently giraffes in natural habitat are not found in India but the fossils of four genera have been found in Siwalik rocks. This indicates that a variety of giraffes existed in the Siwalik region during Plio-Pleistocene period (about 1 to 7 million years ago) and evolved along diverse lines.



- NEAREST AIRPORT: CHANDIGARH (63 KM)
- NEAREST RAILWAY STATION: KALKA (~60 KM)
- THE FOSSIL PARK IS LOCATED ABOUT 5 KM NE OF KALA AMB ON A FAIR WEATHER ROAD (KALA AMB-BIKRAMABAD ROAD).





STROMATOLITE BEARING CARBONATE

Sikkim

Huge bouldery outcrop of Stromatolite Dolostone at Mamley, South Sikkim, is the only exposure of stromatolite bearing carbonate in the state of Sikkim.

The stromatolite dolostone belongs to the Buxa Formation of Proterozoic Daling Group. More than one generation of stromatolite (Conophytes) are distinctly evident, which may be of more than 1 billion year age, considering their association with Daling Group of rocks. It is characterized by fine grained, finely laminated to massive, grey and pink dolostone and



limestone beds, often with a weathered, pitted surface. Dolomite outcrops occur as cliff, scarp faces and scattered boulders in Mamley area. They are marked by elephant skin weathering and are highly jointed.

The site is an outstanding example of ancient life on the Earth and represents a major stage of earth's early history, including the record of life in form of stromatolites, which is significant in relation to the past geological processes, and evolution of life on the Earth. They help in unraveling the palaeogeography and palaeoenvironment of the area.



- NEAREST AIRPORT: BAGDOGRA (100 KM)
- NEAREST RAILWAY STATION: SILIGURI (49 KM)
- LOCATED 6 KM NNE OF NAMCHI, ON NAMCHI-DAMTHANG-WAK-SIKKIM SH.





STROMATOLITE PARK

Rajasthan

Evidence of Precambrian life has been found in different parts of the world including India. The early atmosphere was deficient in oxygen and enriched in carbon dioxide and nitrogen, but oxygen began to accumulate through the activity of photosynthetic organisms – the blue green algae. Stromatolites are structures produced by blue-green algae, which through their filaments, attract and bond carbonate particles forming a mat. They are stratiform, columnar and nodular structures in carbonate rocks resulting from the combination of life activity, sediment

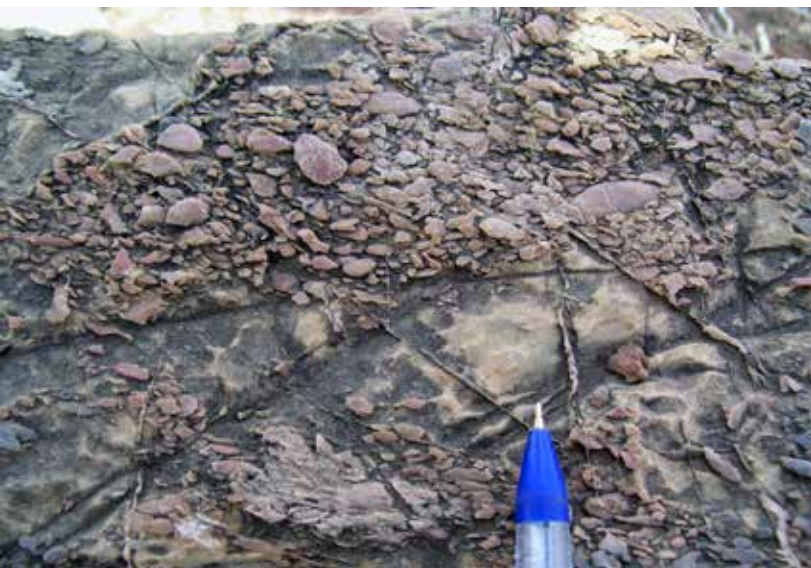


trapping and binding ability of algal assemblages and preying bacteria.

The rock phosphate horizon at Jhamarkotra, district Udaipur, Rajasthan forms discontinuous outcrops over a strike length of 15 km and occurs in a thick succession of rocks of Precambrian Aravalli Supergroup. This is the largest and richest deposit of phosphorite associated with stromatolite. Considering the variety of stromatolitic structures, the area has been fenced to preserve this unique occurrence of biostrome. The Fossil Park was declared as National Geological Monument in January 1978. The rock phosphate of Jhamarkotra area occurs in dolomitic limestone associated with stromatolites which are grey to bluish-grey in appearance.



- NEAREST AIRPORT: UDAIPUR (25 KM)
- NEAREST RAILWAY STATION: UDAIPUR (25 KM)
- JHAMARKOTRA IS LOCATED 25 KM SE OF UDAIPUR ON THE UDAIPUR-SALUMBAR ROAD.





SUNDARBAN: THE MANGROVE FOREST

West Bengal

The Sundarban comprises the Sundarban mangrove forest and its adjacent impact zone and has both local and global significance due to its diversity, uniqueness, and richness of the ecosystem. It is the largest mangrove forest in the world and has earned global attention among conservationists, researchers, and nature lovers. It has been recognized as a Natural World Heritage Site in 1997 (UNESCO) and Ramsar Site of International Importance in 1992.

Sundarban, a cluster of 102 islands, hosts landmark ancient heritage of mythological and historical events bestowed with wide bio-diversity of mangrove flora and fauna, magnificent

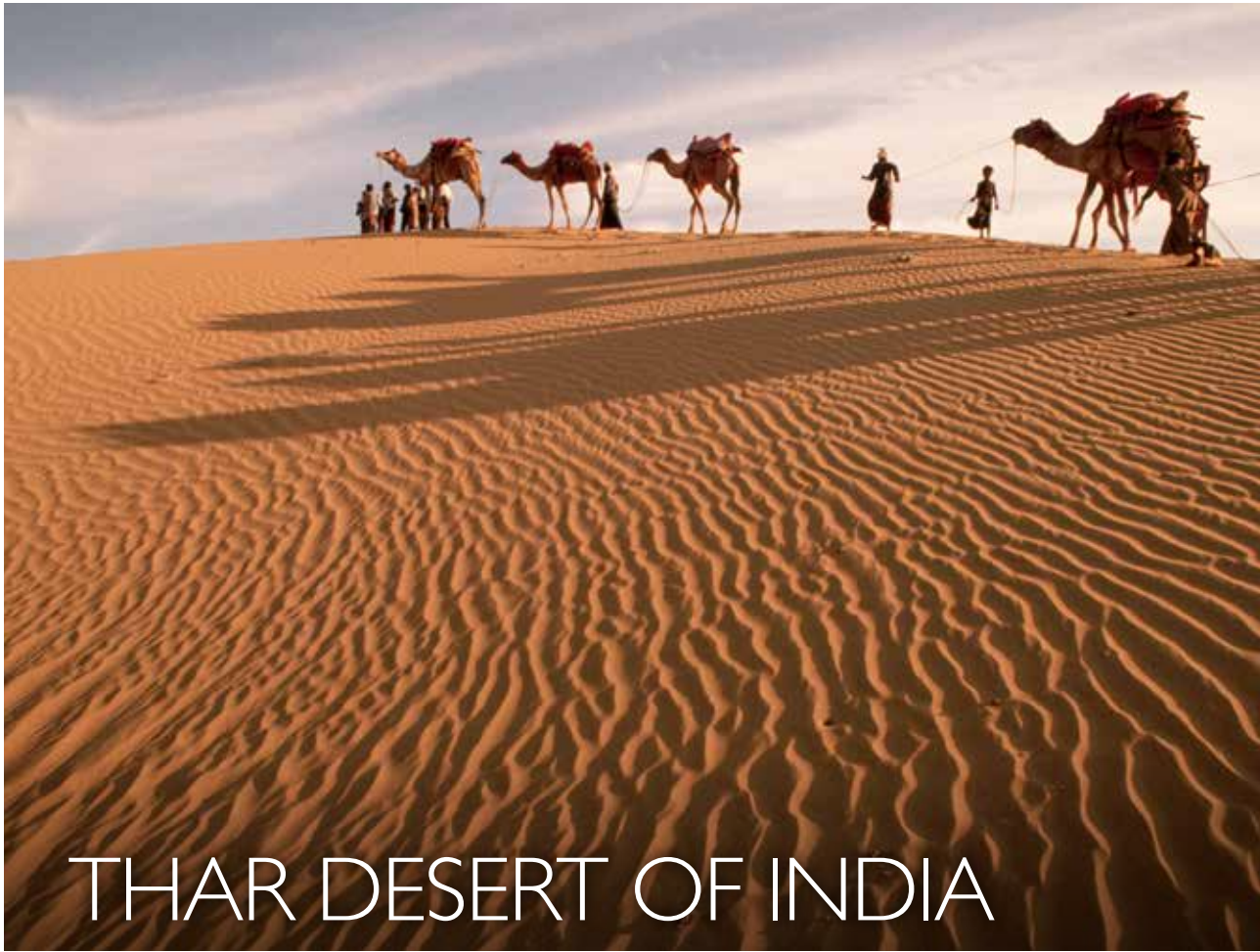


scenic beauty and natural resources of immense geological, anthropological and archaeological interests. The Sundarban delta is located in the lower Ganga river basin in south-western Bangladesh and southeastern India.



- NEAREST AIRPORT: KOLKATA (109 KM)
- NEAREST RAILWAY STATION: CANNING (45 KM)
- IT IS APPROACHABLE FROM KOLKATA BY ROAD UPTO NAMKAHANA JETTY THEREAFTER ALL INDIVIDUAL ISLANDS ARE TO BE VISITED BY LAUNCH.





THAR DESERT OF INDIA

Rajasthan

Thar Desert in Western India covers around 2,59,000 km² in the states of Rajasthan, Gujarat, Haryana and Punjab. It is the world's seventh largest desert on the subtropics. It is characterized by hot and dry climate, aeolian landforms, salt marshes and saline lakes. The Thar Desert is one of the most populous and fertile deserts of the world and is well known for its spectacular landscapes and rare geological sites.

Quaternary Formations of aeolian, fluvial and lacustrine origin are geologically important to study



the evolution of the Thar Desert. The aeolian deposits formed over 200 ka ago display various types of sand dunes with calcrete of pedogenic and non-pedogenic origins. Alluvial deposits are abundant in northern part of the desert and along the ephemeral river courses in the western part. The lake sediments (~40 ka), consist of evaporite and silt-clay and occur as lenses in the abandoned and ephemeral lakes.



- NEAREST AIRPORT: JAISALMER (90 KM)
- NEAREST RAILWAY STATION: JAISALMER (90 KM)





TIRUVAKKARAI FOSSIL WOOD PARK

Tamil Nadu

Tiruvakkarai, in district Villupuram, Tamil Nadu, contains some of the most spectacular fossil trees preserved in rocks. These are Mio-Pliocene in age (20 m.y.).

The trees belong to several rare species of conifers and palms. The absence of branches and roots in these horizontally disposed trees, indicate that they were transported by rivers to their present sites of deposition in inland seas. The fossilized conifer species are typical of hilly regions corresponding to elevations (~750 m), later penneplained to the present level. They were subsequently petrified and the woody matter was replaced by silica and water expelled due to compaction of

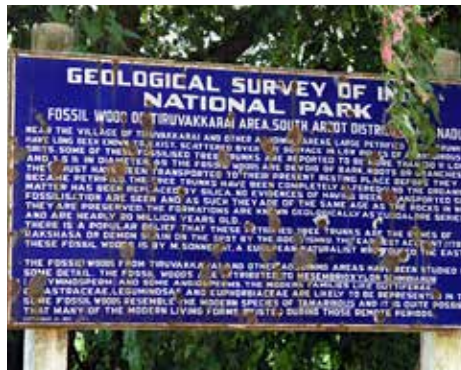


the superposed sediments. The fine woody structure, the annular rings, the pit structure and the knots are intricately preserved.

In Tiruvakkarai, as many as 200 fossil trees varying in length from 3-15 m and up to 5 m girth are observed lying embedded horizontally in Cuddalore Sandstone. The maximum length recorded is 28.80 m. The fossil woods are classified as Mesembrioxylon Schmidianum (gymnosperm) and Peuce Schmidiana (angiosperms). The families like, guttiferae, leguminosae, anacardiaceae, sonnaratiaceae and euphorbiaceae are represented in them. Some of them belong to the genera palmoxyton, albizzia, mangifera, shorea, terminalia. Some fossil woods resemble the modern species of tamarindus.



- NEAREST AIRPORT: PUDUCHERRY (50 KM)
- NEAREST RAILWAY STATION : PUDUCHERRY (28 KM)
- NATIONAL FOSSIL PARK AT TIRUVAKKARAI IS LOCATED 1 KM EAST OF THE VILLAGE TIRUVAKKARAI AND LIES 155 KM SSW OF CHENNAI NH-45.





VARKALA CLIFF

Kerala

Varkala, a major cliff in the west coast of India, district Thiruvananthapuram, Kerala is the type section of the Tertiary sedimentary rocks (Warkalli Formation). The cliff sections first described by King (1882) and Foote (1883) are exposed from Edava in the north to Vettoor in the south. The cliff sections not only provide a visual impact of great aesthetic value, but is also an established tourist destination. It is a preferred destination for geoscientists to visualize the concepts of sedimentation, environment of deposition and tectonics.



In the type section at Varkala, the cliff exposes about 60 m of the Warkalli Formation. It is composed of unconsolidated sand, variegated, white plastic and carbonaceous sandy clay enclosing impersistent seams and lenses of lignite. The carbonaceous clays and lignite are often impregnated with nodules of marcasite indicating a reducing environment. Sand grains vary in size from coarse to fine. These are angular and poorly sorted. Non-clastic sediments are typically absent due to the rapid influx of detrital material. The lithology of this formation suggests that the Warkalli sediments are shallow water shoreline littoral deposit.



- NEAREST AIRPORT:
THIRUVANANTHAPURAM (55 KM)
- NEAREST RAILWAY STATION: VARKALA
- IT IS CONNECTED BY BUS FROM
THIRUVANANTHAPURAM AND KOLLAM.





GEOTOURISM IN BANGLADESH

Geology of Bangladesh

The country of Bangladesh is bounded by Indian States of West Bengal, Meghalaya and Tripura in the west, north, and east respectively. Myanmar forms the southern delimiting boundary opening up into the Bay of Bengal. Bangladesh comprises 80% plain land under cover of alluvium and rest 20 % consists of Tertiary hills. The oldest exposed rocks in Bangladesh belong to the Tura Sandstone Formation of Paleocene age. Bangladesh can be divided into four regions, with distinct geological characters.

1. The Eastern and Northern Frontier Hilly Regions: This region comprises hills of Lalmai and Sylhet district and a narrow strip of a series of low hill ranges and isolated circular and elongate hillocks separated by recent alluvium along the northern frontier of Sylhet and Mymensingh districts. The hill ranges comprising Mio-Pliocene sedimentary rocks, are steeper on the eastern side.

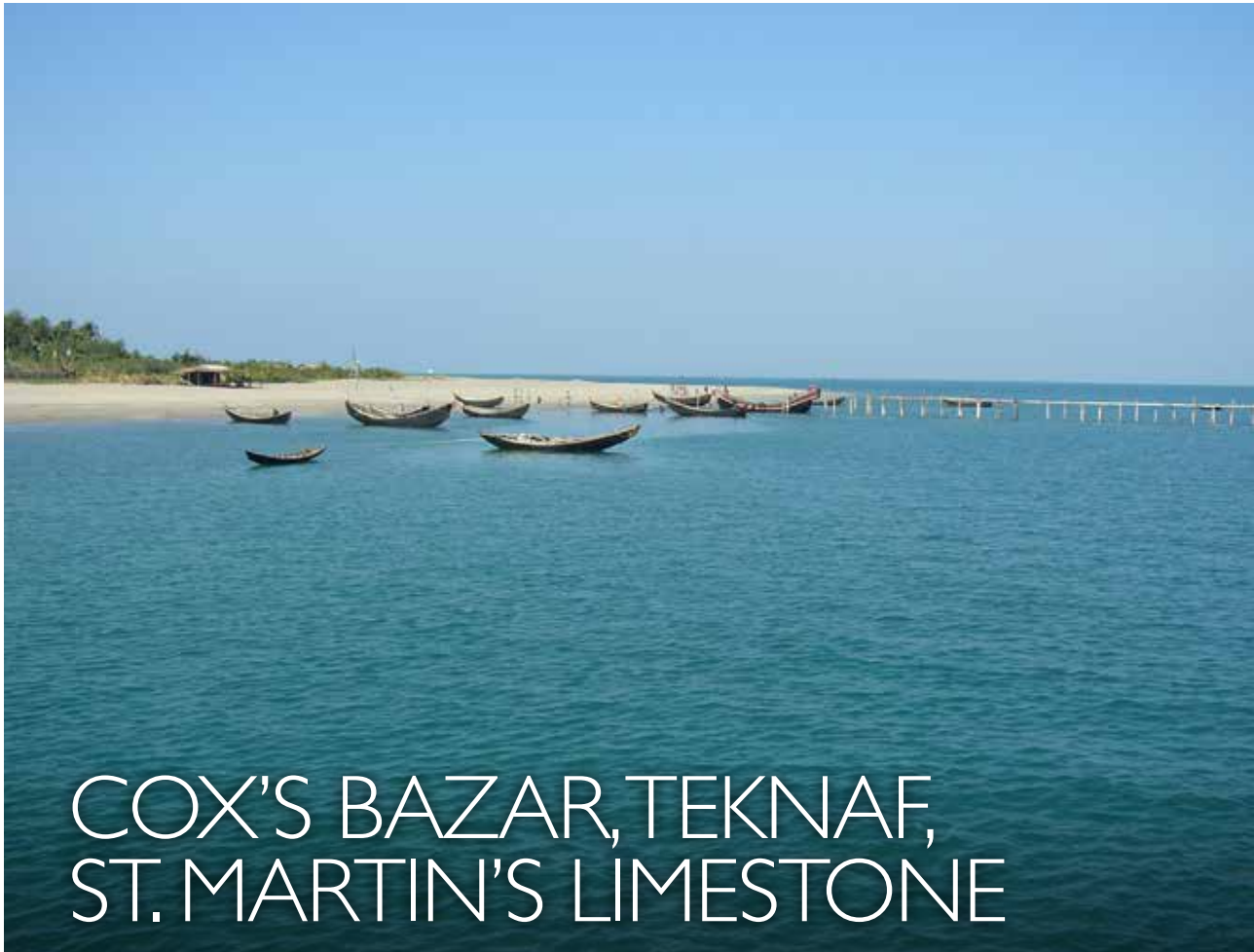
2. The Great Table Land: The area lies between the Lalmai hills of Comilla district and the marginal low hills of the Chittagong and Sylhet districts, in the east of Dhaka and Rajshahi divisions to the West Bengal of India. These high lands exhibit smooth rolling topography. It looks like a chain of isolated, circular or elongated low hillocks forming higher relief as compared to the surrounding flat land comprising alluvium.

3. Floodplains of the Ganga-Brahmaputra-Meghna River systems: These floodplains exhibit flat topography and consist of the floodplains of the Ganga, Brahmaputra and Meghna Rivers. It covers ~40% of the total area of Bangladesh.

4. The Delta: The delta is a combination of three deltas, namely Ganga delta, the Old Brahmaputra-Meghna delta and Ganga-Jamuna delta. It is commonly denoted as Ganga-Brahmaputra-Meghna delta.

Field study, evidences and analysis of bore hole logs indicate that the Holocene sediments comprise major part of the country, except few Pleistocene deposits in the middle parts and Tertiary sedimentary rocks in the eastern folded belt of the country. The oldest Precambrian basement rocks have been reported from a depth of 107 m in Madhapara area in the northwestern part of the country. These comprise metamorphosed granite and basaltic rocks, represented by Gneiss, Granodiorite, Diorite, Amphibolites, Gabbro, Dolerite, Schist etc. The Paleozoic Gondwana rocks found at shallower depth is represented by medium to coarse grained whitish to light gray sandstone with carbonaceous shale and coal seams. The Mesozoic rocks occur at various depths in four known areas namely Kansat, Patnitola, Kuchma and Singra.





COX'S BAZAR, TEKNAF, ST. MARTIN'S LIMESTONE

Chittagong

Cox's Bazar is one of the beautiful geotourist places in Bangladesh. The sea beach of Cox's Bazar is unbroken, gently sloping and one of the longest (125 km) sea beach in the world. The sediments of the beach include rock, shell and shell fragments etc. The beach has a gentle gradient (2° - 3°) towards the sea. The heavy minerals of Cox's Bazar beach sands are dominated by garnet, ilmenite, magnetite, rutile etc.

Himchari is located 18 km south of the Cox's Bazar town. It is famous for its rock cliff, tropical rain forest and waterfalls. In this section, the Mio-Pliocene sediments are exposed.





Inani is a very beautiful tourist place near Cox's Bazar. It is located 35 km south of Cox's Bazar. This beach is famous for its rocky boulder and shark free water, ideal for sea bathing.

Dakhin Nhila is a type section of early Miocene Surma Group of sediments. The sediments of the Upper Bhuban Formation form the top and flanks of the anticline are occupied by well bedded sandstone; laminated shale and siltstone.

Teknaf is the southernmost part of mainland of Bangladesh and also marks the end point of Cox's Bazar beach. Geologically, this area is significant, because of the co occurrence of Tertiary and Holocene marine deposits. The Holocene marine deposits consist of wide tidal-flat, spit and beach deposits etc. It is one of the longest sandy beach ecosystems (80 km) in the world. Important habitats at the site include mangrove, mudflats, beaches and sand dunes, canals and lagoons and marine habitat. The Teknaf mangroves support the habitat of 161 different species of fish.

St. Martin's Island is the only coralline island in Bangladesh. The island is a popular tourist spot. The island is home to several endangered species of turtles, as well as the corals, some of which are found only on this island. St. Martin's Island comprises a sequence of marine sedimentary rocks. The immediate subsurface deposits include St. Martin's Limestone and Tipam shale and sandstone. St. Martin's limestone consists of coral clusters and coquinooid shelly limestone. The Tipam Group of sediments consists of gray to bluish gray color shale with subordinate fossiliferous sandstone, fossiliferous conglomerate and calcareous sandstone.



- NEAREST AIRPORT: COX'S BAZAAR
- NEAREST RAILWAY STATION: CHITTAGONG (152 KM)





SUNDARBAN: THE MANGROVE FOREST

Khulna & Barisal

The Sundarban is the largest continuous mangrove forest in the world, located at the southern extremity of the Ganga River Delta. It covers an area of 10,000 km² of which ~6,000 km² lies in Bangladesh. The Sundarban is intersected by a complex network of tidal waterways, mudflats and small islands of salt-tolerant mangrove forests. The physiography includes innumerable drainage lines associated with surface and subaqueous levees, splays and tidal flats.

Karmajal, a majestic wild life sanctuary in Sundarban is famous for crocodiles, deer, snakes and several other species.



Kotka, another important tourist place is the largest mangrove swamp in the world hosting the famous Royal Bengal Tiger. It is a store house of some of the rare flora and fauna species including the Sundari tree from which the Sundarban derives its name.

Kachikhali, located in the Sharonkhola range of Sundarban is famous for the Great Royal Bengal Tiger. Dotted deer, monkey, tigers, crocodiles and various bird species can also be found here.

Dublarchar is a beautiful island situated in the Chadpai range of Sundarban. It is famous for fishing, spotted deer and is a paradise for fishermen with abundant fish fauna.

Nilkamol (Hironpoint) is one of the famous tourist attractions in Sunderban. During the ebb tide, the forest becomes bare and at high tide the entire territory of the forest floats on water. UNESCO declared three wildlife Sanctuaries (Sundarban east, south and west) in the Sundarban as 522nd World Heritage Site in 1997 and the plaque of world heritage site is located here.



• NEAREST AIRPORT: SAIDPUR (5 KM)





SYLHET LIMESTONE

Sylhet

Sylhet is located in the northeastern part of Bangladesh. Geomorphologically, the area comprises dissected hills, valleys, gullies, abandoned and ephemeral channels, ox-bow lakes, meandering rivers, flood basins and depression etc. The hills of the area consist of sedimentary rocks of Mio-Pliocene age.

Madhabkunda is one of the most beautiful and attractive place. It is famous for its 61 m high waterfall, thronged by tourists at all times of the year. Geological exposures include blue grey laminated shale and sandstone, hummocky cross bedding within the upper marine shale signifying deposition in shallow marine environment.



Hari River also offers an excellent type section depicting lower, middle and upper Bhuban and Boka Bil Formation. The unconformity with the underlying Barail Formation can also be appreciated. The lower Bhuban represents yellow color sandstone and grayish yellow sandy shale, the middle Bhuban Formation consists of bluish shale, sandy shale and siltstone and the upper Bhuban Formation is a repository for light gray to light yellow color siltstone, shale and sandstone. The Boka Bil Formation consists of siltstone and very compact sandstone.

Jaflong is one of the most attractive geotourist spots in Bangladesh. The main attractions include Eocene Sylhet Limestone Formation, collection of rolling stones, colorful tribal life, Khasi people, Khasiarajbari, Dauki and Piyain river, tea garden, orange, jackfruit, betel leaf and arca nut gardens. The Eocene Sylhet Limestone Formation comprises fossiliferous limestone with foraminifera and other invertebrates. The color and fossil assemblage of the Sylhet Limestone easily distinguishes it from the surrounding formations. The Jaflong section includes Kopili Shale overlying the Sylhet Limestone Formation which in turn is overlain by the Tura Sandstone Formation. The Kopili Shale Formation consists of dark gray and black shale interlayered with fossiliferous limestone. The Tura Sandstone Formation is represented by sandstone, fossiliferous limestone with shale and coal.



- NEAREST AIRPORT: SYLHET
- NEAREST RAILWAY STATION: SYLHET
- THERE ARE TRAIN SERVICES FROM DHAKA, CHITTAGONG AND COMILLA.





GEOTOURISM IN NEPAL

Geology of Nepal

Nepal Himalaya occupies the central 800 km part of the 2400 km east- west expanse of the Himalayas. It is divisible into (1) Terai Plain (2) Sub Himalaya (Siwalik Range), (3) Lesser Himalaya (Mahabharat Range and mid valleys) (4) Higher Himalaya and (5) Inner Himalaya (Tibetan Tethys).

Nepal has sites of immense geological importance and some picturesque locations from the tourism point of view.

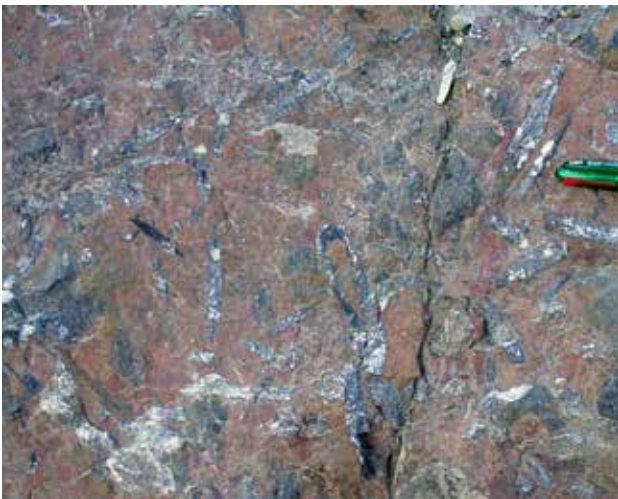
Pokhara Valley, Western Nepal

The Pokhara valley is the second most favoured destination of tourists. The valley is famous as a base station to Himalayan trekking in mid-west such as Annapurna base camp and the Kaligandaki valley. Visitors are greatly impressed by the enchanting view of the Machhepuchre (Fish Tail Mountain) and Annapurna Range and beautiful Phewa and Begnas lakes. The Pokhara Valley extends in NW-SE direction, is 20 km (long) and 5 km (wide) and the valley fill sediments have been deeply eroded by the Seti River.

The Midland of the Himalaya is composed of old Lesser Himalayan metasediments of Lower Proterozoic to Eocene age. It lies between the Main Central and the Main Boundary Thrust, and has undergone strong denudation over a long period of time. The Pokhara Valley is an intermontane valley and the floor is believed to have formed by a repeated debris flow and associated Glacial Lake Outburst Flood (GLOF) at higher reaches. The sediments are young in age (Quaternary including Holocene).

The basement for Pokhara Basin is the Proterozoic Kuncha Formation which comprises phyllite, meta-sandstone and meta-igneous rocks. Directly resting over the basement rocks are the Quaternary sediments, few meters to some hundred meters thick. It mainly includes consolidated (debris flow formations) which are the most characteristic Quaternary deposits in the basin. The debris flow deposit include slightly to moderately cemented conglomerate composed of limestone, schist, gneiss and granite with silty and sandy matrix. Due to high lime content in the deposit, groundwater makes intricate network of caves and caverns within the sediment at various depth.







Tinau River Corridor (Butwal to Tansen Road)

The Tinau River in Central West Nepal exposes rocks of Lesser Himalayas and Siwaliks of the Nepal Himalaya. This corridor exposes the Main Boundary Thrust. The fossil horizon 'Ramaphithecus' teeth also lie in this section. From Srinagar Hills of Tansen, the complete Annapurna and Dhaulagiri Range can be viewed.

Kaligandaki River Section

This river in the Central West Nepal offers an excellent chance to study the Lesser Himalayas, the Higher Himalayas and the Tibetan-Tethys zones of the Nepal Himalaya. Good exposures are found between Beni and Muktinath.

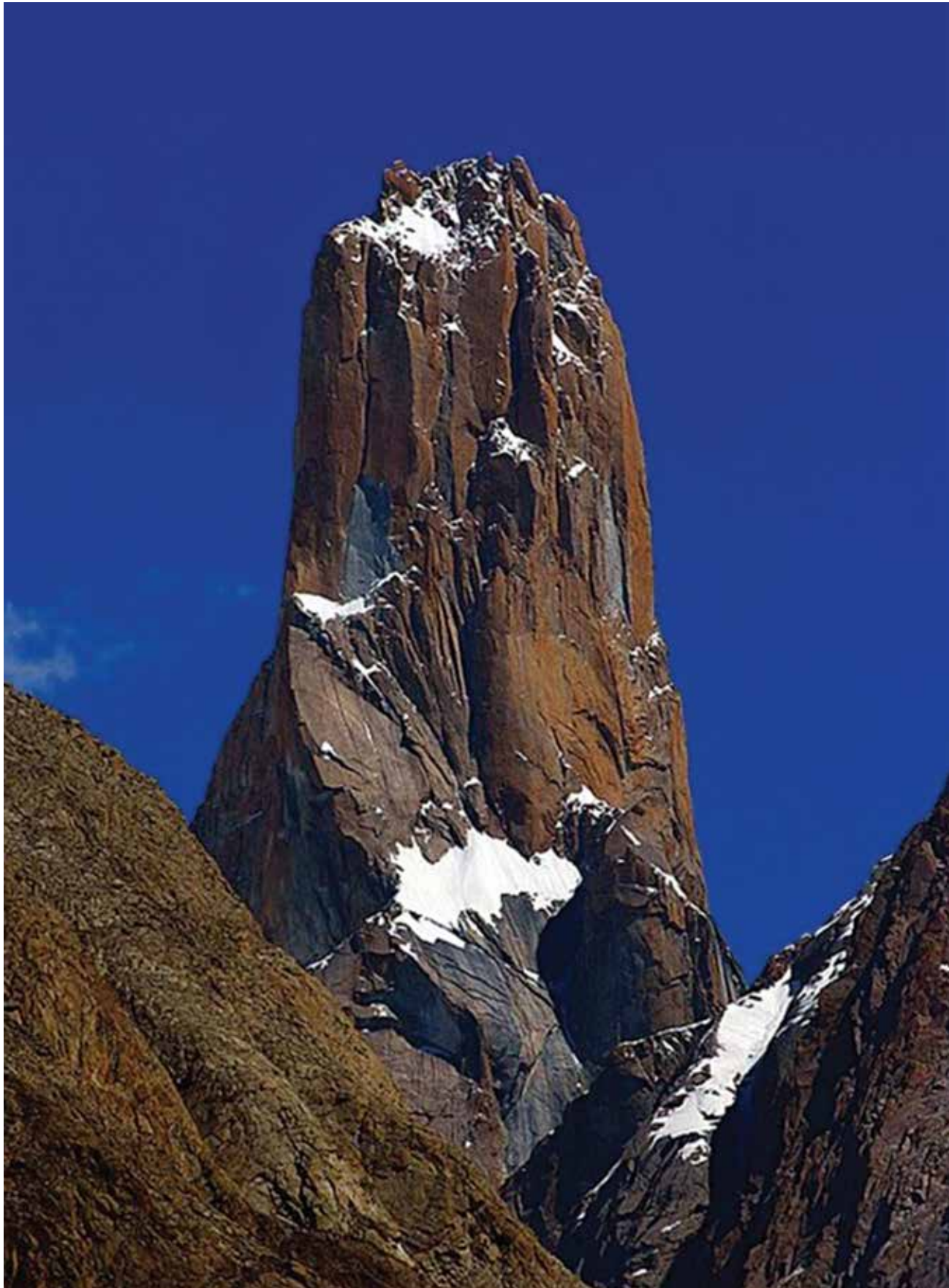
Kathmandu valley

The Kathmandu Valley is an ancient lake filled up in recent geological times by the sediments derived from rapid erosion of the surrounding hills and mountains. The lake-bed sediments are up to 350 m thick and they consist mainly of soft and weak organic silts and clays. The city hosts many temples and tourist spots.

Salleri - Lukla -Namche Corridor

The world's highest peak, Mt. Everest which is a major tourist attraction can be seen from here. Lukla also has a small airport of critical importance. Observation of Himalayan glacial terrains and glacial valley can also be made in this corridor.





GEOTOURISM IN PAKISTAN

Geology of Pakistan

The geological and structural framework of Pakistan is the result of coalescence of three crustal plates- Arabian, Eurasian and Indian. Broadly, Pakistan is divided into two parts, northern and southern. The northern part comprises the Himalayan Tectonostratigraphic Basin, divided into Higher Himalaya and Lesser Himalaya and the Kohistan Island arc. On the other hand, the southern part of Pakistan includes Indus Basin comprising Kohat-Potwar Province and Sulaiman Kirthar Province; the Axial belt comprising northern and southern sectors and the Balochistan basin, divided into the Chagai— Raskoh Province and; the Makran Accretionary Province.

The Salt Range contains the most important geological and paleontological localities in Pakistan. It is easily accessible and exposes richly fossiliferous stratified rocks. These include the Permian carbonate succession with its outstanding brachiopod fauna, Lower Triassic ammonoid beds (the Mianwali Formation, formerly known as “Ceratite Beds”), and Lower Tertiary marine strata with age diagnostic foraminifera. In addition to the easily available roadside geology, some prominent gorges provide fantastic locations to study the sedimentary succession. Excellent exposures of the older strata can be found in the eastern Salt Range between the Khewra-Choa Saidan Shah and Fort Kussak including the famous Khewra Gorge. In the west, beyond Kallar Kahar, are younger strata such as in the Nilawahan Gorge at Nurpur; the Nammal Gorge near Mianwali, the Chichali Gorge near Kalabagh, and further west the Lumshival Nala at Makerwal. The Salt Range is unique and attracts geologists from all over the world to study Cambrian stratigraphy, the Permian-Triassic boundary and Lower Tertiary foraminiferal biostratigraphy.

Pakistan has huge deposits of coal, copper, lead, zinc and gypsum. The Thar coalfield located in Thar Desert in Pakistan (district Tharparkar, Sindh province) was discovered in 1991 and is one of the largest in the world. It has estimated reserves of more than 175 billion tons. A large deposit of copper is located near Reko Diq town in district Chagai, Balochistan, Pakistan. The Reko Diq area is part of the Tethyan Magmatic Arc, extending through central and southeast Europe. Another lead and zinc mine is located at Duddar in Balochistan. The country also has large deposits of marble and decorative stones, iron ore, of salt and gypsum.





GEOTOURISM IN SRI LANKA

Geology of Sri Lanka

Geologically, about 90% of Sri Lanka is covered by highly metamorphosed Precambrian rocks. These rocks vary in composition and metamorphic grade. Pegmatite and mafic dykes intrude the basement rocks. The cover sediments exposed along the southeastern coastline are limestone (Miocene) and sandstone (Jurassic). Apart from these, Red beds, Ratnapura beds, coral reefs, beach sand and Quaternary alluvium are also found.

The Precambrian basement has been subdivided into four main lithotectonic units (a) Highland Complex (b) Wannai Complex (c) Vijayan Complex (d) Kadugannawa Complex.

Highland Complex (HC): It comprises 50% of the Precambrian basement rocks which underwent granulite facies metamorphism. The lithounits include metasedimentary rocks such as quartzites, marbles, calc-silicates and garnet sillimanite gneisses, meta-volcanic suites, mafic to granitic granitoid intrusives and mafic dykes.

Vijayan Complex: The Vijayan Complex is exposed in eastern and southern part of Sri Lanka. Rocks of the Vijayan Complex are of 1100 Ma age. These are metamorphosed to amphibolite grade during 456-591 Ma. The Vijayan basement is composed of granitoid gneisses (Tonalite to Leucogranite) and migmatites. Metasedimentary rocks are found in minor amounts as xenoliths. Hornblende bearing calc-alkaline plutonic rocks are common in this unit.

Wanni Complex: This unit comprises granitoids, gneisses (migmatitic to charnockitic gneisses) and minor metasediments which have been subjected to granulite facies metamorphism.

Kadugannawa Complex: It is composed of hornblende- biotite and quartzo-feldspathic gneisses, minor amphibolites, anorthosite and supracrustal rocks. These occur around Kandy and Peradeniya and have been subjected to amphibolite grade metamorphism.

A wide geomorphological variation can be observed in Sri Lanka varying from rugged mountain ranges, flat plains, deep valleys and isolated hills.





Some of the major geotourist spots are

Ginigalpelassa: It hosts a green coloured serpentinite deposit located north of Embilipitiya-Kiriibbanara road occurring at the tectonic contact of Highland and Vijayan Complex.

Akarella: The area exposes quartz reef which is mined at present.

Mahapelassa: Location of hot water spring. Temperature of the water is around 44°C. Origin of this spring is related to the boundary between the Highland Complex and the Vijayan Complex which is thought to be a deep seated fracture zone. This location is accessible from Suriyawewa - Padalangala new road.

Madunagala: Madunagala ridge comprises granitic gneiss and is famous due to the presence of a monastery. Ruins of an ancient Buddhist religious place are found in the vicinity of the ridge. It is accessible from Mirijjawila - Suriyawewa new road.

Hambantota: It exposes beach sand comprising garnet.

Kalametiya: This area exposes shell beds that have been deposited during a marine transgression during Holocene Period. These beds are composed of shells of bivalves species *Meretrix*, *Anadara* and *Cerithidea*. C14 ages of these shells suggest 4650 ± 60 – 3570 ± 60 B.P.

Rambuka: Gem mines yielding very good quality yellow sapphires are found here. It can be accessed from Kalawana – Rakwana main road via Pothupitiya.

Eppawala: The area hosts apatite mineralization which is mined. The deposit contains 40 million tonne of apatite.

Gal Viharaya: Three seated and lying statues of Lord Buddha are situated at Gal Viharaya of Polonnaruwa. The statues are made of hornblende biotite gneiss.

Pulmoddai: A beach sand deposit composed mainly of ilmenite exists along the beach from Arisimalai to Kokilai lagoon. This deposit contains about 75 - 80% ilmenite, 8- 12% rutile, 8- 10% zircon and 2 – 3% magnetite.

Panirendawa: This area hosts a banded magnetite iron ore deposit. It contains 65% iron and occurs at a depth of 24-120 m.

Polwatta: Colourless topaz of colluvial origin occurs in Polwatta colony of Rattota. This place is accessible from Ambagaswatta road.





Bangladesh

Nepal

India

Pakistan

Sri Lanka



ACKNOWLEDGEMENT

The Indian sub-continent, a geological, natural and cultural treasure trove, has always attracted people from all over the globe. The exercise to bring out a volume on Geotourism hotspots in Indian subcontinent was a gigantic one and has been possible with contributions from geoscientists from various institutions. The scientific content and field photographs for this volume have been contributed by many officers of Geological Survey of India. Prof. V C Tewari, Former Head, Sedimentology Group, WIHG, Dehradun; Dr. Nehal Uddin, Director General, Geological Survey of Bangladesh; Dr. Ranjan Kumar Dahal, Associated Professor, Central Department of Geology, Tribhuvan University Nepal; Prof. M. Qasim Jan, Adviser, COMSTECH, Islamabad, Pakistan and Dr. C.H.E.R. Siriwardana, Deputy Director (Geology), Geological Survey and Mines Bureau, Sri Lanka are thankfully acknowledged for their contribution to this volume.



36th International Geological Congress (IGC)
Secretariat
C/o Geological Survey of India
C-II Pushpa Bhawan, New Delhi 110062, INDIA
Tel: + 91 11 29965750, + 91 11 26057035
Email: igc.delhi2020@nic.in
Website: www.36igc.org

