



INTACH

A MONOGRAPH ON POTENTIAL GEOPARKS OF INDIA

D. RAJASEKHAR REDDY, Editor

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FOREWORD

The monograph, "Potential Geoparks of India" is a topical and welcome contribution providing an engaging overview for establishing the much-awaited geoparks in our country. For the first time, the varied and fascinating details on geological heritage of India have been collected into a book, to explore the exciting world of potential Indian Geoparks. Oriented towards the concerned authorities and general public, this absorbing book proposes fourteen geoparks from seven states in the country with valuable information on geological, archaeological, historical and cultural attractions that constitute each geopark.

This book is an engaging read and enhances an understanding of the various areas covered. Readers will be able to take a look at the spectacular coastal heritage features in a Geopark at Visakhapatnam, the captivating landscape of desert heritage in Jaisalmer, awesome meteorite crater heritage in Ramgarh, nostalgic mining and metallurgical heritage in Zawar, breath-taking volcanic features and landscape in a geopark at Pune - Ahmednagar, highly fascinating fossil heritage of Kutch and Renukaji geoparks to name a few of the geological treasures across India which this book showcases.

The monograph caters to academics, practitioners, and students in the fields of geology, geography, archaeology, culture, tourism, and also environmental and conservation science, who can learn more about the geopark movement and this emerging new discipline. It is anticipated that this book will act as a reference document and prompt the government and concerned authorities for hastening the decision to establish geoparks in our country, which will not only conserve valuable geoheritage resources for future generations but also create economic value for alleviating the poverty of local communities by encouraging geo-tourism.

As detailed in the introductory note, this publication is a beginning in this direction and there is a tremendous scope and need for several similar books as India has vast potential to establish many geoparks. It is a testimony to the belief and confidence of the people across India who seek to conserve our geological heritage in a responsible and holistic manner, - a manner which is supported by INTACH which has taken the initiative to bring this detailed and comprehensive publication into the public domain and to draw the attention of the Government of India and garner further support from scientific institutions and UNESCO.

**Maj.Gen. (Retd) L.K. GUPTA
CHAIRMAN, INTACH**

“POTENTIAL GEOPARKS OF INDIA” – A CURTAIN RAISER

Geoheritage refers to sites or areas of geologic features with significant scientific, educational, cultural, or aesthetic value. A geopark is a unified area that advances the protection and use of geological heritage in a sustainable way, and promotes the economic well-being of the people living there. There are global geoparks and national geoparks. UNESCO Global Geoparks are single, unified geographical areas where sites and landscapes of international geological significance are managed with a holistic concept of protection, education and sustainable development. A UNESCO Global Geopark uses its geological heritage, in connection with all other aspects of the area's natural and cultural heritage, to enhance awareness and understanding of the key issues facing the society in the context of the dynamic planet we all live on, mitigating the effects of climate change and reducing the impact of natural disasters.

The UNESCO Geoparks are not entirely the geological parks. Though a UNESCO Global Geopark must have geological heritage of international significance, the purpose of a UNESCO Global Geopark is to explore, develop and celebrate the links between the geological heritage and all other aspects of the area's natural, cultural and intangible heritages. It is about reconnecting human society at all levels to our planet and to highlight how our planet and its 4.6 billion-year long history has shaped every aspect of human lives and societies.

Community-led approach

The Geopark concept arose in the mid-1990s in European countries as a response to the need to conserve and enhance the value of areas of geological significance in the Earth history. Landscapes and geological formations are key documents of the evolution of our planet and determinants of our future sustainable development. From the outset, Geoparks adopted a “bottom-up” or community-led approach to ensure that an area's geological significance could be conserved and promoted for science, education and culture, in addition to being used as a sustainable economic asset through the development of responsible tourism.

Evolution of the Regional and the UNESCO Global Geoparks Networks

From the beginning of the development of the concept, networking has been one of the core principles of the Geoparks. Networking strongly contributes to the success of the Geoparks movement and plays a valuable role in facilitating the sharing of experience, quality management, formation of joint initiatives and projects and capacity-building. The European Geopark Network (EGN) was the first network in the world created in 2000 by four Geoparks. UNESCO's work with Geoparks began in 2001. In 2004, seventeen European and eight Chinese geoparks came together at the UNESCO headquarters in Paris to form the Global Geopark Network (GGN), where national geological heritage initiatives contribute to and benefit from their membership of a global network of exchange and cooperation. The Asia Pacific Geopark Network (APGN) was founded in 2007 based on the proposal at the 1st Asia Pacific Geoparks Symposium in Langkawi (Malaysia). The African Geoparks Network (AGN) was founded in 2009 in Abidjan by the African Association of Women in Geosciences (AAWG) during the 5th Conference of Women and

Geosciences for Peace. The scope of the organization is not limited to Africa strictly, but the Middle East is also associated with it. The official declaration of the foundation of the UNESCO Global Geoparks Network for the Latin America and the Caribbean (GeoLAC) was issued in 2017 May, during the "4th Latin American and Caribbean Symposium on Geoparks", by four founding members (Araripe, Grutas del Palacio, Comarca Minera and Mixteca Alta UNESCO Global Geoparks).

The UNESCO encourages the strengthening of the regional Geopark networks and the Global Geoparks Network (GGN) which represents, advances, and disseminates knowledge in Geodiversity management and other disciplines related to studies in Geo-conservation, Geo-tourism, Geo-education and/or the management and activities of Global Geoparks. UNESCO, inspired by the work of the Geopark networks, will continue to offer its support and assistance to such networks, will coordinate capacity-building for UNESCO Global Geoparks and will encourage the exchange of the best practices amongst the UNESCO Global Geoparks.

UNESCO Global Geoparks

During the 38th session of the UNESCO's General Conference in 2015, the 195 Member States ratified the creation of a new label, the UNESCO Global Geoparks. This expresses governmental recognition of the importance of managing outstanding geological sites and landscapes in a holistic manner, and also provides a new international status to a former network of sites of geological significance, preferably allowing the Organization to more closely reflect the societal challenges of Earth Science today. At present, there are 161 UNESCO Global Geoparks in 44 countries. China alone has 41 UNESCO Global Geoparks, followed by 15 in Spain, nine each in Italy and Japan, seven each in France and North Ireland, five each in Canada, Germany, Greece, Indonesia and Portugal, four in Republic of Korea, three each in Norway and Vietnam, two each in Austria, Croatia, Finland, Hungary, Iceland, Ireland and Mexico, and one each in Belgium, Brazil, Chile, Cyprus, Czechia, Denmark, Ecuador, Iran, Malaysia, Morocco, The Netherlands, Nicaragua, Peru, Poland, Romania, Tanzania, Thailand, Turkey and Uruguay. It is interesting to note that there are four transnational UNESCO Global Geoparks in Europe, *viz.*, Austria and Slovenia, Germany and Poland, Hungary and Slovakia, Ireland & U.K. and Northern Ireland. The UNESCO in close collaboration with the GGN supports Member States' efforts to establish UNESCO Global Geoparks, especially the developing countries without Geopark.

Geoparks in China

Until 1980s there were no serious efforts in China to conserve geoheritage resources from unsustainable resource utilization and other intensive anthropogenic activities. However, in the past two decades China has seen a rapid growth in interest and demand for geoheritage protection, and has embraced the international initiatives to develop the geopark concept. China set up 11 National Geoparks for the first time in the year 2000, under the guidance of the UNESCO Earth Science Division, and hence has become one of the pioneers in this aspect. During the period 2000–2011 a total of 27 Global Geoparks and 140 National Geoparks have been established in China, and 79 other parks have obtained the qualifications to become National Geoparks. At present there are 41 UNESCO Global Geoparks, More than 200 (219 as of October 2019) National-level and nearly 400 Provincial-level Geoparks in China. Chinese geoparks have been

divided into eight types, which covered different geological settings and landscapes. Researchers in regard to these geoparks have made great achievements in different areas including geoconservation, popularization, earth science education, socio-economic and cultural development. Receiving more than 500 million tourists each year, Geoparks in the country have become important basis of nature education. Each Chinese Geopark on an average is generating an annual income of 26 million USD

Geodiversity and Geoparks status in India

The geology of India is very diverse in terms of various parameters, including the ages of rocks, rock types, physiographic features, fossils, landforms *etc.*, having a great scientific value and aesthetic appeal. Different regions of India contain rocks belonging to different geologic periods, dating as far back as the Eoarchean Era (4600 mya – 3600 mya). Recently tiny zircons of 4.24 billion years old, older than the oldest rocks on earth, have been reported from granite rocks in Odisha. Stratigraphically India has a great range with divisions such as Archean System, Dharwar System, Cudappah System, Vindhyan System, Paleozoic, Mesozoic, Gondwana, Deccan Trap, Tertiary and Recent. The geological regions broadly follow the physical features, and may be grouped into three regions *viz.* the Himalayas and their associated chains of linear mountains, the vast Indo-Gangetic Plain, and the Peninsular Shield. There are a variety of awe-inspiring landforms including hills, mountains, plateaus, canyons, and valleys, as well as shoreline features such as beaches, bays, deltas and islands, *etc.*

Owing to such wide geodiversity, India has a huge potential of unique geosites of very high geoheritage value. Based on their geoscientific significance and aesthetic appeal, the Geological Survey of India (GSI) has declared 34 sites as National Geological Monuments / National Geoheritage Sites, which are broadly categorized under rare rock monuments, stratigraphic monuments, fossil parks, economic mineral deposit monuments, volcanic features and geological marvels. However, there are many more potential geosites that need to be declared as National Geoheritage Sites in India.

Besides many geosites of scientific significance and aesthetic value, India is also rich in archaeological and cultural sites of great importance and value. In spite of such important geological, archaeological and cultural heritage sites in India, so far not even a single geopark is formally established in the country. The fervent pleas of the geoscientific community have not been able to convince the government so far. There is not even a legislation to protect the geological sites like the archeological sites in India, which is a prerequisite for establishing the geopark. It is rather unfortunate that when 161 UNESCO Global Geoparks have been established in 44 countries since 2004, there are no serious efforts even now on the part of the Government to establish the Geoparks and promote geotourism in India.

Road map for geoconservation and establishment of Geoparks in India

In India central and state Governments and government organizations like Geological Survey of India (GSI), NGOs like Indian National Trust for Art and Cultural Heritage (INTACH), geoscientific associations and Universities can play a role in geoconservation and establishment and promotion of geoparks.

It is high time for the government to take initiative to establish the geoparks in the country by involving the Ministries of Mines, Earth Sciences, Science & Technology, Tourism, Culture, Archeology, *etc.*, and assigning the responsibility to one of these ministries to act as a nodal ministry, by constituting Indian Geoheritage and Geoparks Management Authority, and by legislation of the Indian Geoheritage Protection Act, by encouraging the state governments to establish and promote geoparks and by forming Indian Geoparks Network (IGN). Indian government can take initiative in forming the regional network of geoparks involving the neighbouring countries of the Indian subcontinent on the lines of other regional geopark networks like EGN, APGN *etc.* The State Governments can also take the lead in establishing the geoparks in their respective states, as there are number of attractive tourist places in each state. The governments need to incorporate the important geosites with nearby archeological and cultural tourist sites so that it forms an integrated tourism circuit and can be designated as a geopark and managed by State Geoparks Management Authority. Number of such geoparks in each state can be networked to form state geopark network which ultimately can be networked with India Geopark Network.

GSI being a premier national geoscientific organization should accord priority to protection of geoheritage and constitute a committee comprising representatives from other geoscientific organizations, associations, Universities, INTACH, *etc.* for selection of National Geoheritage sites; prepare status paper on permanently lost and critically endangered geoheritage sites for prioritizing the conservation measures; maintain declared geoheritage sites till some organization takes responsibility.

INTACH Geoheritage cell can take the responsibility to document Geoheritage sites and undertake geoconservation of sites till some organization takes responsibility; build data base that can help in drawing conservation plans and in developing geoparks; train tourist guides about Geoheritage sites to update their knowledge. Geoscientific organizations / University geology departments can identify geoheritage sites and popularize them in society; join with other organizations and take lead for protection of sites with the support from public and authorities. Universities should include courses on Geoheritage in geology curriculum. All those concerned should try to change the established misconception that Geological Resources are “Wasting Assets” as these resources can generate sustained income once they are converted into Geoparks.

Though there are some publications on the individual geosites and other aspects hither and thither, there is no single document in which all significant geological, archeological and cultural aspects are assessed and discussed to identify the potentiality of an area to be designated as a Geopark. In this back drop, a pertinent need is felt for preparing an authentic document in which potential geoparks are elucidated, which will act as a reference material for establishing the Geoparks in our country. Geoparks will have an impact on society as they focus on developing the interaction between conservation of the natural environment and socio-economic development as well as raising public awareness of environmental issues. The dynamism of this innovative movement is detailed in this Monograph, an exciting look into the potential geoparks across India and an open invitation to visit and support them.

As detailed above there is a great scope for establishing a number of geoparks in our country. Hence a beginning is made in this direction so that a number of such publications can be planned in future for facilitating the identification and establishment

of Geoparks. It is fondly hoped that this publication will act as a catalyst in well-informed decision making and establishment of Geoparks in our country.

I profusely thank Maj. General (Retd.) L.K. Gupta, Chairman, INTACH who readily accepted and encouraged the publication when the scope and implications to publish a Monograph on the “Potential Geoparks of India” were discussed. I gratefully acknowledge all the authors for their enthusiastic contributions in spite of severe traumatic conditions prevailing due to Covid -19 pandemic. I am very thankful to Dr. P.S. Ranawat, Dr. Om N. Bhargava and Dr. S.K. Wadhawan for meticulously reviewing the papers and valuable suggestions for publication of this Monograph. I thank Dr. T. Karuna Karudu and Mr. K. Sandeep Kumar for technical and computer assistance.

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THE KUTCH RIFT BASIN –POTENTIAL LOCATION FOR A NATIONAL GEOPARK OF INDIA

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INTRODUCTION

The Kutch Rift Basin (KRB), located at the north end of the Western Continental Margin of India, is spread over the entire district of Kachchh (Kutch), Gujarat. Kutch is the largest district of Gujarat in India, with an area of 45,612 sq. km (Biswas, 2016b). The district headquarters, Bhuj city, is located at the center of the district. The city is well connected with all towns and villages of the district with a network of well-maintained motorable roads. It's rich geological heritage qualifies the basin to be recognised as a National Geopark in India. The vast semi-desert landscape with scanty vegetation and first order topography exposes almost 90% of the unique geology of a marginal rift basin in a 3D-model. The complete structural outlay of the basin, with horsts and grabens/half-grabens is exposed, forming the rugged landscape which comprises highlands and intervening plain-lands across the entire basin area (Fig. 1). The highlands with the marginal hill ranges along the master-faults and gentle back-slopes of the tilted blocks expose entire basin-fill sediments ranging from the Middle Jurassic to Early Cretaceous, in extensive outcrops (Figs. 2 and 3) (Biswas 2016b). The hill ranges expose the sediment packages in fault bounded anticlines and domes in continuous outcrops along the tilted-up edges of the uplifts (Fig. 3). The sediment-filled intervening grabens/half-grabens are covered by Quaternary/Recent sediments forming vast mud and salt-flats (Rann) and grassland (Banni) (Fig. 2) (Biswas 2016b). These vast plainlands are unique scenic spots for tourists also. The basin which witnessed post-rift structural inversion followed by continuing transtensional/transpressional movements related to plate motion formed complicated structures in the bordering deformation zones along the master faults (Figs. 2 and 3). The deformation zones are well exposed for detailed studies in three dimensions along the well exposed marginal fault escarpments of the uplifts. Such active tectonic features are evident in the ongoing neotectonic cycle responsible for the first order topography in the present landscape of Kutch (Biswas 2016b).

Further, the basin is located within the distal margin of the Deccan Volcanic Province (DVP). Hence, the Deccan Trap flows are seen covering the Mesozoic sediments in the southern coastal plain as the boundary between the syn-rift Mesozoic and post-rift marginal sag basin-fill Tertiary (Palaeocene to Pliocene) sediments (Figs. 2 and 3) (Biswas 2016b). The Tertiary belt is well exposed in the southern coastal part of the basin bordering the Gulf of Kutch. The scanty rainfall and network of roads provide favorable logistics for approaching all the proposed geosites and detailed studies (Fig. 4). This adds to the geopark potential of the basin.

As such, the entire Kutch District is highly qualified to be identified as the premier National Geopark of the country. We have tried to illustrate this in the following



Fig. 1. (A) Photograph showing typical landscape of the Kutch Basin. Highlands with intervening lowlands. Figure presents typical fault-controlled rift-topography: Plain-land over down-faulted block abutting against fault-escarpment face of the highland (uplifted block). Location: View of Great Rann of Kachchh against Khadir escarpment in IBU. (B) View of Great Rann abutting against Kutch Mainland Uplift. View from Mainland. (C) Typical landscape view of Kutch highlands: Rugged, rocky terrain exposing continuous geo-outcrop. Interior view of Kutch Mainland Uplift.

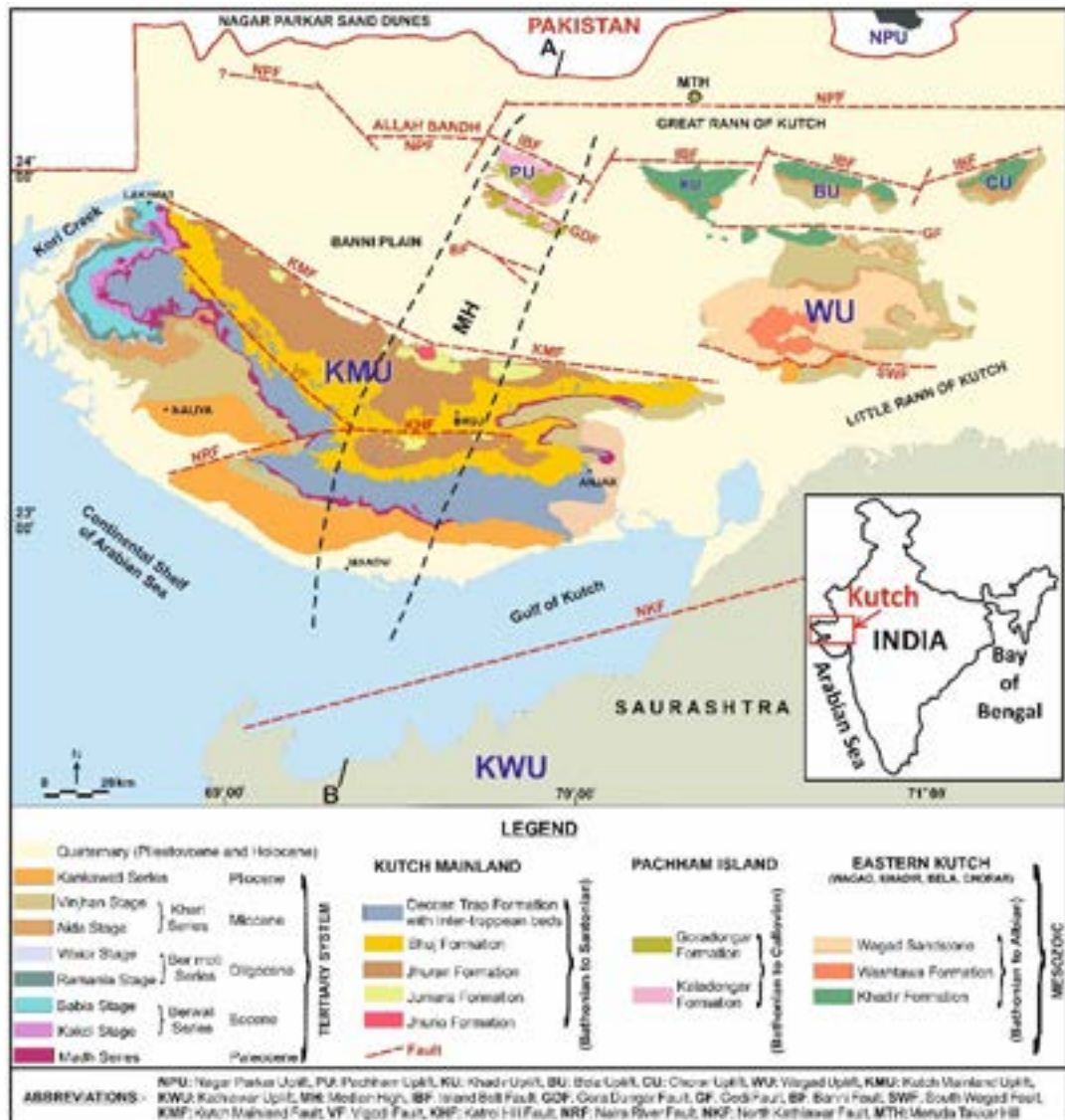


Fig. 2. Geological Map of Kutch (Biswas 2016 a).

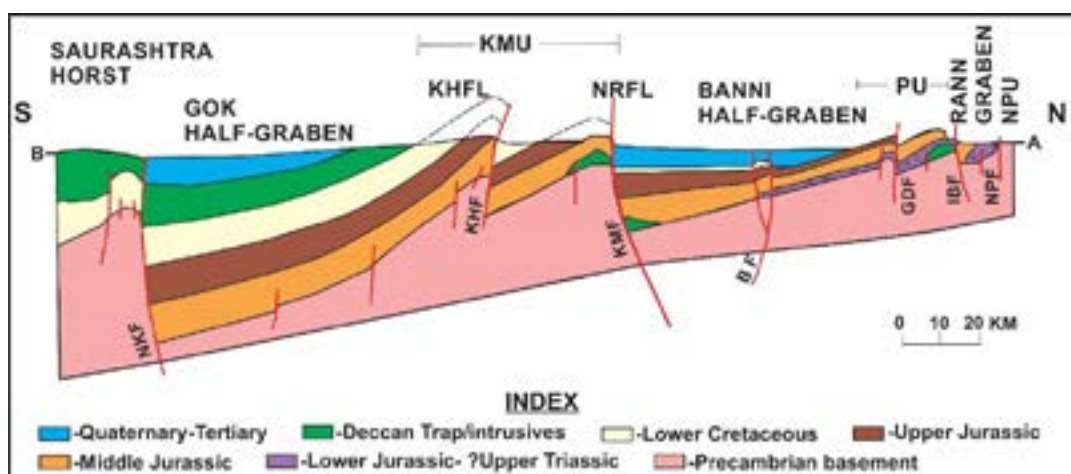


Fig. 3. Geological section across central Kutch Rift along line A-B shown in Fig. 2 (after Biswas, 2005). Note that all uplifts along marginal faults form Highlands and grabens/half-grabens between them form extensive Plain-land in the typical Kutch landscape (Fig. 1).

pages and discussed the rich geoheritage of the basin in this context. We describe here the geopark potential of the Kutch Basin along with the challenges and threats to the preservation of the unique geological features of the basin. A geopark plan has been prepared. In this paper, we briefly describe the proposed 70 geosites grouped under 9 geostations (Table 1). These geologically significant unique sites are discussed with necessary details as also the possible plan of conserving these sites. The important aspects of sustainable economic development through geopark establishment in Kutch District are also discussed.

The District of Kutch is already a famous tourist spot in Western India. Every year number of tourists come for pilgrimage to the famous Matanomadh, Narayan Sarovar, and Koteswar temples and also to visit scenic spots like desert beaches, mud and salt-flats of the Great and Little Rann of Kutch and archaeological sites including geo-architectural ruins like the Harappan site at Dholavira. Further, tourists are also attracted by the rich bird population and rare wildlife like Wild Ass and the Great Indian Bustard, which are on the verge of extinction. The Kharai swimming camels of Kutch (Fig.9H) is a special variety of camels found in Kutch. They can swim over a couple of kilometres in sea water. Not only are these camels capable of swimming, but they are also able to survive in saltwater.

Geotourism will soon be added to this popular tourism industry with the recognition of the Kutch Geopark. The district headquarter, Bhuj, is centrally located with very good road connections (Fig. 4). Bhuj is also well connected with the rest of India by roadways, railways, and airways. The city has an archeological monument at the city center and a geological museum located in the Department of Earth & Environmental Science of the local University (KSKV Kachchh University, Bhuj). The museum has over 4000 geological specimens (Rocks, minerals, and fossils) from the Kutch basin and other parts of India and abroad.

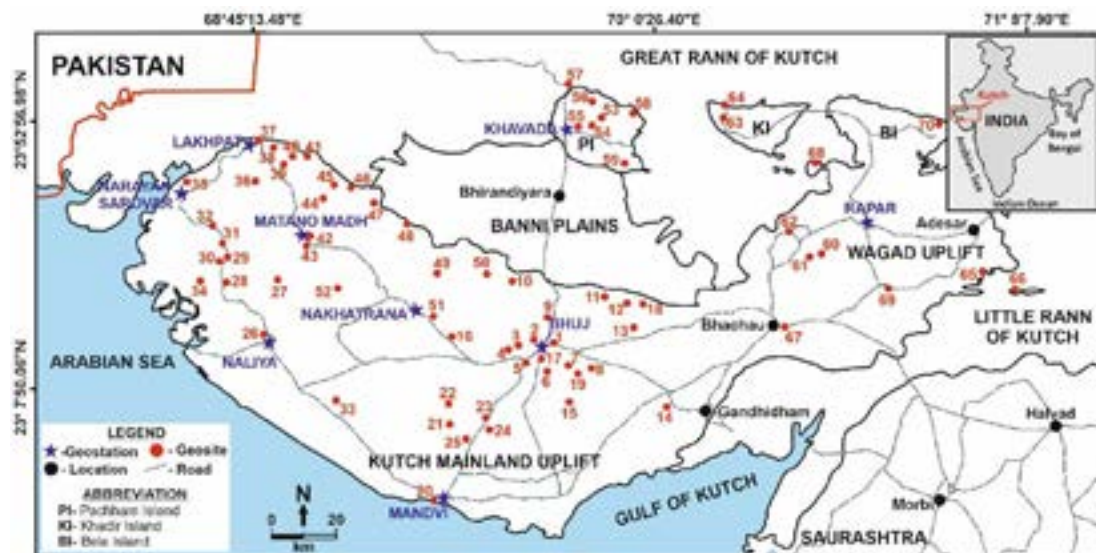


Fig. 4. Map of Kutch Showing locations of selected geostations, geosites, and road connections (mentioned in Table 1).

KUTCH GEOPARK

As discussed above, the Kutch Basin is a well exposed natural model for the study of the geology of a marginal rift basin in all aspects: syn-rift/post-rift sedimentation and

stratigraphy, structure/tectonics, and geomorphology/morphotectonics. About 23,310 sq. km of mud- and salt-flats devoid of vegetation are novel areas for Quaternary studies (Figs. 1A, 1B and 2).

In the present study, we have chosen 70 geologically significant geosites (single or multiple sections/plan views, see Fig. 4) across the basin grouped under 9 geostations (Table 1). Almost continuous rock outcrop spreads over the entire district as Highlands with gaps in the intervening plain-lands of the Rann and Banni (Fig. 1A). The geosites are grouped under 9 selected geostations for the ease of maintenance, administration and monitoring of field-visits/geo-tours. Continuous outcrop facilitates tracing geological features from one geosite to another. We have discussed below the geological significance and details of each geosite grouped under each geostation.

1. Bhuj Geostation and “Geopark Headquarter”

Bhuj, the capital city of the district, is a small historical town situated in the middle of the district (Fig. 4). The Bhuj city has a bus, train as well as air connection. Road connections with the rest of Gujarat, allow favorable logistics for industrial and tourism development. Bhuj city has good hotels/guesthouses, *dharamshalas*, and restaurant facilities. All the 70 proposed geosites are well connected with this city by metal and/or non-metal roads. The entire geology of the Kutch Mainland Uplift (KMU) which is the biggest horst in the rift complex can be studied in detail from this center. As such, Bhuj city has been designated as the Geopark Headquarter as well as a geostation.

The Bhuj geostation includes nineteen geosites (Table 1). All the geosites are located within a 40 km radius from the city (Fig. 4). These geosites expose varieties of significant geological features like geomorphological, stratigraphical, sedimentological, paleontological, structure, tectonic, volcanic activities, and Quaternary geology (Fig. 5) (Table 1). All the geosites are easily approachable by two-wheeler, bus, car, and even by auto rickshaws.

The Bhujia Hill Fort (Fig. 5A), a prominent landmark and tourist attraction, east of Bhuj city, is a 3D model of a ring-dyke intruded into the Lower Cretaceous Bhuj sandstones. The Tapkeshwari hill section exposes classical geomorphic features related to climatic and tectonic processes. These features are wind caves, knick points, fault scarps, triangular facets, eroded anticlines, *etc.* The Tapkeshwari, Jadura, and Kodki fault (Fig. 5B) sections present structural sections with dykes along faults besides sandstones with varieties of sedimentary structures. The Gangeshwar and Fakirwari domes (Fig. 5G) along Katrol Hill Fault (KHF) near Bhuj and Habo Dome (Fig. 5F) and Kas Hill sections (Fig. 5E) near Lodai village expose fossiliferous Jurassic strata and structural complex related to strike-slip faulting along the primary rift faults (Fürsich *et al.* 2013, 2020; Biswas 2016a, b) (Fig. 5G). From the Kas Hill section, an almost complete skeleton of a marine reptile, Ichthyosaur, was collected for the first time (Prasad *et al.* 2017). In the core area of the Habo Dome, a plutonic body, laccolith, is well exposed along a river section (Fig. 5F). One can see the intrusion of sills and dykes from the laccolithic source in one section.

The Quaternary geological history can be studied from young tectonic features like the Khari Gorge (Fig. 5C), and the valley-fill Quaternary sequences of Gangeshwar Dome. Columnar Joints are commonly seen in volcanic rocks (Deccan Trap basalts here) but in Kutch, they are also seen in the sedimentary rocks of the Bhuj sandstones

near the Kodki Mahadev temple (Thakkar 2017). The Khatrod hill-Ashapura dongar section presents thick Late Jurassic deposits and almost all the components of active fault scarp *i.e.*, free face, triangular facets, colluvial fan, alluvial fan, *etc.* (Chauhan *et al.* 2016). The Vidi railway cut section near Anjar exposes Intra-trappean limestone beds (Biswas 1993) with dinosaur fossil parts. This section is internationally famous for exposing the K-T boundary in India (Fig. 5D) and is also considered as one of the best sections in western India to understand mass extinction across the K-T boundary. The china clay belt of Nadapa exposes the potential of economic geology in Kutch Mainland Uplift (KMU). The quarry section of mines exposes beautiful sedimentary sequences with large scale sedimentary structures of the Early Cretaceous sandstone and shale beds.

Apart from the geological features, a geotourist gets the opportunity to visit several tourist and historical places in and around Bhuj town, *viz.*, Ancient Sun Temple-Kotay (Fig. 9B). Swaminarayan temple- Bhuj, Prag Mahel- Bhuj, Aiana Mahel- Bhuj, Historical Museum- Bhuj, Chatardi Lake Palace- Bhuj, Vande Mataram Memorial-Bhujodi, Rakshak Van- Rudramata, Bhuj handicraft market, Anjar handicraft market, Bhujodi handicraft market, *etc.*

2. Mandvi Geostation

Mandvi is a historical port town located at the southern coast of the Kutch Peninsula (Fig. 4). The Mandvi town has good road and sea route connections with other cities of the Kutch district (Fig. 4). The small town has hotels, guesthouses, and restaurants. The Mandvi geostation includes six geosites (Table 1). These geosites are located within a 40 km radius (Fig. 4). All the geosites are easily approachable by two-wheelers and cars. These geosites display important geological features including economic minerals, Deccan Trap volcanic flows, and coastal geomorphology.

While driving south to Mandvi from Bhuj, one passes through 3 geosites (Fig. 4). At Dahisara geosite, 25 Km from Bhuj, the road section exposes a 3D model of a ‘delta lobe’ of the Bhuj Formation with its typical geometry and all its sedimentological and structural characteristics (Fig. 6A). ‘Delta lobes’ are nearshore sub-sea sediment deposits dumped by the rivers flowing into the sea carrying loads of sediment from onshore. About a kilometer ahead on the same road, the erosional contact between Deccan Trap-Bhuj Formation is laterally well exposed in an E-W cliff section across the road (Biswas 1993). Further ahead near Dhunai village, roadside quarries expose Deccan Trap flows, alternating columnar (Fig. 6B) and amygdaloidal basalt flows (Biswas 1993). Quartz geoids are very common in the latter flows. Quarry sections of basalt provide excellent outcrops for detailed study of the Deccan volcanism and associated igneous bodies. The geotourists can have insights into economic minerals like bentonite, bauxite, gypsum, laterite, *etc.*, in Asambia Nana geosite on the road section before reaching Mandvi Port. The Mandvi and Layja beaches, the popular tourist spots, present coastal geomorphological features *viz.*, coastal dunes (Fig. 6C), barchan dunes, beaches, estuaries, coastal cliffs, mangroves, neo-ichnology, sea-level changes, *etc.*

Apart from the geological features, a geotourist gets the opportunity to visit several tourist and historical places in and around Mandvi town, *viz.*, Vijay Vilas Palace, Shyamji Krishna Varma Memorial, Mandvi beach, shipbuilding yards, Mandvi

handicraft market, Godhara temple, Layza Beach as also the big Jinayal Jain temple at the nearby Koday village, *etc.*

3. Naliya Geostation

Naliya township located in south-western Kutch is the gateway to the well-known Tertiary province of Kutch (Biswas 1993). The Naliya town is well connected with Bhuj and the rest of Gujarat (Fig. 4). It also has an air-strip for air connection, presently under the control of the Indian Air Force. The town has hotels, guest houses, and restaurants. The Naliya geostation includes nine geosites located within a 50 km radius (Table 1) (Fig. 4). All the geosites are easily approachable by two-wheelers and cars along with a network of good roads on both sides of the Naliya-Lakhpat main road. These geosites have exposed almost continuous stratigraphic sections of the Tertiary formations along stream sections and road cuttings (Figs. 6 D, E, F, G) (Biswas 1993). Naliya-Lakhpat road traverse presents a complete succession of the Tertiary stratigraphy of Kutch from the Supra-Trappean Paleocene deposit at the base (on top of the Late Cretaceous Deccan Trap) to the Pliocene/Recent on the top. The Oligo-Miocene section of Kutch exposed in the river section of Waior geosite (Fig. 6G; Fig. 7A) is the only remaining reference section of the Campanian-Aquitania stages in the world. The Tertiary section is the on-shore extension of the stratigraphy of the oil-rich Western off-shore Basin. As such, the outcrops in Kutch provide an opportunity to physically study the petro-physical properties of the off-shore reservoir rocks (Shekhar *et al.* 2019). The biostratigraphy of some sections from this area has the potential to be recognized as Global Boundary Stratotype Sections. The Tertiary sections have global recognition and attract researchers from foreign countries.

The Naliya geostation area also has economically important mineral deposits such as gypsum, laterite, and limestone. Extensive limestone deposit has attracted several major cement factories in the country endangering the preservation of these internationally famous fossil-rich deposits for scientific research. All stratotype sections of Tertiary formations are located under six geosites: Paleocene-Eocene in Naredi geosite, Eocene in Harudi Cliff geosite, Oligocene in Maniyara Fort geosite, Oligo-Miocene in Waior geosite and Miocene in Khari Nadi geosite, Pliocene is partially exposed in Naliya River section.

Apart from the geological features, a geotourist gets the opportunity to visit several tourist and historical places in and around Naliya town, *viz.*, Jakhau Fish Port, Pingleshwar Beach, Chachhi Beach, *etc.*

4. Narayan Sarovar Geostation

Narayan Sarovar is a small pilgrim village located at the western tip of the Kutch Peninsula (Fig. 4). The village town is a well-known and important Hindu pilgrim spot. The town is well connected with Bhuj and other towns of Kutch (Fig. 4). The town has a Dharamshala and small restaurants. The Narayan Sarovar geostation includes two geosites (Table 1). These geosites are located within a 40 km radius. Both the geosites are easily approachable by road (Fig. 4). Geosite 1 presents excellent geomorphological features like stabilized sand dunes, mudflats, and mangrove fields. Geosite 2 is a Lignite mine (Fig. 7C) near Panandhro village which is one of the largest open cast mines in Gujarat state. The mine is now in a closing stage. The mine sections include the classical sections of the Palaeocene-Eocene

sediments (Biswas 1993). The Babia Hill section above the mine is an excellent outcrop of the Eocene-Oligocene limestone topped by the Oligocene coral reef (Fig. 7A, B).

Apart from geosites, Narayan Sarovar Lake and temple, Koteswar Mahadev temple (Fig. 9D), and view of the Arabian Sea from the Koteswar are tourist attraction points.

5. Lakhpat Geostation

Lakhpat is a small village with ruins of an ancient fort (Fig. 9A), located at the north-western corner of the Kutch Mainland overlooking the Arabian Sea (Fig. 4). It is an important tourist spot of historical importance. The basement of the fort and the village is the highly fossiliferous nummulitic limestone (Eocene Fulra Limestone). It has a good road connection with Bhuj. It has an old temple, a *Gurudwara*, and a *Dargah*, a small state guest house as also a small tea shop with an eating facility. Historically, the Lakhpat Fort used to be a big trading center between Gujarat and Sindh. The fort was constructed with the cement of local limestone in ancient times. Hence, most part of the fort is ruined except the boundary wall and the gate. The fort is located exactly on the faulted geomorphic contact of the Eocene limestone and the salt flat of the Great Rann of Kutch (Biswas 1993). The Lakhpat geostation includes five geosites (Table 1). These geosites are located within a 25 km radius (Fig. 4). All the geosites are easily approachable by vehicles. There is a regular bus service between Bhuj and Lakhpat. The geotourists can have a good overview of the Upper Mesozoic to Tertiary stratigraphic sequence, its sedimentological, and paleontological characteristics as well as the structure at the Ghuneri geosite. The Kutch Mainland Fault (KMF) between the Kutch Mainland Horst exposing the Mesozoic strata and Banni Half-graben exposing the Tertiary strata is well exposed in Ghuneri Dome (Fig. 7D) (Biswas 1993, 2016b). All geosites present excellent outcrop showing details of structural and tectono-geomorphic features.

Apart from geosites of Lakhpat geostation, a tourist may also visit various historical and tourist places, viz., Lakhpat Fort (Fig. 9A), Lakhpat Gurudwara, Lakhpat Dargah, Great Rann of Kutch, Ghuneri caves, Katesar Budhhist caves, and temples.

6. Matanomadh Geostation

Matanomadh is a famous place of Hindu pilgrimage in Gujarat. It has good road connections with the rest of Gujarat State (Fig. 4). The small fast developing township has good hotels, *dharamshalas*, guest houses, and restaurants. The town is located on top of the Deccan Trap amid the supra-trappean volcano-clastic deposits of the Paleocene Matanomadh Formation, well exposed around the town. The place is surrounded by residual hills of Bhuj sandstone capped by the Deccan Trap basalts (Biswas 1993). The Matanomadh geostation includes six geosites (Table 1). These geosites are located within a 50 km radius. All the geosites are easily approachable by vehicle.

The mineral Jarosite found in Mars is present in the supra-trappean volcano-clastic rocks of Matanomadh Formation. This attracted the attention of ISRO scientists to this area. Therefore, this geostation is also an important site for planetary science.

The geosite, the Matanomadh cliff section, along the left bank of the Matanomadh River, below the local helipad station (Fig. 7E), is an excellent geo-section. A condensed Eocene to Miocene sequence showing lateral facies changes is exposed in this cliff section (Biswas 1993). In this section, one can see white open marine coralline Oligocene limestone changing into black kerogen rich shale in a continuous strike section. The gradual change of open marine environment into black lagoonal shale can be visually traced. This is a valuable evidence for the presence of petroleum in the basin.

Other geosites are famous for researches on stratigraphy and paleontology as the Jurassic sequences are highly rich in fossils. Hundreds of varieties of invertebrate and ichnofossils are present as also plant fossils in local beds. The geosites: the Jara Dome, Jumara Dome, Ukra Hill strato-type sections are world-famous for fossil rich Jurassic stratigraphy which have been attracting researchers on palaeontology and stratigraphy from all over the world since the eighteenth century till date (Biswas 1993, 2016a; Fürsich *et al.* 2013, 2020). Kutch is famous for ammonites, most of which were collected from these geosites. The structural style and geomorphic features of these geosites are also unique which could be used as 3D models for teaching (Fig. 7E, F). The Manzal (Nara) Dome section near Nara village is like a textbook figure of a laccolith at the core of a domal structure (Biswas 1993, 2016a).

Apart from the geosites, the Matanomadh temple (Fig. 9C), Jara-Mara war memorial, Kamleshwar Mahadev temple with Kalp-Vruksh, and the hill stations near Matanomadh are tourist attraction points.

7. Nakhatrana Geostation

Nakhtrana is a small town located on the Bhuj-Lakhpatri highway (Fig. 4). It is well connected with the rest of Gujarat via Bhuj. Hotels, guesthouses, and restaurant facilities are also available. The Nakhatrana geostations include five geosites (Table 1). These geosites are located within a 40 km radius around the geostation and are easily approachable by vehicles through a network of well-built roads (Fig. 4). These sites preserve classical geological features related to the Jurassic-Cretaceous stratigraphy/paleontology and sedimentology, and the Deccan Trap volcanic and syn-rift plutonic activities.

The Keera dome is one of the famous domes in Kutch located in the northern deformation zone of Kutch Mainland Uplift. The availability of sumptuous fossiliferous beds of Middle to Late Jurassic formation in and around Keera dome is portrayed as nature's museum for fossils (Biswas 1993). The dome is also dissected by several radial faults (Biswas 1993). The Keera plutonic plug of basic rock, located on the faulted northern part of the dome, provides a better understanding of the syn-tectonic plutonic activity that occurred during the Late Jurassic-Cretaceous period. The xenoliths present in the Keera plug rocks indicate intrusion of the mantle derived magma from the deeper crust.

The Dhinodar Hill, a prominent landmark in Kutch panorama is an extinct volcano displaying a typical central crater with a steep flank. This and similar other extinct volcanoes in the neighborhood prove the volcanic origin of the Deccan Trap flows and no fissure eruptions as believed by earlier workers.

The Nirona canyon, a fault-controlled river segment located northeast of Nakhatrana geostation, exposes black shale and sandstone sequences of the Late Jurassic period indicating prospects of hydrocarbon in the basin. The Nirona canyon (Fig. 7G) looks like a tiny replica of the Grand canyon, Colorado. This canyon section is one example among many such river sections, particularly in the Tertiary limestone area of southern Kutch. These canyon cuts are evidence of the active neotectonic movements in the present tectonic cycle.

Apart from geosites of the Nakhatrana geostation, the Mota Jakh temple, ancient Punereshwar Shiv temple, the Roha-Kotda fort, the Vithon-Khetla-Bapa temple, the Dhinodhar temple, the Kutch Fossil park, the Than Jaagir historical site and the Chhari Dhandh lake are some of the tourist attraction spots.

8. Khavda Geostation

Khavda is a big village located in Pachham (palaeo-) Island (Fig. 4), the westernmost and the biggest block of the 'Island-belt Uplift (IBU)' (Fig. 2). It has good road connections with the rest of Gujarat via Bhuj (Fig. 4). It also has small hotels, resorts, homestays, restaurants, and *Dharamshala* facilities.

Khavda geostation includes seven geosites (Table 1). These geosites are located within a 40 km radius around the station. All the geosites are easily approachable by vehicles. The geological features of the Pachham Island uplift related to the Middle Jurassic stratigraphy, sedimentology, paleontology, the Miocene deposits, and the Quaternary Geology as also the Structure/Tectonics and geomorphologic evolution of Island Belt Uplift, can be studied in great details in this hilly region of the continuous outcrop.

The Raimalro hill section near the western margin of the uplift is topped by a cherty, dolomitic limestone bed which is a characteristic marker-defined unit in the Middle Jurassic stratigraphy of the Island Belt uplift. The Simri Nala sections expose the folded Raimalro Limestone with well-defined ichnofossils. The fold is a symmetrical anticline with a normal faulted limb (Fig. 7H) (Thakkar 2017). Bandi River section has exposed the Quaternary fluvial deposit underlain by the Miocene lateritic beds. Paiya dome near the Paiya village represents a classic example of an un-eroded, fully exposed small dome. The Kaladongar hill range is an excellent example of a faulted and eroded, marginal flexure over the Island Belt (rift) Fault. One can see an excellent aerial view of the tectono-geomorphic features like receding fault-line escarpment, triangular facets, and colluvial fans from the Babia Peak on top of the Kaladongar hill (Biswas 1993, 2016a). The adjacent Kuar bet section after crossing the "India Bridge", exposes the oldest Early Middle Jurassic strata of the syn-rift deposit. Several dinosaur fossils were collected from this section.

The Nir-Wandh section is a classic example of a big igneous complex where one can study a variety of plutons resulted from multiple phases of syn-tectonic igneous activities. The mantle derived xenoliths in the basic/ultra-basic rocks of the plutons confirm the deep crustal source of the magma.

Apart from geosites, the Dattatreya temple on the top of the Kaladongar hill, the highest point in Kutch, the Dhordo white Rann (Salt-Flat), the India Bridge, the

Dharamshala War Memorial, the Bhediya Bet Hanuman temple, the Vighokot Fort, and the Bhirandiyara handicraft market (Fig. 9F, 9G) are important tourist attraction points.

9. Rapar Geostation

Rapar is a small town located in northern Wagad in Eastern Kutch (Fig. 4). It has good road connections with the rest of Gujarat (Fig. 4). Small hotels, homestay facility, *dharamshala* and restaurant facilities are available.

The Rapar geostation includes eleven geosites (Table 1). These geosites are located within a 120 km radius around the station. All the geosites are easily approachable through a network of good roads. Sections near the Dholavira and the Hadibhadang escarpment of the Khadir Island Uplift (Figs. 1A and 8C), the Kanthkot Hill, the Bharodia, and the Gangta Bet sections of the Wagad Uplift (WU), are excellent outcrops for the study of the older part of Kutch stratigraphic sequence, *i.e.*, early Middle Jurassic to Late Jurassic sequence (Fürsich *et al.* 2013, 2020). Several fossiliferous marker beds are exposed in the road and river sections near Bharodia and Kanthkot. The Ammonite bed exposed in the Trama River bed is a good example (Fig. 8A, 8B) to understand the sedimentological, paleontological, and geological history of this sequence.

The Hadibhadang fault-escarpment along Island Belt Fault (IBF), *i.e.* the northern margin of the Khadir Island exposes the oldest sequence of the Kutch stratigraphy above the Precambrian granitic basement. The basal conglomerate with granite and gneiss boulders is best exposed in the Cheriya bet at the foot of the escarpment in the middle. The only basement outcrop in the basin is exposed in the Meruda Hill in the middle of the Rann mudflat, 28 km north of the Cheriya bet. The large wood fossils of Kanthkot and Dholavira (Fig. 8C), dinosaur fossil fragments, ammonites, lamellibranchs, gastropods, belemnite, and a variety of other invertebrate and ichnofossils are the geological treasure of this region. The outcrops of the South Wagad Fault, the Gedi Fault, and the Island Belt Fault expose various structural and neotectonic features displaying the fault dynamics.

The Mardakh Bet in the Little Rann of Kutch is a weathered Deccan Trap section that yielded colourful agate pebbles strewn over the bet (islet) surface (Fig. 8F) (Biswas 1993). This adds to the commercial value of the basin. Varieties of the Miocene vertebrate fossils *viz.*, rhinoceros, sharks, elephant, snakes, giraffe, crocodile, *etc.*, are seen in the Palasawa section (Kapur *et al.* 2019). The Bhachau section along the Mehsana-Bhuj national highway exposes large scale sedimentary structures of fluvio-deltaic sandstones of the Early Cretaceous Bhuj Formation (Fig. 8E). The Dholavira archaeological site is the biggest Indus valley Harappan archaeological site in India (Fig. 8D). This site provides the opportunity to study geo-archaeology and past life, culture, and natural events.

Apart from geosites, the Dholavira archaeological museum, the Dholavira wood Fossil Park, Hadibhadang hill station, the Gangtabet temple, the Ekal Rann, the

Vrajvani temple, the Flamingo City, the Bhanjada Hill, the White Rann near Amrapar, Mogal Dham, Momaimora temple, *etc.*, are important tourist attraction points.

HISTORICAL AND CULTURAL VALUES OF KUTCH

Kutch Region is a very ancient place since the beginning of the civilization as indicated by Harappan archeological sites. Kutch is an entity of novel, individualistic culture, history, art, environment, and geology. Since pre-historic times, Kutch is famous across the borders, be it far destinations of Indus civilization or its reference in the literature of Chinese traveller Huen-Tsang traveling to Buddhist caves of Katesar or mention by Alexander the Great. In seventeen and eighteenth centuries, this was also one of the most well-mapped and studied land especially by Sir Alexander Brunes, a Scottish explorer, and diplomat, who gave a detailed political account of the Kutch court in 1826.

Kutch is located at a critical position between three ancient provinces like Sind on the West, Gujarat on the South and East, and Rajasthan on the North. Initially, it was a part of the Sindh state ruled by the Sindhi rulers. Later, Rajasthani royalty occupied the region creating the kingdom of Kutch that continued as the state of Kutch ruled by Rajput kings through the British era. As such, there is a clear mix up of the culture of the three adjoining states which is very much evident among the aboriginal population of Kutch known as Kachchhis. The cultural mix up is mainly between the migrant Sindhi and Gujarati populations. The mixed population culture of Kachchhis is clearly evident in the language and lifestyle. Sindhi influence is more towards the west while eastward Kachchhi culture and mixed language merge with the Gujarati population. The Sindhi heritage distinguishes the Kachchhis from the Gujaratis. Rajasthani influence is seen in professional creativity in handicrafts. Like in Rajasthan, Kutch is also famous for its style in textile, pottery, and jewelry handicrafts. Major tribal handicraft markets are Khavda, Bhujodi, and Bhirandiyara.

The population also consists of nomadic and semi-nomadic tribes. The spoken language is *Kachchhi*, a dialect of the Sindhi Language. However, there are minor variations in the *Kachchhi* dialect depending on the area its origin. The staple food of people, mainly dominated by nomadic tribes includes *Bajra* and *Chhas* (buttermilk). More recently, *Dabeli* has becoming famous as popular snacks. Apart from Food, Kutch attracts many tourists across the globe for its annual *Rann Utsav*, a tourist attraction in the Great Rann of Kutch, referred to as “White Rann” near Dhordo, Ekal, and Amrapar. The Rann Utsav displays a rich Kachchhi tradition of music and dance. Several religious fairs are also held across the year which include Jakh Bhotera fair, fairs of Haji Pir, and Mekan Dada. Matanomadh is the most important religious place in Kutch which attracts millions of people during its annual Navaratri festival.

Tourist attractions include archeological sites of Dholavira, Surkotda, *etc.* Historic sites include palaces and historic buildings in Bhuj and Mandvi cities, the ancient battlefield of Jara Mara, and the ancient port city of Lakhpatri.

The tribal people have a typical architectural style of building village huts for protection against natural hazards. The typical round, circular mud huts, covered by dry grass roofs are called *Bhungas* (Fig. 9E). The *Bhungas* are round, cylindrical huts

(Fig. 9E) built to face local climatic, environmental, and geological hazards. These typically styled tribal huts are the identity of Kutch's rural region and are the museums that showcase the lifestyle of Kachchhi people and their rural talent. The *Bhungas* are mostly found in semi-desert areas of the Banni plain-land and rugged hilly areas of Pachham in the northwestern part of Kutch. These traditional *Bhungas* are built with superior architectural knowledge, gained over centuries of living experience. The *Bhungas* are considered engineering wonders as they preserve the internal environment of the house which keeps the home cool in summers and warm in winters. With light super-structure on a hard rocky basement, *Bhungas* are specially designed to withstand frequent earthquakes.

Kutch has many religious and ethnic groups. The majority of the inhabitants are Hindus and Muslims, but the Jains and numerous other communities are also there. However, Hindus and Muslims are the two major groups. The religious culture of Kutch is unique and is rarely seen. There is homogeneity in the coexistence of the religious groups, particularly Hindus and Muslims. There is hardly ever any report of conflict between the two populations. On the contrary, participation in each other's religious functions is unique. There are important places of pilgrimage of both religions in Kutch like Hindu pilgrimages at Matanomadh temple (Fig.9C), Narayan Sarovar lake and Koteswar Mahadev temple, and famous Muslim pilgrimage at Hajipir Dargah. The important religious places and tourist spots have also been mentioned above under various geostations.

THREATS TO THE GEOSITES OF KUTCH

As discussed above, the Geological features of the Kutch basin have both national and international significance of high geo-scientific value which make the basin eligible to be selected as an ideal Geopark in India. Thus, the proposed 70 geosites under 9 geostations must be preserved for the future generation of geologists and geotourists and protected from natural and human destruction. These geological features are the result of long geological processes and once destroyed cannot be created again.

In India, the biggest threat to geoheritage sites is mining and Industrial development. Due to ignorance and lack of awareness about the scientific and aesthetic values of geosites, there is no law or regulation for protecting geoheritage sites from random mining, construction, and other developmental works. Such works under Government contracts continue with total disregard to precious geological heritage – a gift of Nature to the Nation. Unfortunately, many sites of the highly significant geological heritage of Kutch will soon cease to exist since major parts of the region have already been leased out for mining limestone, laterite, and bentonite deposits for cement and porcelain industries. There is an immediate and urgent need for declaring Kutch as a restricted area since its geo-resources are under grave threat with increasing mining activities, as industrial development activities are gaining pace. It has already lost a unique geological feature - an Early Eocene, fossil rich lagoonal deposit with varieties of fauna, in the Panandhro region of the Western Kutch, due to random mining for lignite. The region was a 3D-model of a sediment-filled lagoon with a treasure house of rare fossils. It had been a classic example for the students of geology for studying the depositional environment and paleoecology of lagoons. A potential area for research is thus lost. Presently, the entire limestone areas stretching from Lakhpat to Naliya has been leased out for mining for cement. These Paleogene limestone packed

with varieties of fossil forms (recording the life that existed in 20 to 50 million years ago) are a very precious treasure for the geologists and are often visited by geologists from abroad for research work. Unless the mining activities are controlled and regulated, nothing will remain of this precious gift of nature, a few years from now. Thirty million years of earth's history will be lost forever. Further, while undertaking development activities such as construction of roads, bridges, dams, and other engineering structures, it should be ensured that the geologically important sites are not destroyed.

CONSERVATIONS OF GEOSITES AND DEVELOPMENT OF GEOTOURISM IN KUTCH

Kutch as a National Geopark is a geological wonder, a proud heritage of nature. Its unique stratigraphy, structure, geomorphology, and a wide variety of fossils, both invertebrate and vertebrate, including fossil dinosaurs, plant fossils, and micro-fossils, attract geologists from all over the world. It is a potential location for the newly evolving geotourism industry. This does not mean, however, that activities for industrial development should be stopped or retarded. Conservation only means protection of important and significant rock sections by controlled and regulated mining. As in other countries, mining regulations should have the mandatory provisions to prevent the total excavation of a leased area as happened in the coastal area of Tiruchirappalli, where all the precious limestone representing 150 to 65 million years of earth's history were entirely excavated. It should be mandatory for all the mining companies to leave portions of the rock formations of specified size as sample sections for study. These sections will be like monuments representing parts of the geological history and nature's original creation.

EMPLOYMENT OPPORTUNITY AND ECONOMIC DEVELOPMENT THROUGH GEOPARK ESTABLISHMENT AND GEOTOURISM DEVELOPMENT IN THE DISTRICT OF KACHCHH (KUTCH)

Geotourism activities may have the potential to raise the profile of the Earth sciences, including helping activities, funding research, and employment opportunities (Kelley *et al.* 2019). Geoparks can play a significant role in the economic development of local or rural areas through geotourism. Like a tourist place, museum, wildlife park, and forest, revenue can also be generated from the geopark.

The geopark can be designed in such a way that not only geologists, but common people also get attracted to geology by viewing an interesting stratal pattern, rock colour, structure and get interested to know the story behind it. As the local people are earning revenue through guiding the tourist at every tourist place, the same local people can be trained as a geotourist guide. The government can popularise geoparks by displaying posters/banners *etc.*, to highlight the scientific and scenic values of particular geosites. Walking and cycling tracks can also be constructed in the geopark. Restaurants, hotels, and camping sites should also be allowed near the geoparks. The statues of fossils and keychains, showpieces, T-shirts, caps having photos of local geological features can also be made for sale. With these types of efforts, the

government will get revenues, and the local population will get employment opportunities.

CONCLUSIONS

- The Kutch Basin is a well-known basin in geology that has been attracting geologists and research workers from all over the world since the 19th Century.
- The region of Kutch is like nature's geological museum and a large laboratory. Once destroyed, it cannot be recreated. We need to protect such geoheritage from human activities or else we will lose in a short time such a captivating expanse of landscape with rich geoheritage that could be an ideal place for India's first National Geopark.
- The logistics and communication in Kutch are excellent as the sections are easily approachable by road as well as cross-country driving. The winter climate is most favourable for field visits.
- Various significant geological heritage sites discussed in this paper indicate that the basin area is *de facto* a natural text book for teaching, learning, and researching on any discipline of geology. These heritage features are spread all over the basin and visitors need to be taken to various spots to show them the objects, depending upon their subject of interest. The entire district of Kachchh (Kutch) needs to be declared as a National Geopark in India.
- The purpose of this article is to create awareness among the state and central government authorities to protect the natural geological sites as geological monuments and national parks in our country for our future generations to study geology in the field and promote geotourism.
- In the last two decades, the government of Gujarat took various initiatives as far as industrial and economic developments (Vibrant Gujarat) and Tourism developments (Rann Festival, Statue of Unity, Ahmedabad riverfront, *etc.*), are concerned. The Gujarat Government can take lead in establishing geoparks in India by declaring the Kutch basin as India's first National Geopark.
- All the geoscientists, researchers, and students will have the opportunity to study geological features in the field which is mandatory for geological studies.
- Varieties of geological features such as rock types, sedimentary structures, fossils, folds and faults, intrusive bodies, volcanic flows, *etc.*, exposed in scenic views will also create the common tourist's interest in geology promoting geotourism.
- The geological studies in Kutch will provide an opportunity for advanced studies in the geosciences for the future generation.
- Considering the above merits, it is proposed to create a National Geopark in Kutch. Seventy geosites grouped under 9 geostations have been identified (Table 1) in the plan of the proposed "Kutch National Geopark".

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LIST OF ABBREVIATION USED IN THE TEXT AND FIGURES

WCMI: Western Continental Margin of India	BF: Banni Fault
KRB: Kutch Rift Basin	SWF: South Wagad Fault
DVP: Deccan Volcanic Province	KMF: Kutch Mainland Fault
KT boundary: Cretaceous-Tertiary Boundary	VF: Vigodi Fault
NPU: Nagar Parkar Uplift	KHF: Katrol Hill Fault
IBU: Island Belt Uplift:	NRF: Naira River Fault
PU: Pachham Uplift	NKF: North Kathiawar Fault
PI: Pachham Island	MTH: Meruda Takkar Hill
KU: Khadir Uplift	NPF: Nagar Parkar Fault
KI: Khadir Island	IBF: Island Belt Fault
BU: Bela Uplift	GDF: Goradongar Fault
BI: Bela Island	GF: Gedi Fault
CU: Chorar Uplift	NRFL: Northern Range Flexure
WU: Wagad Uplift	KHFL: Katrol Hill Flexure
KMU: Kutch Mainland Uplift	KWU: Kathiawar Uplift
GOKHG: Gulf of Kachchh Half Graben	MH: Median High

FIGURE 5 to FIGURE 9

Fig.5. (A) View of Bhujiya Hill Fort near Bhuj. The fort-wall marks the top of the Bhujiya Ring dyke around the circular hill. (B) Kodki Fault, a small scale normal fault, very common in the crestal part of the uplifts, often filled with basic dykes. (C) Khari River Gorge: a sharply incised vertical valley cut indicating active neotectonic uplift. (D) Vidi railway crossing section near Anjar. Intertrappean limestone bed is exposed. Cretaceous/Tertiary (K/T) boundary is precisely delineated in this fossiliferous limestone, rich in micro fossils, dinosaur bones and mega-fossil assemblage. This section is one of the globally important sections for research on K/T boundary. (E) Section of the steep dipping Jhuran Formation exposed in the northern flank of Kas Hill anticline, steepening towards near vertical KMF (Fig.2). (F) Laccolith exposed at the core of Habo Dome in Northern Kutch Mainland. (G) KHF exposed at Fakirwadi section. Shows sharp fault plane between Cretaceous Bhuj (right) and Jurassic Jumara (left) formations. Older left-side is folded with chain of dome whereas younger right-side is undisturbed, low-dipping homocline of younger rocks, suggest strike slip movement.



Fig.6. (A) Road cutting section showing delta lobe structure in deltaic Bhuj Formation (Lower Cretaceous), near Dahisara on Bhuj-Mandvi road. (B) Columnar joints in Deccan basalt exposed in quarry sections near Dhunai on Bhuj-Mandvi road. Here one can see and study alternating columnar and amygdaloidal basalt flows of Deccan Trap. (C) Beach dunes in Mandvi beach. (D) Fulra Limestone is exposed in vertical cliff sections along rivers flowing across it in southern Kutch. Becomes caving Limestone along Rakhadi River upstream. (E) Close up field view of bio-clastic, Fulra Limestone (Mid-Eocene), exposed in Rakhadi River. Note that almost 100% of the rock sample is packed with fossils, mostly *Nummulites*, both mega and micro fossils. (F) Fulra Limestone (Eocene) and Maniyara Fort formation (Oligocene) boundary at Rakhadi River downstream. (G) Waior river section: Internationally important reference section for Chatian-Aquitanian stages. Presently destroyed by miners.



Fig.7. (A) Waior River bed exposing Coral biostromes and bioherms (small mound near the man) in Oligocene Limestone of Maniyara Fort Formation. (B) Fossil coral from Babia Hill top reef. (C) Panandhro Lignite mine section – Remnant of an Early Eocene coastal lagoon where thick black shale (lignites), potential petroleum source rock, were deposited. (D) KMF zone, north of Ghuneri, marked by sheared vertical beds between two parallel vertical late generation faults on the surface, mark the subsurface basement location of the KMF, the original rift fault, now covered by folded ductile sediment carapace during rift inversion. (E) Matanomadh River cliff section, exposes Eocene, Oligocene and Miocene sedimentary sequences. Part of this section near helipad, shows white Oligocene limestone laterally changing to black sulphurous shale as environment shift from open marine to restricted

lagoon. A rear section showing lateral facies variation with shift of depositional environment. **(F)** Jara dome section in North-Western Kutch Mainland. View of the western part of the dome showing map view of the extensively exposed Mid-Jurassic formations with well-defined boundaries. Oldest Jhurio Formation is on the foreground. Jaramara cliff section on the background is the reference section of Jhuran Formation. Note the excellent quality of this vast outcrop (in plan-view like a geological map) which is common in Kutch. **(G)** Nirona River canyon along a cross fault, northeast of geostation 7. **(H)** Folded and faulted Goradongar Flagstone Member at Simri Wandh Nala, Pachham Island.



Fig.8. (A) Ammonite fossil from marlite band exposed in Tramau River bed – north of Kanthkot Fort. (B) Belemnite fossil from Tramau River bed – north of Kanthkot Fort. (C) Jurassic wood fossil at fossil park – north of Dholavira archaeological site. (D) View of entrance gate of ancient Harappan Civilization site, Dholavira. View from ancient palace ground. (E) Road cutting section exposing mega sedimentary structure on Bhachau-Samakhyali Highway. (F) Agate deposit at Mardakh bet in the Little Rann of Kutch: loose agate pebbles covering the small islet.



Fig.9. (A) The gateway of Lakhpat Fort. (B) The ancient Sun temple at Kotay village. (C) The temple at famous Matanomadh pilgrim center. (D) Koteswar Mahadev Temple. (E) *Kutchchi* tribal mud huts, *Bhungas*, in Banni area. (F) Hand crafted *Kutchchi* potteries. (G) *Kutchchi* textile handicrafts showing characteristic style in design. (H) Kharai swimming Camel herd in the Banni region.

Table 1: Selected geostations and geosites of the Kutch Basin

Geostation	Geosite No.	Name of geological/ archaeological and cultural sites	Location coordinate	Geological aspect	Geological age	Geological/ archaeological, cultural Features	Type of interest	Suitable transportation mode	Nearby place having accommodation and lodging facilities
1. Bhuj	1	Bhujjiya Hill	23°14'48.30"N 69°41'14.68"E	Igneous activity historical Fort	Late Cretaceous	Ring Dyke, fort wall	Scientific, educational, tourist	Two-wheeler, auto and car	Bhuj city
	2	Khari Gorge	23°15'3.25"N 69°37'48.88"E	Sedimentology, ichnology, neotectonic and paleoclimate	Early Cretaceous	Gorge, erosional terrace, sedimentary structures, trace fossils	Scientific, educational, tourist	Two-wheeler, auto, car, bus	Bhuj city
	3	Kodki Fault	23°14'37.57"N 69°34'58.63"E	Structural geology, igneous activity	Early & Late Cretaceous	Faults and dyke	Scientific & educational	Two-wheeler, auto, car, bus	Bhuj city
	4	Kodki Mahadev Temple	23°13'54.16"N 69°33'24.73"E	Structural geology and sedimentology	Early Cretaceous	Columnar joints in sandstone	Scientific & educational	Two-wheeler, auto, car, bus	Bhuj city
	5	Fakir Wadi Section near Shivparas Dome	23°11'39.10"N 69°36'24.95"E	Structural geology, sedimentology, paleontology	Mid- late Jurassic to Early Cretaceous	Katrol Hill Fault, dome, fossils	Scientific, educational, tourist	Two-wheeler, auto and car	Bhuj city

6	Tapkeshwari Hills	23°10'52.27"N 69°40'0.81"E	Geomorphology, structures, tectonics, stratigraphy, sedimentology, paleontology, hydrogeology	Late Jurassic to Early Cretaceous	Faults, caves, artesian well, Trace fossils, fault scarp, historical temple, knick points	Scientific, educational, tourist	Two-wheeler, auto and car	Bhuj city
7	Gangeshwar Temple	23°11'36.86"N 69°43'36.37"E	Neotectonics, paleoclimate, paleontology, stratigraphy, sedimentology	Mid- late Jurassic and Late Quaternary	Dome, dyke, fossils, dhosa oolite, milliolites, fault scarp	Scientific, educational, tourist	Two-wheeler, auto and car	Bhuj city, Madhapar village
8	Khatrod hill Ashapura Ma temple	23°10'50.11"N 69°48'11.44"E	Tectonic geomorphology, stratigraphy	Late Jurassic to Early Cretaceous	Fault scarp morphology, drainage divide, caves, paleontology stratigraphy	Scientific, educational, tourist	Two-wheeler, auto and car	Bhuj city, Madhapar village, Kukma village
9	Khari River Section near Rudramata Dam	23°19'20.06"N 69°40'15.69"E	Stratigraphy, sedimentology	Late Jurassic	Late Jurassic paleo-channel, sedimentary structures, stratigraphy, ichnology	Scientific & educational	Two-wheeler and car	Bhuj city
10	Jhurio Hill, Badi Nala	23°25'44.16"N 69°33'52.38"E	Stratigraphy. sedimentology, structures, paleontology	Mid- Late Jurassic	Fossils, golden oolites, faults, fold, sill, dyke, sedimentary structures	Scientific, educational, tourist	Two-wheeler and car	Bhuj city

11	Habo Hills	23°22'34.44"N 69°50'26.72"E	Stratigraphy sedimentology, paleontology structures igneous activity	Mid- Late Jurassic and Late Cretaceous	Laccolith, sill, dyke, sedimentary, structures, fossils dome, fault, fold	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Habai Mataji temple, Dhrang Mekran Dada temple
12	Kas Hills, Loday Dam	23°22'46.18"N 69°54'25.14"E	Tectonic geomorphology, stratigraphy, paleontology, structures, igneous activity	Late Jurassic and Late Cretaceous	Volcanic plug, eroded anticline, fossils, young fault scarp, alluvial fan	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Habai Mataji temple, Dhrang Mekran Dada temple
13	Nadapa China Clay area	23°17'33.53"N 69°55'38.65"E	Stratigraphy sedimentology mining geology	Early Cretaceous	China clay mineral deposits, sedimentary structures, open cast mine	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Habai Mataji temple, Dhrang Mekran Dada temple
14	Vidi Section	23° 4'24.56"N 70° 1'24.96"E	Igneous activity sedimentology stratigraphy, K-T boundary	Late Cretaceous	Deccan Traps, intra-trappean beds	Scientific and educational	Two-wheeler and car	Bhuj city, Anjar city, Gandhidham city

15	Chakar-Kotada River	23° 5'20.26"N 69°44'11.58"E	Sedimentology, stratigraphy, igneous activity	Early Cretaceous and Late Cretaceous	Stratigraphic contact of Bhuj formation and Deccan Trap, columnar joints in basalt, sedimentary structures	Scientific and educational	Two-wheeler and car	Bhuj city
16	Palar Dhuna Water Fall	23°16'5.81"N 69°23'3.77"E	Geomorphology, igneous activity	Late Cretaceous, Quaternary Geology	Deccan trap, knick point, water fall	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Nakhrana city
17	Geological Museum, K.S.K.V. Kachchh University, Bhuj	23°12'52.38"N 69°39'18.99"E	Geological specimens	Precambrian to recent	Minerals, rocks, fossils (vertebrate, in-vertebrate, trace fossil, plant fossil etc.), ore etc..	Scientific and educational	Two-wheeler, auto and car	Bhuj city
18	Jhuran River & Jawahar Nagar road section	23°21'13.47"N 69°59'29.13"E	Stratigraphy, sedimentology, paleontology	Mid- late Jurassic	Jumara Formation, Jhuran Formation, ammonite, belemnites, bivalves, trace fossils	Scientific and educational	Two-wheeler and car	Bhuj city, Dhurang Dharamshala

	19	Ler Section	23° 11' 23.17" N 69° 45' 39.59" E	Stratigraphy, sedimentology, structures, paleontology	Mid- late Jurassic	Jhurun Formation, ammonite, belemnites, bivalves, trace fossils, Kachchh Mainland Fault	Scientific and educational	Two-wheeler, auto and car	Bhuj city
2. Mandvi	20	Mandvi Beach	22° 49' 31.57" N 69° 20' 16.41" E	Geomorphology, neo-ichnology	Quaternary	Beach, estuary, coastal dunes, the historic Vijay Vilas Palace is just 10 km away from beach site, sea	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Mandvi city
	21	Khojachora bentonite field	23° 0' 51.82" N 69° 23' 34.11" E	Economic Geology	Tertiary	Bentonite minerals, mining geology	Scientific & educational	Two-wheeler and car	Bhuj city, Mandvi city
	22	Gadhsisa Bauxite Field	23° 5' 2.82" N 69° 22' 39.79" E	Economic Geology	Tertiary	Bauxite minerals, mining geology	Scientific & educational	Two-wheeler and car	Bhuj City, Mandvi city
	23	Dahisara Road Cutting Section	23° 4' 38.05" N 69° 30' 50.72" E	Sedimentology	Early Cretaceous	Sedimentary structures related to deltaic environment	Scientific & educational	Two-wheeler, auto, car, bus	Bhuj city, Mandvi city

3. Naliya	24	Dhunai Quarry Section	23° 4'1.29"N 69°30'49.08"E	Igneous activity and mineralogy	Late Cretaceous	Deccan trap, cavity filling minerals, columnar joints	Scientific, educational, tourist	Two-wheeler and car	Bhuj city, Mandvi city
	25	Punadi-Asambiya Field	22°59'56.46"N 69°25'6.75"E	Sedimentary processes, chemical weathering, economic geology	Tertiary	Laterite deposit, lateritic bauxite, mining geology	Scientific & educational	Two-wheeler and car	Bhuj city, Mandvi city
	26	Naliya River	23°16'21.55"N 68°49'28.75"E	Stratigraphy, sedimentology	Pliocene	Soft sedimentary deformation	Scientific & educational	Two-wheeler and car	Naliya city
	27	Khari Nadi section	23°25'45.00"N 68°49'40.00"E	Sedimentology, stratigraphy, paleontology	Miocene	Wood Fossil, molluscus shale verigated sandstone	Scientific & educational	Two-wheeler, car and bus	Naliya city
	28	Waior village	23°25'15.70"N 68°41'59.93"E To 23°25'32.68"N 68°41'59.19"E through river bed	Stratigraphy, sedimentology, paleontology	Miocene, Oligocene	Fossils, Limestone, sedimentology, unconformity	Scientific & educational	Two-wheeler, car and bus	Naliya city
	29	Rakhadi River A	23°28'44.77"N 68°40'48.91"E	Stratigraphy, sedimentology, paleontology, fuel geology	Eocene, Oligocene	Fossils, Limestone, sedimentology, unconformity	Scientific & educational	Two-wheeler and car	Naliya city

30	Rakhadi River B	23°29'16.95"N 68°41'46.06"E	Stratigraphy, sedimentology, paleontology, fuel geology	Eocene	Fossils, limestone, sedimentology	Scientific, educational, tourist	Two-wheeler and car	Naliya city
31	Harudi Cliff	23°31'36.03"N 68°41'8.63"E	Stratigraphy, sedimentology, paleontology, fuel geology	Paleocene, Eocene	Fossils, Limestone, sedimentology, shale, laterite, unconformity	Scientific & educational	Two-wheeler and car	Naliya city, Narayan Sarovar
32	Kakdi River	23°34'35.54"N 68°38'38.59"E	Stratigraphy, sedimentology, paleontology, igneous activity	Late Cretaceous, Paleocene, Eocene	Unconformity, Deccan trap, tertiary basement	Scientific & educational	Two-wheeler and car	Naliya city, Narayan Sarovar
33	Kankawati River sections	23° 6'24.50"N 69° 2'31.77"E	Stratigraphy, sedimentology, paleontology	Paleocene, Eocene	Fossils, Limestone, sedimentology, stratigraphic contact	Scientific & educational	Two-wheeler and car	Naliya city, Narayan Sarovar
34	Ber-Nani River Section	23°27'11.53"N 68°37'24.35"E	Stratigraphy, sedimentology, paleontology	Eocene, Miocene	Fossils, Limestone, sedimentology, stratigraphic contact	Scientific & educational	Two-wheeler and car	Naliya city, Narayan Sarovar

4. Narayan Sarovar	35	Koteshwar-Pinjur Pir	23°42'41.32"N 68°33'13.24"E	Sedimentology, geomorphology	Quaternary	Stabilized dunes, mud-flats, historical temples, westernmost continental end of India, Arabian Sea	Scientific, educational, tourist	Two-wheeler and car	Narayan Sarovar, Verma Nagar, Panandhro village
	36	Panandhro Lignite Field	23°42'24.19"N 68°46'38.84"E	Sedimentology, stratigraphy, economic deposits	Paleocene, Eocene	Lignite deposits, limestone	Scientific, educational, tourist	Two-wheeler and car	Narayan Sarovar, Verma Nagar, Panandhro village
5. Lakhpat	37	Lakhpat Fort	23°49'32.04"N 68°46'23.02"E	Sedimentology, stratigraphy, geomorphology, geo-archeology	Paleocene, Eocene	Limestone, Great Rann of Kachchh, historical fort, Gurudwara	Scientific, educational, tourist	Two-wheeler, car and bus	Lakhpat, Verma Nagar, Panandhro village
	38	Ghuneri hills	23°48'9.90"N 68°49'40.70"E	Stratigraphy, sedimentology, structural geology	Early Cretaceous	Dome, fault zone, kachchh Mainland Fault	Scientific & educational	Two-wheeler and car	Lakhpat, Katesar temple, Matanomadh, Dayapar
	39	Ukra Hills	23°45'30.78"N 68°51'39.15"E	Sedimentology, stratigraphy, paleontology	Early Cretaceous	Fossils, sedimentary structures	Scientific & educational	Two-wheeler and car	Lakhpat, Katesar temple, Matanomadh, Dayapar

	40	Katesar Hills	23°46'21.31"N 68°52'47.19"E	Sedimentology, stratigraphy, paleontology, geo-archeology	Early Cretaceous and Holocene	Sedimentary structures, fossils, structural features, Buddhis caves, temple	Scientific, educational, tourist	Two-wheeler, car and bus	Lakhpat, Katesar temple, Matanomadh, Dayapar
	41	Sahera- Mundhan Hill section	23°46'9.15"N 68°55'3.64"E	Sedimentology, stratigraphy, paleontology, structures, tectonic geomorphology	Late Jurassic- Early Cretaceous	Sedimentary structures, fossils, structural features, neotectonic features	Scientific & educational	Two-wheeler and car	Lakhpat, Katesar temple, Matanomadh, Dayapar
6. Matanumadh	42	Matanomadh	23°32'44.25"N 68°57'0.35"E	Stratigraphy, igneous activity, planetary science	Late Cretaceous	Deccan Trap, pyroclastic deposits, martian landscape, temple of goddess Ashapura	Scientific, educational, tourist	Two-wheeler, car and bus	Matanomadh, Dayapar
	43	Helipad Section of Matanomadh River cliff	23°31'42.49"N 68°56'36.27"E	Stratigraphy, sedimentology, paleontology, fuel geology	Eocene, Oligocene, Miocene	Fossils, limestone, unconformity, kerogen shale	Scientific & educational	Two-wheeler and car	Matano madh, Dayapar
	44	Amyu	23°39'35.31"N 68°59'12.51"E	Stratigraphy, sedimentology, paleontology	Early Cretaceous	Fossils, unconformity	Scientific & educational	Two-wheeler and car	Matanomadh, Dayapar

45	Jara Hills	23°41'43.19"N 69° 1'0.09"E	Stratigraphy, sedimentology, paleontology, tectonic geomorphology, volcanic activity, structural geology	Late Jurassic to Early Cretaceous	Fossils, unconformity, sedimentary structures, fault scarp, historical war memorial site, fault, dyke, fold	Scientific, educational, tourist	Two-wheeler and car	Matanomadh, Dayapar
46	Jumara Hills	23°41'34.39"N 69° 4'11.52"E	Stratigraphy, sedimentology, paleontology, structural geology, geomorphology	Mid- Late Jurassic	Fossil, sedimentary structures, dome, fault, Great Rann of Kachchh	Scientific, educational, tourist	Two-wheeler and car	Matanomadh Dayapar, Hajipir
47	Kaya Dongar Hill (Manjal Dome), Nara Road	23°38'2.53"N 69° 8'27.80"E	Stratigraphy, sedimentology, paleontology, volcanic activity, structural geology	Late Jurassic- Late Cretaceous	Stratigraphic contact, laccolith, dyke, sill, Kachchh Mainland Fault, dome	Scientific, educational, tourist	Two-wheeler and car	Matanomadh, Dayapar, Hajipir

7. Nakhatrana	48	Keera Hills	23°35'4.63"N 69°14'34.86"E	Stratigraphy, sedimentology, paleontology, structural geology, geomorphology, igneous activity	Mid- Late Jurassic	Sill, dyke, volcanic plug, dome, fault, fossil, sedimentary structure, unconformity, Chhari Lake – 10 km from the site, Banni Plains, Hajipir Dargah	Scientific, educational, tourist	Two-wheeler and car	Hajipir, Nakhatrana
	49	Dhinodhar Hill	23°27'16.60"N 69°20'31.05"E	Geomorphology, igneous activity	Late Cretaceous	Volcanic plug, columnar joints in basalt	Scientific, educational, tourist	Two-wheeler and car	Than Jagir, Hajipir, Nakhatrana
	50	Nirona river	23°26'40.32"N 69°29'13.86"E	Geomorphology, stratigraphy, sedimentology, structural geology	Mid-Late Jurassic	Canyon, structurally controlled river, faults, sedimentary structures, black shales	Scientific, educational, tourist	Two-wheeler and car	Bhuj, Nakhatrana
	51	Vithonia Hill near Vithon	23°19'31.40"N 69°20'35.75"E	Geomorphology, igneous activity	Late Cretaceous	Volcanic plug, columnar joints in basalt	Scientific, educational, tourist	Two-wheeler and car	Nakhatrana, Vithon, Bhuj
	52	Netra Inter- trappean beds	23°25'25.31"N 69° 2'48.83"E	Igneous activity, K-T Boundary	Late Cretaceous	Deccan trap, inter-trappean beds	Scientific & educational	Two-wheeler and car	Nakhatrana, Matanomadh

8. Khavada	53	Simri Wandh Nala	23°52'19.50"N 69°49'22.03"E	Structural geology, stratigraphy, paleontology, sedimentology	Mid-Jurassic	Sedimentary structures, trace fossils, fold, faults	Scientific & educational	Two-wheeler and car	Khavada village, Dutt temple-Kaladongar, Dhordo village
	54	Bandi River	23°51'58.86"N 69°48'19.35"E	Stratigraphy, paleontology, geomorphology, quaternary climates and tectonics	Miocene and Quaternary	Incised meander, strath terrace, root fossils laterite	Scientific & educational	Two-wheeler and car	Khavada village, Dutt temple, Kaladongar, Dhordo village
	55	Goradongar Hills	23°51'9.57"N 69°46'12.28"E	Geomorphology, structural geology	Mid-Jurassic	Stratigraphy, small scale dome, doubly plunging anticline/syncline, fault	Scientific & educational	Two-wheeler and car	Khavada village, Dutt temple, Kaladongar, Dhordo village
	56	Kaladongar Hills	23°56'13.73"N 69°48'51.97"E	Stratigraphy, paleontology, geomorphology, structural geology	Mid-Jurassic	Highest peak of Kachchh Basin, eroded anticline, fossils, sedimentary structure, aerial view of the Great Rann of Kachchh, God Dutt temple	Scientific, educational, tourist	Two-wheeler and car	Khavada village, Dutt temple-Kaladongar, Dhordo village

57	Kuar Bet	23°59'20.09"N 69°44'26.66"E	Stratigraphy, paleontology, geomorphology, structural geology	Mid Jurassic	Oldest sedimentary carbonate of the Kachchh Basin, fossils, India Bridge, 1971 war Memorial	Scientific, educational, tourist	Two-wheeler and car	Khavada village, Dutt temple- Kaladongar, Dhordo village
58	Nir Wandh	23°54'7.48"N 69°56'27.66"E	Igneous activity	Late Cretaceous	Unique igneous complex	Scientific & educational	Two-wheeler and car	Khavada village, Dutt temple, Kaladongar, Dhordo village
59	Sadhara Hills	23°45'18.94"N 69°54'39.54"E	Stratigraphy, paleontology, geomorphology, structural geology, igneous activity	Mid- Jurassic and Late Cretaceous	Dome, sill of Picro-Basalt, fossils, unconformity	Scientific & educational	Two-wheeler and car	Khavada Village, Dutt temple, Kaladongar, Dhordo village
60	Kanthkot- Tramau River	23°29'29.96"N 70°29'42.95"E	Stratigraphy, paleontology	Mid-Late Jurassic	Fossils marker bed	Scientific & educational	Two-wheeler and car	Rapar, Kanthkot temple
61	Kanthkot Fort temple	23°29'4.81"N 70°27'42.46"E	Stratigraphy, paleontology, structural geology	Mid-Late Jurassic	Fossils, sedimentary structures, fault, historical fort, temple	Scientific, educational, tourist	Two-wheeler and car	Rapar, Kanthkot temple
62	Bharodia	23°33'26.39"N 70°24'27.36"E	Stratigraphy, paleontology	Mid-Late Jurassic	Fossils, unconformity	Scientific & educational	Two-wheeler and car	Rapar
9. Rapar								

63	Dholavira-Arch	23°53'13.90"N 70°12'52.88"E	Geo-archeology	Holocene	India's biggest Harappan civilization cite	Scientific, educational, tourist	Two-wheeler and car	Rapar, Dholavira
64	Dholavira-Geol	23°55'23.30"N 70°13'35.81"E	Stratigraphy, sedimentology, geomorphology, paleontology	Mid-Jurassic	Mega wood fossil, sedimentary structures, Great Rann of Kachchh	Scientific, educational, tourist	Two-wheeler and car	Rapar, Dholavira
65	Palasava	23°26'13.21"N 70°59'22.27"E	Paleontology	Miocene	Vertebrate fossils	Scientific & educational	Two-wheeler and car	Rapar, Adesar
66	Mardakh Bet	23°23'19.69"N 71° 5'13.76"E	Gemology, geomorphology	Late Cretaceous to Paleocene	Agate deposits derived from Deccan Trap, historical temple of Mardakh Dev, Little Rann of Kachchh	Scientific, educational, tourist	Two-wheeler and car	Rapar, Adesar
67	Bhachau Road Section	23°17'37.56"N 70°22'53.68"E	Sedimentology, Igneous Activity	Early Cretaceous and Late Cretaceous	Erosional contact of Deccan Trap and deltaic Bhuj formation	Scientific & educational	Two-wheeler, car and bus	Bhachau, Samakhiali

68	Gangta Hills	23°44'24.38"N 70°29'49.77"E	Stratigraphy, sedimentology, geomorphology, structural geology, paleontology	Middle – Late Jurassic	Dome, fault, fold, fossils, sedimentary structure, Great Rann of Kachchh, Mahadev temple	Scientific, educational, tourist	Two-wheeler, car and bus	Rapar
69	Rapar-Chitrod road section	23°23'50.57"N 70°43'1.37"E	Stratigraphy, sedimentology, geomorphology, structural geology	Middle – Late Jurassic	Dome, South Wagad Fault, sedimentary structures	Scientific & educational	Two-wheeler, car and bus	Rapar, Samakhyali
70	Mouana Dome	23°52'38.86"N 70°52'43.65"E	Stratigraphy, sedimentology, geomorphology, structural geology, paleontology, volcanic activity	Middle Jurassic and Tertiary	Dome, Island Belt Fault, fault scarp, sedimentary structures, sill, duke, fossils, China clay mines	Scientific, educational, tourist	Two-wheeler and car	Dholavira, Rapar

RENUKAJI: AN IDEAL SITE FOR GEOHERITAGE AND GEOPARK

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1. INTRODUCTION

The UNESCO has suggested to establish an international framework of Geoparks to enhance the value of the Earth's heritage, its landscapes and geological formations, which are key witnesses to the history of Mother Earth.

A 'Geopark' can be defined as a geographical area where geological heritage sites are part of a holistic concept of protection, education, and sustainable development. The Geopark should take into account the whole geographical setting of the region, and shall include non-geological themes of ecological, archaeological, historical, and cultural values, especially when their relation to landscape and geology can be demonstrated to the visitors. It imparts knowledge of the geological history to the layman.

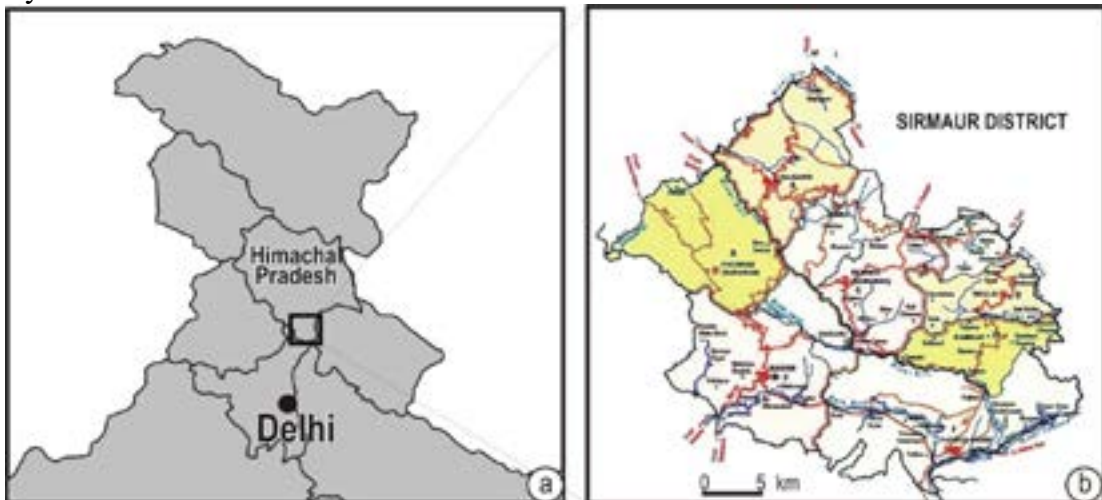


Fig. 1 (a-b): Map of Sirmour district (inset) shows its location in Himachal Pradesh.

Renukaji-Koti Dhaman-Sataun stretch, located in the Renuka Tehsil of the Sirmaur district (Fig. 1), occupying an area of 70 sq. km, is ideal for setting up a geoheritage and geopark. Sirmaur is the southeastern most district of Himachal Pradesh. On the East of Sirmaur district is the Jaunsar-Bawar area of district Dehradun (Uttarakhand) and towards the south lies the Panchkula district of Haryana. Renukaji, besides being famous for its lake, also finds a mention in the Hindu mythology. Koti Dhaman village is situated NE of Renukaji at a distance of 20 km in the North direction along an untarred road. Sataun is about 40 km from Renukaji. All these areas are well connected by a network of roads. The climate of the area is of sub-tropical monsoonal type. The average precipitation at the Renukaji wetland area is 150-199.9 cm/ annum and average maximum temperature is 30°C. Winter is mild to moderate in low-lying areas, whereas high mountain ranges experience severe cold with heavy snowfall; the average snow fall around Haripurdhara is 70-100 cm. The Renukaji-Koti Dhaman-Sataun stretch embodies an interesting array of rocks ranging in age from

Neoproterozoic to lower Ordovician. The district is also endowed with rich fauna and flora.

2. GEOLOGICAL SETUP

The stratigraphic order of the formations exposed in this area is presented in Table 1. This order has been disrupted due to tectonics, as a result, the older rocks rest over the younger along well defined thrusts (Fig. 2). The fresh water rocks of the Nahan Formation (Siwalik Group), exposed south of Renukaji form the lowest tectonic unit. The Middle Eocene Subathu Formation of the Foreland Basin tectonically rests over the Nahan Formation; it is a shallow marine sequence and crops out west of Renukaji and at Kansar. At Kansar, between the Nahan Formation and the Subathu, Palaeoproterozoic quartzite with basic rocks of the Dharagad Group are developed. In strike continuity towards the East, stromatolitic Sataun Limestone (Deoban Group) occurs as a tectonic wedge between the Nahan Formation and the Jaunsar Group. The Jaunsar Group sequence, deposited in subtidal to the shallow marine environment, is exposed along the Renukaji-Sataun road. Along the Renukaji-Koti Dhaman road, the Jaunsar Group rocks are followed upward by the glaciomarine diamictites and cap carbonate of the Blaini Formation. The overlying black shale of the Infra Krol Formation, deposited in a barred subtidal environment, appear above the Blaini Formation. The Krol Group, mainly a shallow marine sequence comprises five formations viz., A (dolostone), B (red shale), C (dolostone, limestone), D (shale, dolomitic limestone), and E (limestone, shale, sandstone). The Tal Group, divisible in Shaliyan, Sankholi, and Koti Dhaman formations, conformably rests over the Krol Group. The Ediacaran (Precambrian)-Cambrian boundary lies within the Shaliyan Group which encloses *Shaanxilithes ningqiangensis* in the basal part and Shelly Microfauna in the overlying beds. The explosion of life is recorded throughout the world at the end of the Ediacaran and the advent of Cambrian. The Sankholi Formation encloses ichno and trilobite fossils of lower Cambrian age. Along an angular unconformity, the Koti Dhaman Formation is overlain by the Deona Formation containing the lower Ordovician trace fossils.

The Blaini Formation, the Infra Krol Formation, Krol Group, the Tal Group, and the Deona Formation are folded in two synclines designated as the Korgai and the Nigali Dhar synclines intervened by the Barbas anticline. These constitute part of the Inner Krol Belt (Auden, 1934; Bhargava, 1972, 1974; Singh et al., 2019).

Being the leading edge of the Inner Krol Belt, the rocks of the Jaunsar Group and also the Krol Group occurring in the southern Korgai syncline are tectonically disturbed, in the northern Nigali Dhar syncline the original order of superposition is preserved.

3. GEOMORPHOLOGY

The southern part of the Renukaji sector forms part of the Sub-Himalaya, while the Renukaji and the area north of it falls in the Lesser Himalaya; the former is constituted of low-rising hills with comparatively gentler topography and somewhat wider valleys, the latter is characterised by steep hills as high as ~2000 m. The Chur (originally the Chaur) Dhar, situated in the Sirmaur district rises to an elevation of 3647 m (11965 feet) above mean sea level. The Chaur Dhar is a synclinal hill, from

which several rivulets originate forming a radial drainage pattern. The Chaur Mountain is an important religious place for all the residents of Sirmaur.

Table 1. Stratigraphic order of rocks in Renukaji sector

Group/Formation Age	Lithology	Environment of deposition
Siwalik Group ca 16-2.6 Ma	Conglomerate, sandstone, clay	Fresh water fluvial
Sirmur Group ca. 58-16 Ma	Micaceous sandstone, shale, red sandstone, shale, calcretes, limestone, sandstone, marl, carbonaceous shale, mudstone, coal, oyster-bearing limestone	Shallow marine, deltaic, and freshwater
Deona Formation ca. 488	Quartz arenite, shale, algal limestone -----Angular unconformity----- -----	Shallow marine
Tal Group ca. 542-513 Ma	Phosphorite, chert, Carbonaceous shale, siltstone, quartz arenite, limestone	Subtidal to shallow marine
Krol Group 630-542 Ma	Limestone, dolostone, sandstone, red shale, breccia, gypsum,	Shallow marine
Infra Krol Formation ca. 635-630 Ma	Carbonaceous, slate, shale, siltstone	Subtidal
Blaini Formation 678-630 Ma	Lower and upper diamictite, intervened by sandstone, shale, siltstone, cap carbonate. -----Unconformity-----	Glaciomarine
Jaunsar Group ca. >800-730 Ma	Sandstone, shale, siltstone, limestone, conglomerate -----Nonconformity----- Tholeiitic basalt	Subtidal to shallow marine
Tattapani Volcanics ca. 830		Submarine volcanism
Deoban Group ca. 1500-950 Ma	Limestone, dolostone, sandstone, quartz arenite, breccia -----Nonconformity-----	Shallow marine to supratidal
Rampur Group ca. 1800 Ma	Quartzite, phyllite, schist, gneisses, volcanics	Shallow marine

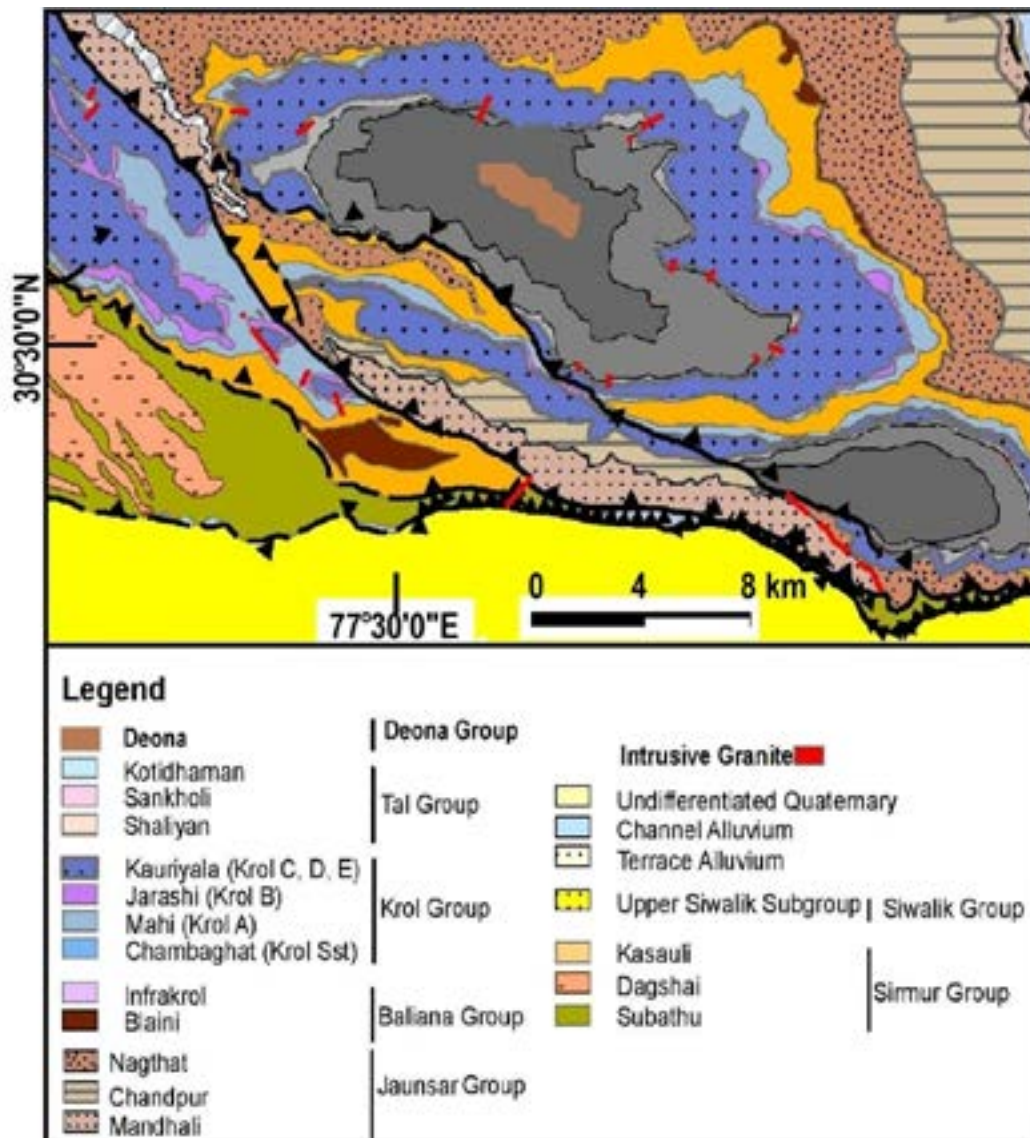


Fig. 2. Geological map of a Renuka-Koti Dhaman-Sataun and adjoining area (after various published resources).

The Renukaji area has been classified as a wetland. Geologically, the Giri River flowed through the present site of the Renuka Lake (Fig. 3a). Due to a huge landslide, the river seems to have been dammed at Khar to form a lake. The over-flowed river level due to damming was captured by headward erosion by a small nala— a tributary of the Jalal River (Fig. 3b) (Bhargava, 1974). There are no surface feeders, the recharge of water to the Renukaji lake is subsurface, most likely the Giri river upstream of the lake through a ‘U-tube’ process. As the channels recharging the lake water are getting clogged owing to the deposition of salts, the recharge is getting diminished with the gradual shrinking of the lake.

4. PROPOSED GEOLOGICAL SITES

4.1 Sataun Bridge: Below the bridge on the left bank of the Giri river, the Nahan Formation and the stromatolitic Deoban Limestone (=Sataun Limestone) are exposed (Fig. 4). On the right bank, the Jaunsar Group rocks appear. The limestone has been extensively mined for CCI Cement Factory located at Rajban. The Nahan Formation

rocks were deposited by rivers ensuing out of freshly elevated Himalaya, whereas the Deoban Limestone represents 1500-950-million-years ago (Ma) old sequence deposited in a shallow marine to the supratidal environment. The Jaunsar Group also represents 800-730 Ma old sediments formed in a shallow marine environment.

4.2 Four km south of Dadhau, the Subathu Formation can be seen. It is believed to be a source rock for oil. It also represents the time of the creation of the Foreland Basin as a consequence of the collision of the Indian and Asian plates around 58-54 Ma.

4.3 West of Renuka, along the Dadhau-Sangra road, at a distance of about 2.3 km, diamictites of the Blaini Formation (Fig. 5) crop out, signifying glaciation in this area about 678-635 Ma.

4.4 Between 12 and 14 km, along the Renukaji-Koti Dhaman road, the Krol sequence is exposed (Figs 6-9) denoting the existence of shallow sea dating back to 630 Ma; the red shale of the B Formation (fig. 7) is reminiscent of extensive aridity stretching from Salt Range (Pakistan) to Nainital around 600 million years ago.

4.5 Fifteen Km, along the Koti Dhaman road, rocks enclosing *Shaanxilithes ningqiangensis* (Fig. 10) representing the youngest Ediacaran fossil are exposed, these are overlain by the chert. The Precambrian/Cambrian boundary is located in this stretch.

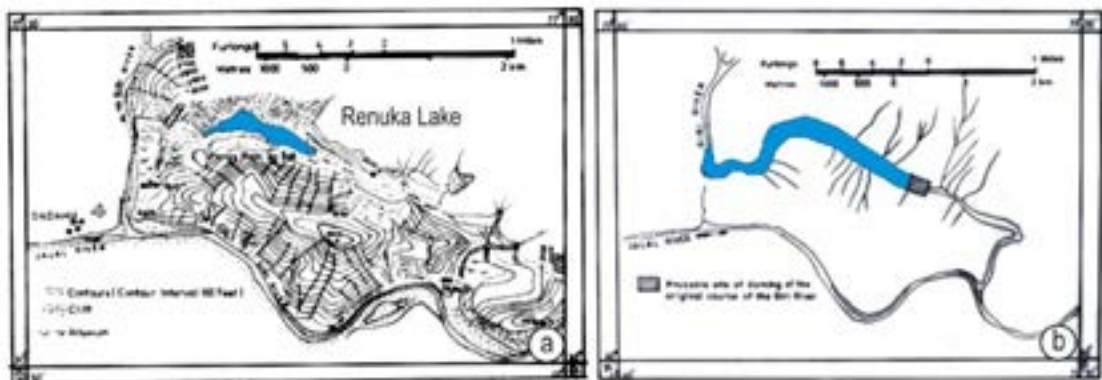


Fig. 3. (a): present course of the Giri River and location of Renuka lake. An alluvial tract exists from the lake to the Giri river and also further east, (b) possible location of the landslide causing damming of the erstwhile Giri river (modified after Bhargava, 1974).



Fig. 4. (a) A view of stromatolitic Deoban Limestone (=Sataun Limestone), (b) close-up of columnar stromatolites in the Deoban Limestone.



Fig. 5. A view of glaciomarine diamictites of the Blaini Formation.



Fig. 6. Limestone of the Krol-A, ~10.7 km from Renukaji on road leading to Koti Dhaman village; (GPS: N30°36'57.3", E077°28'42.4").

4.6 At ~34 km, angular discordance between the Cambrian Tal Group and lower Ordovician Deona Formation (Fig. 11) can be observed along the road from Renukaji to Ganog locality. It provides evidence of a major orogeny, designated as the Kurgiakh Orogeny dating back to 515-490 Ma.

4.7 Fauna and flora

Simbalbara wildlife sanctuary, situated in the Paonta Valley, is an abode for a variety of mammals, birds, amphibians, reptiles, and insects. Goral (*Nemorhaedus goral*), sambar (*Cervus unicolor*), barking deer (*Muntiacus muntjac*), wild pig (*Sus scrofa*), langur (*Presbytis entellus*), jackal (*Canis aureus*), Porcupine (*Hystrix indica*), cheetal (*Axis axis*), leopard (*Panthera pardus*), jungle cat (*Felis chaus*) and pangolin (*Manis crassicaudata*) are the main mammal species. Birds are represented by kaleej pheasant (*Lophura leucomelana*), grey and black partridge (*Francolinus* sp.), saker falcon (*Falco biarmicus*), and imperial eagle (*Aguila heliaca*). Approximately 70 species of butterflies have been identified in the sanctuary.

Around 352 species of phanerogams comprising 251 dicotyledons, 97 monocotyledons, and four species of gymnosperms belonging to 85 families are known from the Nohra Forest Block (Churdhar Wildlife Sanctuary). These include 13 threatened species and 35 species are endemic to the western Himalaya. Some of them are of medicinal value

The Forest around Renukaji contains Anogeissus, Lucinea, Terminalia, Khair, Shisham, Carrie, Cordia, and a variety of creepers in moist depressions. The fauna of the area comprises leopard, sambar, spotted deer, barking deer, jackal, hare, jungle cat, plam civet, porcupine, blue jay, black partridge, drongos, hill crow, scarlet minivet, bulbul, common coots, green pigeons.

Renukaji has a Mini Zoo--founded in 1957 with rescued, stray, and deserted wild animals from the forests. The first animal brought to the Zoo was a male spotted deer followed by a female chital. Later more animals were introduced. To accommodate the increasing number of animals, the idea of an open park was conceived, which was set up in 1983. A pair of Lions was brought to Renukaji Zoo from Zunagarh in 1975. Subsequently, an aviary was also added.



Fig. 7. Red shales of the Krol-B ~12.8 km from Renukaji on road leading to Koti Dhaman village, (GPS: N30°37'32", E077°29'18").



Fig. 8. Dolostone of the Krol-C ~13.4 km from Renukaji on road leading to Koti Dhaman village (GPS: N30°37'40", E 077°30'30").



Fig. 9. Contact of the dolostone of the Krol E (Krol Group) and the Earthy Siltstone Member (Shaliyan Formation) of the Tal Group, containing the Ediacaran fossil *Shaanxilithes ningqiangensis* at Tipri village, which lies ~16.9 km from Renukaji on road leading to Koti Dhaman village (GPS: N 30°37'31", E077°31'47").



Fig. 10. A siltstone slab showing the Ediacaran tubular body fossil of *Shaanxilithes ningqiangensis* in the Earthy Siltstone Member (Shaliyan Formation), Tal Group.



Fig. 11. Angular discordance between the Cambrian Shale Member (Koti Dhaman Formation, Tal Group) and lower Ordovician Deona Formation.

5. HAZARDS

- 5.1. Being located close to the Main Boundary Fault (erstwhile Main Boundary Thrust), which is believed to have become active during the 1905 Dehradun-Kangra Earthquake. The area lies in the Seismic Zone IV, which is prone to earthquakes.
- 5.2. Landslides are of common occurrence during the monsoon, particularly along the newly constructed road.
- 5.3. Siltation in the Renukaji lake.
- 5.4. Destruction of important geological features during road construction and landslides. Several fossil localities have been destroyed in the past.

6. REMEDIAL MEASURES

- 6.1. Most of the old houses are wooden structures, following local '*Dhajji-Kabari*' design (wooden frame filled with stone/mud), which are earthquake resistant. The newly constructed cement-concrete houses need to follow aseismic design. Multi-storied constructions should be avoided.
- 6.2. While planning the road, the help of geologists should be sought to (i) avoid weaker zones, if unavoidable, provide support depending on the terrain, (ii) provide proper slope as per joints/weaker zones present in the area, and (iii) scrupulously avoid fossiliferous and other rare geological features.
- 6.3. Afforestation of barren slopes to provide them stability and avoid over-grazing by cattle, particularly by sheep and goats.

7. CULTURAL AND ARCHITECTURAL CHARACTERISTICS

Sirmaur was an independent kingdom in India, founded around 1090 by Raja Rasaloo of Jaisalmer, one of whose ancestors was named Sirmaur. It became an Eleven Gun Salute princely state in British India.

A majority of Sirmur's population (90%) lives in villages and agriculture is their main profession. Nahan (district Headquarters), Dadhau, and Paonta Sahib are its important towns.

The Renuka Tehsil encompasses about 75 villages having a total population of 47,338 (2001 census) with 7,276 houses. Out of the total population, 24,221 are males and 23,167 are females. The principal cash crops are ginger and potato. A rigid cast system is followed, even houses of different casts are segregated. Marriages are arranged and are fairly big events. All religious festivals are enthusiastically celebrated. Traditionally, polyandry was prevalent in the area, which with education has greatly diminished, if not eliminated. Hinduism is the only religion in the Renuka Tehsil.

Some houses older than 100 years coexist (Fig.12) with not so old (Fig.13) and also newer constructions (Fig.14) The ground floor is reserved for cattle and the first floor is used for residential purposes. Surplus grains are stored in large wooden boxes.



Fig. 12. (a-b): More than 100-year-old houses.



Fig. 13. 40-50-year-old construction.



Fig. 14. A modern cement house above a traditional house.

Renukaji (Fig. 15a-b) is endowed with religious and cultural values. According to mythology, Renukaji, supposedly an incarnation of the Goddess Durga, was married to Rishi Yamdagni. Parshuram believed to be the sixth incarnation of the Lord Vishnu, was the youngest of the five sons of the couple. Once to obey his father, Parshuram severed the head of his mother. After killing Renukaji, Parshuram begged his father to restore his mother to life, which he did. Renukaji was an extremely beautiful lady. Sahastarvahu wanted to marry her and once in the absence of

Parshuram, he killed Rishi Yamdagni and his four sons to marry Renukaji. To escape Sahastarvahu and unable to bear the grief of the death of her husband and four sons, Renukaji jumped into a small pond known by the name of the Ramsarover at that time and disappeared into it. Ever since the lake is worshiped as Renukaji Lake. The shape of the lake is believed to resemble that of a lady (Figs. 15 a-b). Parshuram returned and eliminated Sahashtrabahu in a fierce battle. With his divine powers, he gave a new life to his father and on the bank of the Lake prayed his mother to come out of the Lake. Renukaji responded to his prayers and said that she would permanently live in the Lake. But on the request of Lord Parshuram she promised to emerge out of the Lake on the occasion of Kartika Ekadashi every year to meet her son. She also promised that people gracing this pious occasion of mothers' affection and sons' devotion, would be showered with divine blessings. A huge annual fair is held at Renukaji sometime during November to celebrate the union.

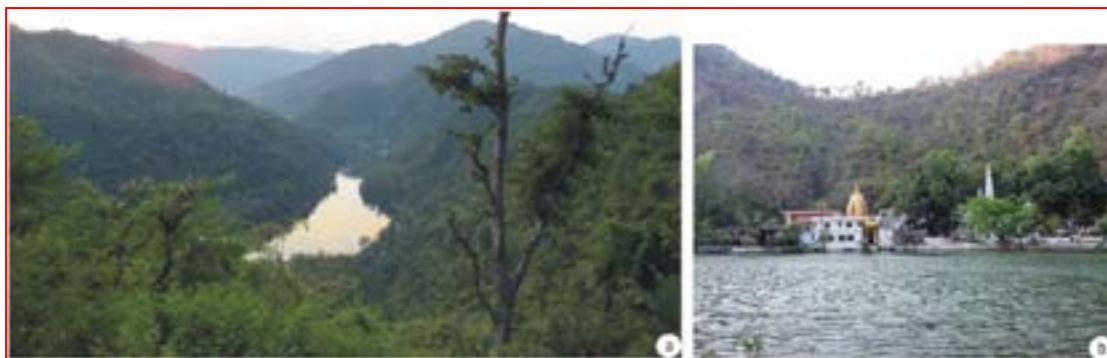


Fig. 15. (a) A view of Renuka Lake, resembling an outline of a lady; (b) Renukaji Temple; Photo (b) @ Harvinder, Chandigarh.

8. CURRENT TOURIST STATUS

On the eve of the Kartika Prabodhini Ekadashi, a five day long International level Renukaji Fair is organised by the Renuka Development Board. During this event, the brass idol and mask of Lord Parashu Rama is brought from village Jamu in a silver palanquin. The deity remains in the temple for three days, i.e. sudi, dashmi to dwadashi (from 10th to 12th of the bright half). Several lakhs of devotees from all over the country arrive here to witness the holy occasion of the divine meeting of Lord Parshum and his mother Renukaji and take a dip in the holy lake. In the night, the Pujari goes into trance and turns oracle; he is pried by the locals. His answers foretell events and often suggest some offering or sacrifice to the deity or some other act for deliverance from some misery or recovery from some disease. On dwadashi, generally, the people offer alms after the holy dip in the Renukaji lake.

Bhagwan Parshu Ram and other deities are welcomed during the fair by the Chief Minister. His excellency the Governor of Himachal Pradesh pays obeisance to deities on concluding day.

Renukaji is an important link in the tourist circuit of the Department of Tourism, Himachal Pradesh. A Forest Rest House and a hotel run by the Himachal Tourism exist at Renukaji. In addition to a PWD rest house, several hotels have come up at Dadhau and its vicinity.

A facility for boating in the lake and a drive through the Lion safari are available.

8.1. Nearby places of tourist or cultural importance

8.1a. Chur Dhar (originally Chaur Peak) located in the Sirmaur district soars to an elevation of 3647 m (11965 feet) above mean sea level. It is the highest peak in southern Himachal Pradesh. The famous granite of the Jutogh Group is named after this peak (Fig 16). The mountain is also an important religious place for the local inhabitants. The Chaur Peak offers a panoramic view of lowland tracts towards the south and snow-capped ranges, including the peaks of Badrinath and Kedarnath, in Uttarakhand, towards the north. It is becoming popular with trekkers.

It is believed that this is the very place where Hanuman lifted the life-restoring *Sanjivini Booti*, which revived Lakshmana. Ruins of an ancient town have been discovered at the nearby Dundi Devi.

8.1b. Sirmauri Tal was the original capital of the Sirmaur kingdom during the reign of King Udit Prakash 1217-1227 AD. He shifted his capital to Kalsi. It's ruins covered by alluvium are still sporadically present, much of its stone carved architectural remains have been vandalised by curio collectors. Only now the site has been protected. The city was destroyed by unprecedented floods, possibly associated with an earthquake, which diverted the course of the Giri river. According to local folk lore, this place was cursed by a courtesan who was killed by the king; the curse caused widespread flood that swept the whole kingdom.

Now Sirmauri Tal has now been renamed as Rajban, meaning "Forest of the King". Rajban is a very small town with a dense forest adjacent to it and high steep hills. It is located on the river bank, at the confluence of the Tons and Giri rivers (Fig. 17). One of the oldest cement factory (CCI) in Himachal is situated at Rajban.



Fig. 16. Chur peak made up of 830 million year old Chaur granite (Source: Wikipedia).

Rajban has always been a favourite point for neighbouring people to spend Dusshera Durga Puja and other festivals of the year. The Holy temple La Devi also attracts a number of pilgrims throughout the year.



Fig. 17. A view of Sirmauri Tal (Source: Wikipedia).

8.1c. Saketi Fossil Park: It is about 65 km from Renukaji. Life-size models of some Cenozoic vertebrates (Fig. 18) like a giant tortoise, an elephant with large tusks (*Stegodon ganesa*), ancestor of giraffe (*Sivatherium*, Fig 18a), etc. are displayed in the Fossil Park. It also houses a museum displaying fossils collected from nearby localities.



Fig. 18. (a) A life-size model of *Sivatherium*, ancestor of giraffe, (b) *Megalochelys atlas*, giant land tortoise, (c) *Hexaprotodon sivalensis*, ancestor of present day hippopotamus.

8.1d. Paonta Saheb: Located 50 km from Renuka is an important Gurudwara, located along the bank of the Jamuna river (Fig, 19). Shri Guru Govind Singh Ji, the tenth Guru of Sikhs, stayed here for about 4 years from 1742 to 1745.



Fig.19. A view of Paonta Saheb (Source: Wikipedia).

9. COMMUNICATION

Renukaji is well connected with Shimla, Chandigarh, Dehradun, and Ambala with a network of well-maintained roads. The nearby rail heads are Chandigarh, Ambala, and Dehradun. Chandigarh and Dehradun are connected with Delhi by air.

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PROPOSAL FOR PUNE -AHMEDNAGAR DECCAN GEOPARK, MAHARASHTRA, INDIA.

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INTRODUCTION

Geoheritage encompasses global, national, state-wide, and local features of geology, at all scales that are intrinsically important sites or culturally important sites offering information or insights into the evolution of the Earth; or into the history of science, or that can be used for research, teaching, or reference (Brocx & Semeniuk, 2007). Since 2004, UNESCO has been working towards a globally unified approach for the preservation and holistic management of international significance under the label of 'UNESCO Global Geopark'.

The Deccan Volcanic Province occupies ~500,000 sq. km, most of it in the state of Maharashtra. Considering the size, it is difficult to envisage a single geopark in this vast terrain. The proposed 'Pune – Ahmednagar Deccan Geopark' occupies a part of the Deccan Traps and has the potential to become a Global Geopark.

Pune (18°32' N: 73°51' E) and Ahmednagar (19.08°N 74.73°E) are prominent cities in the state of Maharashtra which are mainly constituted of the Deccan flood basalts. These cities occupy what is known as the '*Desh*' or plateau region of the state. The main rivers of this region are the Godavari and Krishna, which flow south-easterly irrigating the plateau region and empty into the Bay of Bengal. The plateau receives 600 – 1000 mm rainfall and the average temperatures range from 14° to 29° C with a maximum of 38°- 40° C in April and May.

The human settlement in the Deccan area spans 2200 years. The early historical use of the landforms dates back to circa 100 BCE (Satvahana Dynasty). Marathi, an Indo-Aryan language is the principal language spoken here. The other languages spoken here are Konkani and English.

The Deccan Volcanic Province

The area covering the proposed Geopark is a part of the Deccan Volcanic Province (DVP), one of the largest continental flood basalt provinces in the world. They are popularly known as Deccan Traps, a term coined by W.H. Sykes in 1833 and is derived from a Sanskrit word *Dakshin* meaning south or southern and a Swedish word *Trapp/Trappa* meaning Stair. The step like or terrace like topography is characteristic of this 3500 m thick lava terrain. The eruption of the Deccan basalts took place ~67-65 million years ago, when India was close to the equator, was drifting northward and it passed over the 'Reunion volcanic hot spot'. Deccan volcanics have a unique position in Indian Geology and have immense geo-tourism potential, with many interesting features of volcanological significance like the lava tubes/channels, giant dyke swarms, flow morphology. Numerous geomorphic features of the erosional type such as the

steep western ghat escarpment, entrenched meanders with deep gorges, waterfalls, natural bridges, and potholes carved in the basalts are also seen here. The Deccan Traps are also dotted with many forts and caves, which are in turn related to the type of lava flows in the area. Most historical buildings in this area are also built using the Deccan basalts.

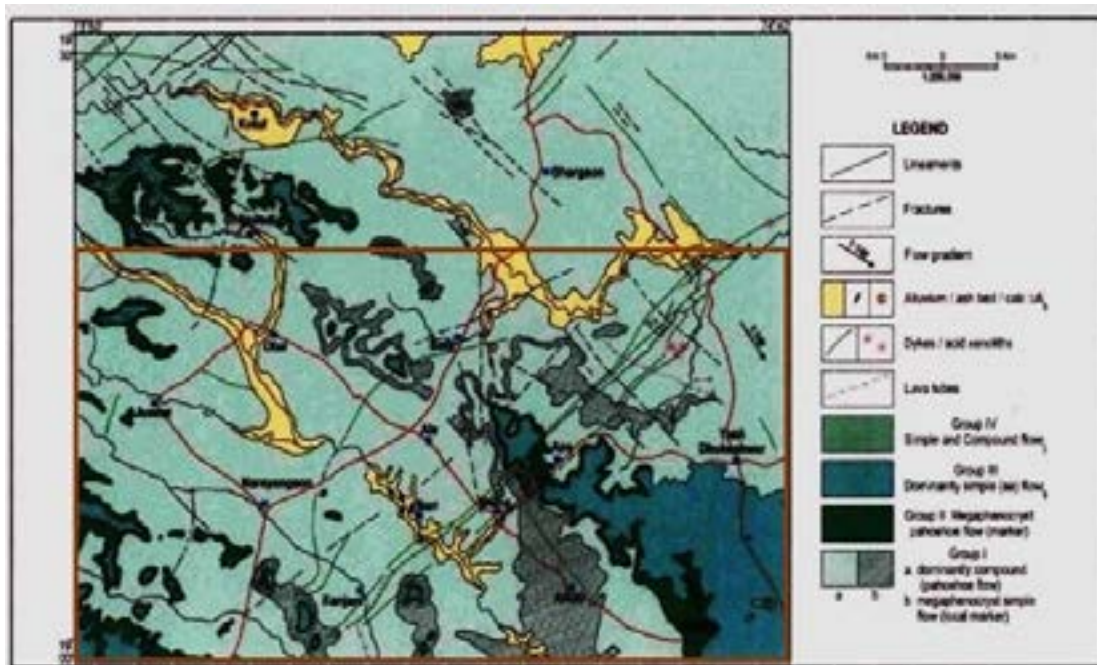


Fig. 1. Geological map on 1:250000 scale, compiled from District Resource Maps, GSI of Pune and Ahmednagar districts. The rectangular area defines the boundary of the Geopark.

Although the studies on Deccan traps date back to 1867, geoscientists started to critically examine the basalts only after the devastating Koyana earthquake in the late sixties. This led to extensive geological mapping and geophysical studies, resulting in a well-defined lithostratigraphy, chemo-stratigraphy, and magneto-stratigraphy (Ramakrishnan and Vaidyanadhan, 2010). The flows exposed in Pune and Ahmednagar districts belong to Ratangad Formation (Group Ia), of the Kalsubai Subgroup and Indrayani (Group III) and Karla (Group IV) Formations of the Lonavala Subgroup of the Sahyadri Group. Two Members, Alkuti GPB (Group Ib) and M3 Megacryst (Group II) which are a part of Ratangad Formation are also exposed in this area (Fig. 1).

The basalt flows are grey, greenish grey in colour, medium to coarse grained, hard, compact, jointed, with small vesicles and amygdalae. The lava flows were classified as pahoehoe and a`a flows because of their resemblance to the lava flows from Hawaii. This classification is based on their surface morphology, internal features, and style of emplacement. Pahoehoe flows are mostly compound in nature, while a`a flows are simple. Flows of transitional type are also documented. An understanding of the surface features and the internal characteristics of the two main types of basalt flows is essential to distinguish the flows in the field.

A`a flows generally have a rubbly, vesicular, fragmented surface composed of blocks of varied sizes, which is referred to as flow top breccia or fragmentary top. The vesicles here are stretched into irregular shapes. Within the massive interior of the flow, partially resorbed fragments of the crust are common. An impersistent zone of clinker marks the basal portion.

Pahoehoe flows are mostly compound in nature, with numerous bun shaped flow lobes/units. A typical flow unit/lobe has a zone of pipe amygdales at the base and a zone of spherical vesicles showing horizontal arrangement towards the top. The upper crust is glassy and often red in colour, with crudely developed ropes and chords. Vesicle cylinders, indicating escape of stream of volatiles are seen in the central core portion.

A. GEOLOGICAL SITES IN THE PROPOSED GEOPARK

The various geological sites in the proposed Geopark are:

1. Lava cave at Ghoradeshwar
2. Volcanic Ash bed at Bori
3. Natural bridge/arch at Gulunchwadi
4. Lava channel and xenolith bearing dykes at Kanherwadi/Masobajhap
5. Lava channel at Gunjale and Calc tufa at Vambori
6. Calc tufa at Wadgaon Darya
7. Giant potholes at Nighoj

1. Lava cave at Ghoradeshwar

Ghoradeshwar (18.69225°N: 73.70406°E) is situated 25 km northwest of Pune. It is located along with the old Pune - Mumbai highway, near Dehu town. This site is accessible by road or rail from Pune and Mumbai. The Ghoradeshwar rock-cut caves also known as Ghorwadi or Shelarwadi caves, are famous locally. These cave temples were originally Buddhist caves belonging to the Hinayana doctrine of Buddhism, which now contains carvings and statues of Buddhist and Hindu deities. It is believed that Saint Tukaram used to meditate in these caves.



Fig. 2. Lava cave, a drained lava tube (Pic: Nikhil Pawar).

In the same flow, on the southern flank of the hill, there is a natural lava cave, which is

formed from a drained lava tube. This lava cave is circular to semi-circular, and has a flat base. The cross-sectional pattern varies along its 20 m passage, with a small portion exhibiting a gothic shape (Fig. 2). Based on the dimensions and related flow morphology, this cave has been categorized as a small sub-crustal lava cave, formed by draining of an inflated pahoehoe lava flow lobe (Pawar et al., 2016). Lava caves are known to have served as homes and temporary shelters throughout history and are significant archaeological sites.

2. Volcanic Ash bed at Bori

Bori village (19.1126°N: 74.1038°E) is situated 87.5 km northeast of Pune, and 15.5 km from the nearest town Narayangaon. The site at Bori Khurd is on the banks of Kukadi River. It is one of the most impressive Quaternary sites, with ~ 8 m thick alluvial deposit, constituted of cemented gravel bar containing animal fossils (elephant tusk), Acheulian tools, and good exposures of Toba Volcanic ash bed at multiple locations. Toba Volcano is situated in Sumatra Island, Indonesia which is 3000 km southeast of Bori. Ash from this volcanic eruption had blanketed the Indian Peninsula and is preserved in numerous localities in the Indian subcontinent, Bori being one of them. This is one of the few discontinuous exposures of the Toba ash (tephra) bed in Maharashtra (Fig. 3). The volcanic ash/tephra bed from Bori was discovered in 1989 by Korrisettar and has emerged as a significant stratigraphic marker unit in the Quaternary sediments of Maharashtra.

Based on the analyses of fission track and trace elements of the glass shards, this tephra has been dated to 75 ka, Youngest Toba eruption (Kale, 2018). This is a remarkable Quaternary deposit site, with a river terrace, gravel bar, and exposures of volcanic ash and an excellent study area for students and scientific discourse.



Fig. 3. Volcanic Ash/Tephra bed.

3. Natural Arch and Dyke at Gulunchwadi

A natural arch formed in the pahoehoe flows of Ratangad Formation is observed in Ane Ghat, on Ahmednagar Kalyan highway near Gulunchwadi (19.1512°N: 74.2169°E), located 115 km north-northeast, from Pune. It can be reached by road from Pune. The arch occurs in Ardara Nala a tributary of the Kukadi River, that occupies an NNE-SSW trending fracture.

The arch at Gulunchwadi is formed in vesicular and amygdular flows (pahoehoe flows) and is 2-7 m high and 10-13 m across. The nala that flows below the arch, forms a waterfall and descends 7 m into a pool at the base. This arch is formed at the toe of a long spur, which occurs within a meander bend. The scouring along the contact of two flow units led to further undercutting, widening the stream course and, the opening was subsequently increased by rockfall from the rocky ledge, giving rise to the Natural arch we see today (Fig. 4).



Fig. 4. Natural Arch/bridge.

In addition to the natural arch, there are some good exposures of compound pahoehoe flows along the ghat road section. Two giant plagioclase basalts, Alkuti GPB and M3 Megacryst Member, which are marker horizons in the lithostratigraphy exposed along this road section. Alkuti GPB is a formational contact within the Ratangad Formation, while the M3 Megacryst occurs at the contact of two formations, Ratangad Formation, and Indrayani Formation, and two subgroups, the Kalsubai Subgroup, and Lonavala Subgroup. A NE-SW trending dolerite dyke intruding the lava pile is also visible at this site (Fig. 5).



Fig. 5. Dyke intruding a lava pile.

4. Remnants of lava tube and crustal xenolith bearing dykes at Kanherwadi / Masobajhap

Kanherwadi / Masobajhap (19.2355°N: 74.2953°E) is ~135 km from Pune. This village is situated northwest of Mandohal dam and Karjule Harya, off the Kalyan -Ahmednagar highway. The small hamlet, Masobajhap, adjacent to the hillock, with exposures of lava tube/channel is distinctly seen in Google images. The Google image shows the location of Masobajhap and the Mandohal dam (Fig. 6). NE-SW and NW-SE fractures control the drainage and the stream here exhibits bedrock incision, resulting in a deep gorge. A segment of the lava tube is exposed 4 km northwest of Mandohal dam near Masobajhap. This exhumed lava tube that can be easily spotted in the image resembles a lava river (Fig. 7). Lava tubes and channels, which are remnants of the lava transport system, were reported for the first time by Sharma and Vaddadi (1996). Lava tubes are conduits beneath the surface of solidified lava through which molten lava flows over large distances.



Fig. 6. Location of Mandohal dam and Masobajhap. (Google Image).



Fig. 7. Lava channel exhibiting sinuous pattern – Microsoft Image.

Morphologically, this lava tube exhibits a spectacular, sinuous disposition with brecciated, reddened accretionary levees forming the margins. These serpentine ridges, with a positive relief of ~25 m stand out in an area with a gentle topography. The average width of the lava tube is 30 to 50 m with a length of more than 8 km. The saucer-shaped base (Fig. 8) can be seen at many places along the length, but the roof is preserved only at a few places.



Fig. 8. Lava channel showing saucer shaped base.

The margins of the channel and the basalt in the central parts of the channel exhibit different characteristics. The margins are glassy, brecciated, indurated, and brick red to pink in colour; the interspaces between the fragments being filled with secondary minerals like scolecite, mesolite, calcite, and sometimes silica. The basalt in the centre is compact and jointed. The flows in this area and lava channel are intruded by dolerite dykes, which host upper crustal xenoliths (Sharma et al. 1999, Ghole et al. 2019).

5. Lava channel and Calc tufa in the Gunjale-Vambori area

A prominent lava channel/tube in pahoehoe flows is exposed in the Gunjale-Vambori area. Gunjale (19.2753°N: 74.7983°E) is situated ~23 km from Ahmednagar, off Ahmednagar–Aurangabad road.



Fig. 9. Panoramic view of lava channel showing the sinuous disposition.

The location can be reached from Pandrichapul or Vambori. The lava channel exposed in this area is spectacular, exhibiting sinuous disposition with brecciated, reddened accretionary levees forming the margins (Fig. 9).

The central/core portion of the lava channel exposed on the small mount, east of Gunjale village, is comprised of picritic basalt with nodules. The various features observed are massive compact basalt, fragmented basalt, reddened, indurated, and glassy basalt (Thorat, 1996; Misra et al, 2001). Reddened basalt occurring along the floor and margin of the channel is extensively quarried for building stone.

A Calc-tufa deposit resembling a frozen waterfall can be seen at Vambori, along a small cliff, at an elevation of about 640 m above MSL (Fig. 10). Vambori (19.2535°N: 74.7579°E) is ~23 km from Ahmednagar, along the Ahmednagar -Vambori Road. It can be approached from Aurangabad road, via Pandrichapul-Gunjale, or directly from Ahmednagar. This cliff is an indurated margin of the lava channel that can be traced from this location to the northeast of Gunjale village. The small spring-fed stream that plunges over the 6-7 m cliff is active during the monsoon period. The calc tufa is light brownish-white in colour, porous, friable, spongy, fine tubular, banded and dense. The precipitation here is mostly biogenic, formed on top of microbial sheaths and mats, and can be termed as Phyto-thermal tufa or micro-thermal tufa. The tufa deposits at Vambori have not been dated, but when compared to the calc tufa deposits occurring in the rest of Maharashtra, are likely to be of early to mid-Holocene age. (Kale, 2018).

The M3 Megacryst Member, a GPB flow separating the Ratangad Formation and Indrayani Formation can also be seen along Vambori ghat road.

6. Spring tufa at Wadgaon Darya

The prominent occurrence of Spring cum waterfall tufa can be seen at Wadgaon Darya (19.0928°N: 74.3364°E) which is located approximately 115 km from Pune, in Ahmednagar district. It is located on the Kanhur plateau (800 – 900 m above MSL), on the right bank of Padli Nadi, a tributary of the Kukadi River.



Fig. 10. Calc tufa deposit – Vambori.



Fig. 11. Calc tufa deposit at Wadgaon Darya.

Calc tufa is formed from springs that feed the rivers and along the rivers, where small rapids are formed. The tufa occurring here is brownish-white in colour, laminated, porous, and at places forms roof pendants within a small cave-like opening. There is a small temple located in this rock shelter. One can see the development of tiny stalactites on the roof and along the walls due to the precipitation of calcium carbonate.

Branches of wood, root casts form the nuclei for the calcium carbonate deposition. Leaf impressions like that of modern plants are seen in the calc tufa (Fig. 11). The leaves are

mostly of *Ficus glomerate*, which grows near springs. The source of calcium is from the dissolution of calcic plagioclase which is one of the dominant mineral phases in giant plagioclase basalt found in the area. The tufa from this area has been dated to 6.6 and 9.2 ka, and the calc tufa of upland Maharashtra has been dated to 8 – 10 ka, using the Uranium series method. The humid phase during the Early Holocene is suggestive of intensification of monsoon (Kale, 2018).

7. Potholes at Nighoj.

The gigantic potholes believed to be Asia's largest natural potholes are developed in the Kukadi riverbed, a tributary of the Bhima River at Nighoj (18.9319°N: 74.2627°E) which is ~90 km from Pune, in Ahmednagar district. The nearest town is Shirur though it can also be reached via Parner. The giant potholes are very famous and are a popular tourist destination. At this location, the river has incised a deep gorge 40-50 m deep, 6 to 10 m wide extending over a length of approximately 200 m. This rocky stretch, in the river bed, is marked by mega-potholes showing various stages of development. The basalt flows exposed in the area are highly vesicular and amygdular, hence shaped easily. The diameter or width of the individual potholes is 2-2.5 m, with a depth of 3 - 5 m or more. The smaller potholes coalesce to form giant potholes. The sidewall of the main gorge is 10-12 m and exhibits the development of multi-storeyed potholes (Fig. 12).



Fig. 12. Multi storied potholes at Nighoj.

8. Zeolites and Secondary minerals - Cavansite at Wagholi

Cavansite is a sparkling blue, beautiful, and rare secondary mineral found in the cavities of the basalts from the Wagholi area. Wagholi lies 25 km east of the city of Pune on the main Pune-Ahmednagar highway. Cavansite is named after its chemical composition, Calcium Vanadium Silicate. They occur as individual balls or as a cluster of balls

(Fig. 13) mostly in the highly vesicular and flow breccia and seldom in the dense, compact basalt. Cavansite is associated variously with pentagonite, calcite, mordenite, as well as the more familiar stilbite, heulandite, and pale green fluorapophyllite. This is one of the few locations in the world, after Oregon, where the mineral Cavansite and its polymorph pentagonite are found. The postal department released a special cover in 2018, with the Cavansite from Wagholi on it, in recognition of its importance.



Fig. 13. Cavansite with apophyllite and heulandite. (Pic: Gery Parent – CC).

B. SIGNIFICANCE AND INTEREST OF THESE AREAS

All the Geosites cited above occur in the Deccan Traps, which is unique in terms of its origin, and emplacement. These sites have immense scientific and educational value not only to students of Earth Science but also to the layman.

The lava cave at Ghoradeshwar reported for the first time in 2016 is one of the few sub-crustal caves that is well documented. The arch at Gulunchwadi is marvellous and can be appreciated by one and all. Besides, the arch, other geological features like flow morphology, dyke, and marker horizons defining contact of stratigraphic units are exhibited in a small area and can become an excellent study area for students pursuing Earth Sciences.

With excellent exposures of lava tube/channel, compound pahoehoe flows, xenolith bearing dyke, and fluvial geomorphic features, the area around Kanherwadi provides an excellent location for students of earth science to understand and appreciate aspects of flow morphology and physical volcanology. Being one of the areas from where the lava channels were reported for the first time in Deccan Volcanic Province, the area will be of interest to geoscientists on a national and international level.

Similarly, the Ash bed at Bori being one of the few exposures of Toba ash reported in India merits national, and international status. This is an excellent site to study the local geological and archaeological features of the area. Solution action and precipitation of calcium carbonate can be appreciated even by the common man at Vambori and Wadgaon Darya.

All the above sites are in close proximity to Pune and have all weather access. Consequently, they provide an excellent opportunity to demonstrate the unique features of volcanism, their associated features, and to showcase the evolution of various geological and geomorphic features unique to basalts. Besides, natural scenic beauty of the sites accompanied by archaeological and historical significance offer immense potential for tourism.

C. ARCHAEOLOGICAL, HISTORICAL, & CULTURAL SIGNIFICANCE

The various sites of archaeological and historical importance in the proposed Geopark are:

1. Pataleshwar cave temple
2. Shaniwar Wada
3. Junnar - Shivneri, Naneghat and Lenyadri
4. Dhokeshwar Cave temple.

1. Pataleshwar temple

The *Pataleshwar* cave temple (18.5268°N, 73.8507°E) also called *Panchaleshvar* is a rock cut cave temple, carved out in the 8th century in the *Rashtrakut* period. The temple is carved in basalt and is dedicated to the Hindu God *Shiv*. The main cave is rectangular on plan and has a pillared porch. There is an exquisitely carved circular *Nandi* shrine in the huge courtyard of the cave.

The umbrella shaped canopy of the *Nandi* mandapa is supported by massive square pillars (Fig. 14). The temple is carved in compound pahoehoe flows, belonging to Karla Formation. The internal morphology of the pahoehoe flow units – pipe vesicles, vesicle cylinders, and upper vesicular and amygdular zone can be seen on the walls in the porch and on the pillars. This cave temple has been declared as a protected monument by the government.



Fig. 14. *Nandi Shrine, Pataleshwar temple.* (Pic - Mukul Hinge).

2. Shaniwar Wada

Shaniwarwada (18.5195°N: 73.8553°E) is a historical fortification in the heart of Pune city, built-in 1732 (Fig. 15). It was originally the seven storeyed capital building of the Peshwas, built partly of brick and stone. There is an ancient well in the courtyard of the fort. During the Peshwa period, Pune had a marvellous canal system, which is a testament to exemplary engineering, administration, and city planning. The system of

cisterns, reservoirs, dipping wells (*Ooswas*), and underground artificial aquaducts (*Nal/Nahar*) constituted a dense network and has worked efficiently from 1750s to the present. Numerous cisterns were built on this aquaduct throughout the city, as means of water supply and some families in the old city area still use water from these underground canals. The gradual decline in the use of this system (Katraj system) started in 1879 when the Pune municipality took over the city's water supply system. This 270-year-old water source was rejuvenated by Pune Municipal Corporation to supply water to the Taljai hills in 2019.



Fig. 15. Entrance of Shaniwar Wada (Pic: Akashrail Cric).

3. Junnar and adjacent areas

Junnar (19.1666°N:73.886°E) is ~95 km from Pune, on the southern bank of river Kukadi, and is accessible by road from the Pune-Nasik highway. This town is encircled by hills, which consist of rock cut caves. According to the Archeological Survey of India (ASI), this is one place in the country, where you have the largest number (200) of caves. The caves belong to the Hinayana phase of Buddhism, of which some are now Hindu temples. The entire cave complex is divided into different groups based on their location. Some of the interesting ones are *Shivneri* caves, *Ganeshi* caves (*Lenyadri*), and caves at *Naneghat*. *Shivneri* caves occur on the steep slopes of the hill, on the top of which is *Shivneri* Fort. The rock cut caves are carved in compound pahoe-hoe flows.

a) Shivneri Fort

The Shivneri Fort (19.1990°N: 73.8595°E) is about 2-3 km from the Junnar town. It is a 17th-century military fortification and is the birthplace of Shivaji, the founder of Maratha Empire.

It was a place of Buddhist dominion from the 1st century CE, with rock cut caves and water cisterns. This group of caves is mostly small and plain, occurring at varying heights of the steep hill. Within the fort are a pond and two water springs. This fort was mainly used to guard the old trading route (*Naneghat*). The *Ganesh* caves (*Lenyadri*), which houses one of the *Ashtavinayak* temple is 2 km from the fort and has been declared a protected monument.

The majority of the flows exposed in the area belong to the Ratangad Formation. Compound pahoehoe flows are exposed all along the route to the fort and alongside the pathways in the fort (Fig. 16). Excellent exposures of GPB flows, with 2-3 cm long plagioclase phenocrysts are seen here.



Fig. 16. Pathway to Shivneri Fort (Pic: Mugdha Chimote).

b) Naneghat

The mountain pass *Naneghat* (19.29194°N: 73.67597°E), is 120 km north of Pune and 165 km east of Mumbai. It is an ancient stone laid hiking trail that stretches over western ghats (Fig. 17). According to the ASI it connected the seaports with the then capital Paithan and other economic centres like Nasik, Ter, etc. The term *Naneghat* indicates that it was a booth collecting toll from traders across the western escarpment; *Nane* (meaning coin) and *ghat* (meaning pass).



Fig. 17. Mountain pass *Naneghat* (Pic : Prajakta Kailas Jadhav).

This was first discovered by William Sykes in 1828, who reported large man-made caves, with stone seats near the top of the pass; which he concluded could be resting places for travellers. He has also described the inscriptions on the cave wall to be one of the oldest Sanskrit inscriptions.

c) **Lenyadri Caves**

The *Lenyadri* group of caves (19.24278° N: 73.58556° E) that are mentioned in the ancient inscriptions as *Kapicht* (beloved to monkeys) is also known as *Sulaiman* hill or *Ganesh Pahad*. The term *Lenyadri* means 'mountain cave' and is derived from *Leni*, in Marathi meaning cave and *adri* in Sanskrit meaning mountain. This group is constituted of 40 caves, of which the main group of 30 caves occurs in a line, facing Kukadi River to the south (Fig. 18).



Fig. 18. Lenyadri caves in a line facing south (Pic - Niemru).

They are numbered east to west. Out of these, Cave 6 and 14 are *Chaityagraha* (prayer halls) and the rest are *viharas* (monasteries). The main *Chaityagraha* is in Cave 6 and is comparable to the ones in Ajanta, Karla, Bhaja, etc., with a pillared veranda, apsidal hall with a Stupa at the rear. Out of the *Viharas*, Cave 7 is the largest, with twenty cells. The two central cells are joined, which houses the *Ganesh* image and is currently worshipped as one of the *Ashtavinayaks*. This group of caves dates back to the 1st – 3rd century CE. All the caves are carved in compound pahoehoe flows of Ratangad Formation. This site is a protected national monument.

With a large number of rock cut caves and inscriptions therein, Junnar is one of the foremost sites for studying rock cut architecture. Archeologically, anthropologically, and geologically too this site has immense significance.

d) **Dhokeshwar Mahadeva Cave temple**

Dhokeshwar *Mahadev* temple is located approximately 2-3 km from village Takali Dhokeshwar. The temple is on a hillock and is carved out in a cave and built sometime in the 5th – 6th century CE. The fortification around it was possibly built in the 18-19th century. The temple is dedicated to Lord *Shiv*, with beautiful sculptures, motifs, and animal figurines. There is also an empty *vihara* like cave, above the main cave. A water cistern is also present in the area. The cave temples are carved in compound pahoehoe flows of Ratangad Formation.

Numerous lava channels and tubes have been reported in the vicinity of Takli near Shikri, Kanherwadi (to the west), and Gunjale and Mulanagar (to the northeast). Hence it is surmised that the cave temple was in all probability carved out of an existing drained lava tube, that resulted in a lava cave.

D. SUGGESTED REMEDIAL MEASURES FOR GEO-CONSERVATION OF EACH SITE.

Unlike other nations, India lacks a national policy on the protection and preservation of national geoheritage sites. This is compounded by the lack of general awareness about geology and the significance of geological process which have taken place over millions of years. Unfortunately, even today, many geologists consider the Deccan Traps to be a mass of boring black rock with little significance.

A comprehensive action /management plan needs to be formulated in consultation with the various stakeholders like the local, state and national authorities, local population, NGOs, and academia to make this region a potential Geopark. A multi-pronged approach involving protection, conservation, education, popularisation (tourism), and finally legislation needs to be taken up.

As a first step, the local and state authorities need to be convinced about the importance of these sites and get them to initiate conservation by protecting these sites from illegal encroachments, quarrying, etc. Along with this, concentrated action to educate the local population on the importance and potential for revenue generation needs to be carried out. This can be done by out-reach programmes in schools and other educational institutes in the vicinity.

Encouraging tourism to such spots will help in rural development and revitalizing the local economy. Planned tours with specially trained guides from the local population will lead to increased employment. Homestays, selling local handicrafts and geological mementos can be encouraged. Signage boards need to be installed along the highways. Information boards with digital access (QR codes) can be installed at all such sites. In addition, basic infrastructure like clean toilets, inexpensive accommodation, and good eating places need to be developed.

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JAISALMER JURASSIC BASIN IN THAR DESERT- A POTENTIAL GEOPARK FOR SUSTAINABLE DEVELOPMENT IN RAJASTHAN, INDIA

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1. INTRODUCTION

Various facets of spectacular geodiversity and biodiversity together with cultural and built historical heritage deserve to be protected and conserved in the aridity affected region of Jaisalmer. The Jaisalmer Basin hosts unique and continuous rock records: the geological formations ranging from Lower Jurassic to the recently active dune sand deposits and characteristic biodiversity of dryland environment and other associated cultural attributes and the evolving desert landscapes have the potential for developing into a national Geopark (Wadhawan, 2016; 2020). The systematic promotion of geotourism with the application of modern concepts of conservation will enable optimal utilisation of natural resources and sustainable development of the local community. Some selected features of distinctive geodiversity, desert landscapes of dryland environment, biodiversity and Desert National Park (DNP), cultural heritage and ways forward for conservation through geotourism and sustainable socio-economic development of the community are elaborated in the following sections that eminently characterise and enable the development of Jaisalmer Geopark in Rajasthan, India.

2. GEOLOGICAL SUPERLATIVES OF JAISALMER BASIN IN THAR DESERT

The Jaisalmer Basin comprises mainly Mesozoic - Tertiary sedimentary basins that developed over the basement rocks of the Precambrian Malani Igneous Suite and Marwar Supergroup, that occur also as surface outcrops (Pareek, 1984; GSI, 2001). The Jaisalmer Basin formed part of the southern shelf of the Neo-Tethys Ocean during the Jurassic times. The area is well known for its rich geodiversity both in terms of landscapes and outcrops of rock types and the variety of fossils that these rocks have preserved. Litho-stratigraphy of the geologically mapped formations, namely, the Lathi, Baisakhi, Jaisalmer, and Bhadesar Formations is well established that displays an array of Jurassic siliciclastic, mixed carbonate-siliciclastic and carbonate rocks that range in age from Lower Jurassic to Upper Jurassic in geological time scale [200-146 Ma]. A variety of depositional environments ranging from continental fluvial to near-shore and off-shore deep marine are interpreted and well documented in the Jaisalmer basin (Fig. 1).

The sedimentary rocks of the Jaisalmer Basin are mainly sandstones, fossiliferous limestone, and shales, classified into four mapped Formations of the Jurassic age: Lathi, Jaisalmer, Baisakhi, Bhadesar; fossiliferous grits/sandstones and limestone; the two Formations of Cretaceous age include Pariwar, Habur. The Cenozoic age marine rocks comprising shales, bentonite, fuller's earth, fossiliferous limestone, and marl are categorised as the Sanu (Palaeocene); Khuiala and Bandah Formations (Lower to Middle Eocene). The Quaternaries are represented by the continental fluvial

sedimentary deposits of the Shumar Formation and aeolian sand dunes-calcareous clays and silts as playa deposits (GSI, 2001, Wadhawan, 1996).

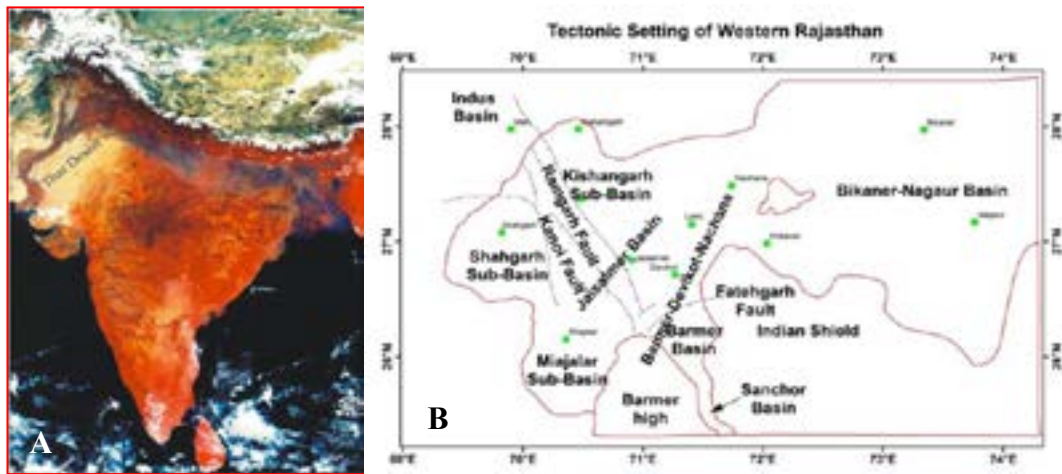


Fig. 1 A. IRS satellite image showing the location of the Thar Desert in India

Fig. 1 B. Sketch map showing Tectonic Setting of Jaisalmer Basin in western Rajasthan, India (Modified after Pareek, 1984).

The sedimentary rocks of the Jaisalmer Basin are mainly sandstones, fossiliferous limestone, and shales, classified into four mapped Formations of the Jurassic age: Lathi, Jaisalmer, Baisakhi, Bhadesar; fossiliferous grits/sandstones and limestone; the two Formations of Cretaceous age include Pariwar, Habur. The Cenozoic age marine rocks comprising shales, bentonite, fuller's earth, fossiliferous limestone, and marl are categorised as the Sanu (Palaeocene); Khuiala and Bandah Formations (Lower to Middle Eocene). The Quaternaries are represented by the continental fluvial sedimentary deposits of the Shumar Formation and aeolian sand dunes-calcareous clays and silts as playa deposits (GSI, 2001).

2.1 Fossil Wood Park at Akal

Jaisalmer sedimentary basin in western Rajasthan has preserved fossil evidence dating back to the Jurassic Period indicating a hot and humid climate characterized by dense forests. 180 million years old fossils of animals and plants are preserved at and around Wood Fossil Park at Akal, situated 18 km SE of Jaisalmer city. The fossil wood park at Akal was discovered by the Geological Survey of India and declared as a National Geological Monument in 1977 (GSI, 2001). It was maintained by GSI till 1985, thereafter handed over to the Forest Department of Government of Rajasthan. The fossil wood logs are considered to represent *Gymnosperms* fossils belonging to the *dicotyledonous stems* (Fig. 2). The Lathi sandstone also preserves leaf impressions of *Petrophyllum* sp. and *ptillophyllum acutifolium*, *Equisetites* sp. and some impersistent thin beds of lignite that are also found buried within the sandstone belonging to the Lathi Formation of Lower Jurassic age.

Several petrified fossil wood logs – old silicified tree trunks, occur randomly embedded within the coarse clastic sandstone that was deposited in a warm and humid fluvial environment bordering the sea during the Lower Jurassic period, i.e. 200-180 Ma ago. Here rocks of the Lathi Formation have a maximum thickness of 360 m and comprise a sequence of conglomerates and glauconitic sandstones unconformably overlying the Precambrian basement rocks of the Malani Igneous Suite, etc. The

conglomerate at the base grades upwards into a coarse ill-sorted arkosic sandstone containing nodules of hematite and thin impersistent lenses of lignite. Incidentally, these sandstones are also very good aquifers for storing potable quality groundwater in the region which is otherwise a water stressed dryland desert at present. The Lower Jurassic Lathi Formation is divided into two Members: Lower Odania Member and Upper Thaiat Member (Das Gupta, 1975). The lithology of the lower Odania Member of Lathi Formation comprises white and maroon sandy siltstone, coarse-grained sandstone, glauconitic sandstone, calcareous sandstone, dark ferruginous sandstone, coarse ill-sorted arkosic sandstone, and petrified wood logs in sandstone beds having cross-bedding and other fluvial sedimentary structures.



Fig. 2. Akal Fossil Wood Geoheritage site - the real Jurassic Park! [Lower Jurassic Lathi Formation] in Jaisalmer Basin - indicate that the Thar Desert, once hosted luxuriant forests and a variety of large reptiles in a tropical climate [hot and humid], bordering the sea some 180 Ma ago.

2.2 Trace Fossils in Akal Area of Jaisalmer Basin

The trace fossils are biogenic structures preserved on or within the sediments and are created by organisms during their various movements such as dwelling, crawling, feeding, resting, etc. They are widely used for the interpretation of the palaeo-environment of the sediments/rocks where they occur. Many trace fossils have already been reported from different Jurassic rock formations of the Jaisalmer Basin by various researchers. All these trace fossil species belong to *Skolithoes* and *Cruziana* facies which indicate that sediments of the Lower Odania Member of Lathi Formation of the Jaisalmer Basin were deposited in shallow water under high to moderate energy conditions that prevailed around Akal (Parihar, 2016).

2.3 Thaiat Ridge Scarp Section Near Thaiat Village

Thaiat Ridge Scarp (N26°55'50.1'', E71°03'54.2'') is about 16 km east of Jaisalmer city on the Jaisalmer – Jodhpur highway. The Lower Jurassic Lathi Formation is divided into two Members: Lower Odania Member and Upper Thaiat Member (Das Gupta, 1975). The geosite is important for two major aspects of geodiversity: 1) Record of terrestrial reptiles, dinosaur foot-prints (Fig. 3), freshwater elements (rootlets), brackish water shell fossils and marine body and trace fossils, gastropods, bivalves, etc. as palaeo-biodiversity; 2) The stratigraphic contact between the Lower Jurassic Lathi Formation and typical yellow coloured marine fossiliferous calcareous and arenaceous rocks of Middle Jurassic Jaisalmer Formation. This overlying Jaisalmer Formation consists of alternations of marine arenaceous limestone and calcareous sandstone with a fossiliferous oolitic bed at the top.

The Thaiat Ridge Scarp is also the type-section of the Thaiat Member (Upper Member) of the Lathi Formation. In contrast to sandstones of the Odania Member (Lower Member), the overlying Thaiat Member is characterised by fossiliferous siltstone with occasional cross-beddings, convolute beddings, and rippled surfaces. The section along the scarp consists of a sequence of red to brown siltstones at the basal part and yellow to grey, poorly cemented, fine-grain, often calcareous fine-grain sandstones and variegated sandy siltstones in the upper parts. The nature of sediments and fossils suggests deposition in brackish to marine, low to high energy water conditions. This section also reveals the first marine incursions in the Jaisalmer Basin during the early Jurassic period. The upper Thaiat Member is best exposed in scarp sections near Thaiat village and bands of sandstone and siltstone show cross-bedding and grading to siliceous limestone with trace fossils and dinosaurs/ reptile footprints (Mathur et al., 1985; Pandey et al. 2014; Pieńkowski et al. 2015). Besides the dinosaur footprints, this geosite presents a very significant geological history of the Jaisalmer Basin showcasing typical aridity affected and wind deflated landforms that must be protected for geotourists and educational and scientific research purposes.

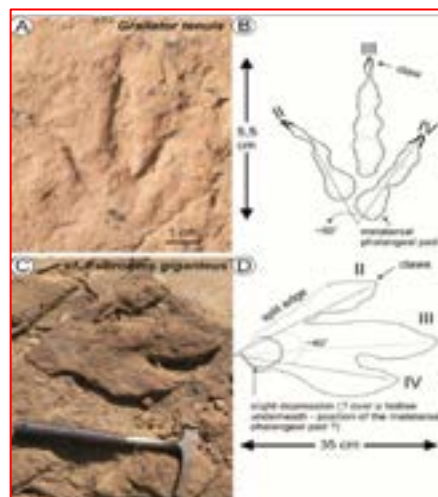


Fig. 3. Dinosaur foot-prints in sandy-siltstone rocks of Thaiat Member of Lathi Formation of upper parts of Lower Jurassic age, Thaiat Ridge, Jaisalmer [Photo courtesy Dr. D. K. Pandey].

Similarly, other richly fossiliferous type sections of different members of the Jaisalmer Formation that are well exposed at Kuldhara Member (Callovian age) and younger Badha Bag Member in the area preserve the petrified diverse ichno-fauna (Bathonian age), etc. These geosites also showcase other cultural heritage sites in addition to the desert landscape. Important amongst these are described below in the section under Cultural Heritage.

3. DESERT LANDSCAPE – VARIETY OF SAND DUNES, GRAVEL SPREADS, AND WIND DEFLATED RESIDUAL ROCKY GEOMORPHOSITES IN JAISALMER BASIN

Landforms in any desert have evolved through a long period of the interplay between fluvial and aeolian processes operative during wet and dry climatic regimes, especially during the Cainozoic Era. However, periodic tectonic activities have also influenced the evolution of the desert landscape in the Thar Desert. The desert landscape comprises a variety of stable and active dune fields including parabolic, linear, transverse, and barchans of different sizes and generations, desiccated rocky plains, desert pavements, and pebble-boulder spreads as deflation lag deposits and salt lakes and playas that are all present here in the Jaisalmer Basin.

3.1 Rocky Uplands and Desert Pavements

Sharply defined rocky uplands or residual hills are developed in arid environments as erosional landforms over horizontally disposed of sedimentary rocks in Jaisalmer Basin. Retreating cliffs produced a smaller table-topped mesa or a cuesta (Fig. 4). High-speed winds in the deserts perform two kinds of erosion work: abrasion and deflation. Loose sand particles lying on the ground surface may be lifted and rolled over thus carving striations and wearing out of edges or polishing, thereby forming sand blasted and faceted ventifacts. Wind deflation blows the sand across the desert surface to downwind destinations.



Fig. 4. Residual rocky uplands form cuesta landscape exposed to the north of Bhadesar (Jaisalmer Basin) the Thar Desert.

Desert pavements are formed when winds deflate the finer sand grains and the residual lag deposits of coarser clastic are left behind that may range in size from pebbles to small boulders (Fig. 5 A&B). These gravel spreads are called **reg** [Arabic for stones] or **serir** and form a protective armour layer of closely packed resistant clasts. Good geosites occur near Hamira, close to the Thaiat ridge, and elsewhere in Jaisalmer Basin.

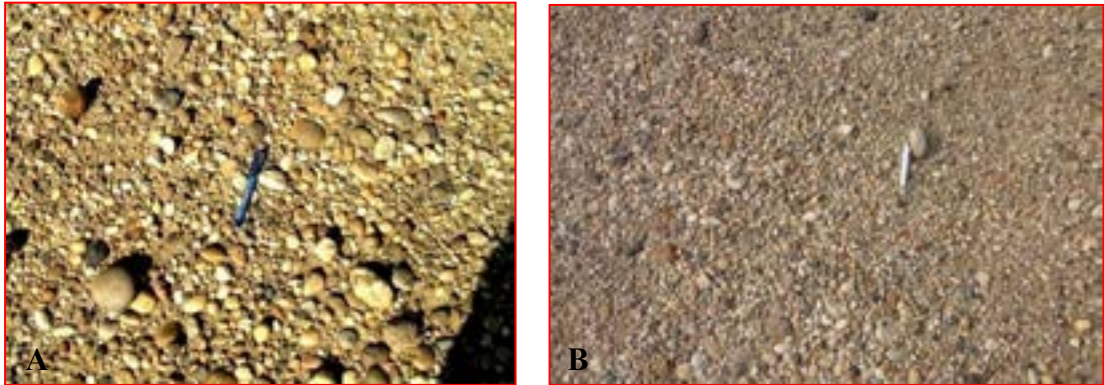


Fig. 5 A&B. DESERT STONY PAVEMENTS – gravelly spread or deflation lag deposits called Serir or Reg in Jaisalmer Basin, Thar Desert.

3.2 Ephemeral River Courses, Lakes and Playas

Owing to scanty rainfall, the deserts are generally devoid of any integrated surface water drainage courses. However, during exceptional heavy downpours, some channels incise their intermittent drainage routes through the aggraded sandy sheets that end up in inland basins. Closed lake basins in the deserts form important landforms in Jaisalmer Basin in the Thar Desert. Lakes and playas have existed in arid regions episodically throughout the Cenozoic. These saline lakes are the repositories of geological, geochemical, bio-geochemical information of the Late Quaternary – Holocene period. A number of inland *ranns* (ephemeral playa lakes), with a flat salt-encrusted surface that gets inundated during monsoon rains, are found within the desert. Some man-made storage tanks are also built near desert dwellings by damming the outlet of inland flowing centrifugal channels into a depression (Fig. 6 A&B).



Fig. 6 A&B. **A:** Desert inland Rann or ephemeral playa located amongst the stable dunes in Jaisalmer Basin. **B:** Gadsisar Sagar Lake: This Lake was built in the 14th century as a water harvesting and conservation reservoir in Jaisalmer, Thar Desert. Hundreds of migratory birds come to this place during winters every year.

3.3 Sand Dunes - Stabilised and Active Sand Dunes

Five basic dune types are recognized in the Thar Desert: crescent-shaped and transverse, linear, parabolic, star, and dome. Here the sand dune covered areas occur in three forms: simple (isolated dunes of basic type), compound (larger stable dunes on which smaller dunes of same shape type form), and more common- complex dunes (combinations of different types). Presently reactivated crestal parts of the older stable parabolic dunes support superimposed aeolian sands in the form of linear dunes as obstacle extensions or climbing and falling barchans, thus forming complex multi-storied aeolian deposits in Jaisalmer Basin in the Thar Desert (Figs. 7& 8).



Fig. 7. Complex Longitudinal dune field superimposed with active barchans, 25 km WSW of Jaisalmer (IRS satellite image).

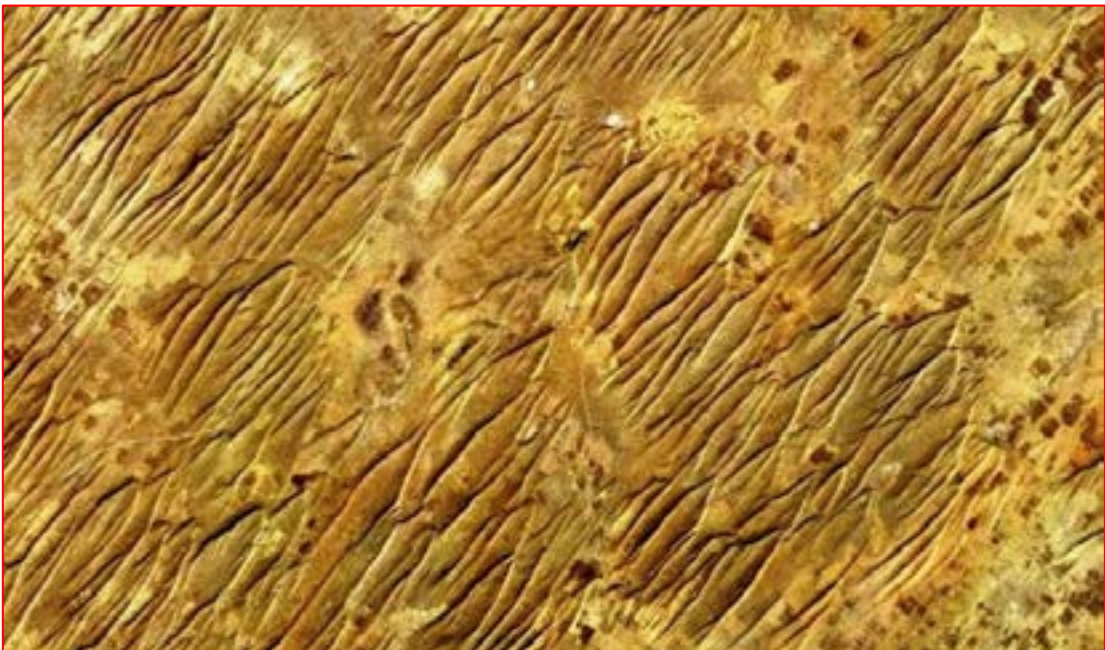
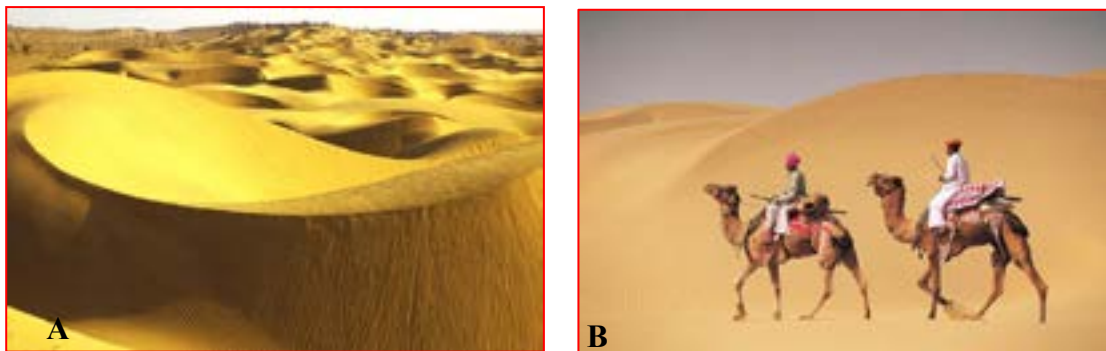


Fig. 8. Parabolic dunes in Thar desert over Jaisalmer basin (IRS satellite image).

A vast spread of active dunes within the DNP is made accessible to tourists in delineated dune fields around Khuri and near Sam which is located about 44 km west-southwest of Jaisalmer, in a region with ~150 mm annual precipitation. Active sand dunes with aeolian rippled surfaces show a variety of aeolian crescent shaped patterns at these famous tourist areas (Figs. 9 A&B). These golden clean sand sites are valued for its aesthetic view of sunset in the desert. The golden yellow quartz sands are well-sorted, fine skewed, and feebly calcareous. The mean grain size is 0.16 mm in the case of stable surface and 0.19 mm for the reactivated barchanoid dunes at the top (Wadhawan, 1996). A dune stabilization programme of reactivated dunes is being implemented here by planting *sewan* grass and other bushes - vegetation that thrives in dryland environment (e.g., *Lasiurus indicus* and *Crotalaria burbia*, *Acacia tortilis*, etc.). Recent TL/OSL dating of series of fossil dune deposits in the Thar suggests that intense aridity in the oldest aeolian deposits are 200 ka; whereas the latest dominant dune building activity here peaked at around 14 ka when the SW monsoon was gradually gaining momentum (Singhvi and Kar 2004; Dhir et al. 2018).



Figs. 9 A&B. Active golden sand dunes at Sam dune field in Jaisalmer Basin of Thar Desert.

4. BIODIVERSITY IN JAISALMER BASIN - DESERT NATIONAL PARK

Presently a delineated and protected territory of about 3162 km² constitutes a Desert National Park [DNP] as a rare and fragile ecosystem in the dryland environment of Thar Desert. Here the fragile dryland ecosystem supports unique and varied wildlife. The vegetation is sparse, and patches of *sewan* grass and *aak* shrubs (*Calotropis*) can be seen in abundance. DNP harbours a wide array of flora and fauna species and naturally supports the symbolic and protected Rajasthan State bird: Godawan – the Great Indian Bustard; animal: Camel; tree: *Khejri* and flower: *Rohida*. Despite a harsh water-stressed ecosystem, there is an abundance of birdlife. Sand-grouse, partridges, bee-eaters, larks, and shrikes are commonly seen. Perhaps the greatest attraction of the DNP is a sedentary bird called the Great Indian Bustard, a critically endangered species found only in India. DNP is one of the last sites where this species can be found in good numbers (Fig. 10 A). In addition to the great Indian bustard, the park supports a variety of other birds of interest to birdwatchers and conservationists alike (Fig. 10 A&B).

The Chinkara or Indian Gazelle (*Gazella gazella bennetti*) is a common antelope of this region. The national park's other notable inhabitants are the desert fox, wolf and desert cat, desert rats and reptiles including snakes, etc. Desert wildlife in this hot sandy desert habitat is vivid and spectacular in many aspects.

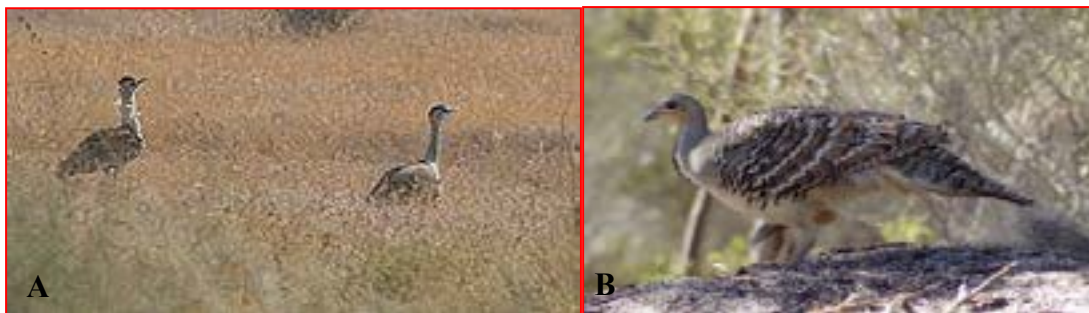


Fig. 10 A & B. Great Indian Bustards [*Godawan*] and Chestnut bellied Sand-Grouse at the Desert National Park, Jaisalmer Basin, Thar Desert.

5. CULTURAL HERITAGE, HISTORICAL FORTS, AND MONUMENTS

The rustic desert landscape, colourful and traditional cultural environment around Jaisalmer city also referred to as the ‘**Golden City**’ has been a major tourist attraction and a very satisfying experience in the core of Thar Desert. Jaisalmer is endowed with more than five hundred years of ancestral legacy, spectacular cultural and historical monuments – the heritage of geoengineering, traditional water conservation practices, all indicative of innovative adoptions of human settlements in dry harsh conditions of the desert.

5.1. Jaisalmer Fort – The World Heritage Site

Jaisalmer city in western Rajasthan was founded in 1156 AD. It is located within the western part of the Thar Desert and had been on a historical trade route between Delhi and West Asia. Jaisalmer is a former medieval trading centre and a princely state in the western Indian state of Rajasthan. The entire city is distinguished by its built architecture- utilising locally available dimension stones of yellow sandstone/siliceous limestone of Jaisalmer Formation of Jurassic age. Dominating the skyline is the Jaisalmer Fort built on a 100 m high Trikuta Hill that glows majestically with the evening sun rays (Fig. 11 A&B). It is a sprawling hilltop citadel buttressed by 99 bastions and recognised as a World Heritage site. The Jaisalmer Fort is a rare example of a “living Fort” as it is housing the descendants of the erstwhile courtiers and traders as inhabitants still living within the walled fort. Behind its massive walls stand the ornate Maharaja's Palace and intricately carved Jain temples. Several historical buildings called *Havelis* or the private mansions (Fig. 12 & 13) built by merchants have intricately carved yellow sandstone facades. Other tourist attractions include the Jain and Hindu temples built during the 12th and 15th century showing rare architecture and treasure of intricate carvings on rocks.



Fig. 11 A&B. Golden Fort within Jaisalmer City, built with yellow siliceous limestone of Jaisalmer Formation of Middle Jurassic age.



Fig. 12 & 13. Historical monuments and intricately carved façade on yellow limestone built-in for old *Havelis* and Badha Bag in Jaisalmer city – popular tourist destinations. Here the rocky uplands also support numerous Wind-mills – modern source of renewable energy.

5.2. Kuldhara - An Ancient Abandoned Village

Kuldhara- an ancient village settlement is located 20 km west of Jaisalmer city and exhibits ruins of a well-planned ancient human settlement that prospered till 1291 AD, but was abandoned for reasons not yet fully understood and authenticated (Fig. 14 A&B and 15). The huge human settlement laid out in the core of the desert provides an aura of serene, super-natural, and haunting impressions. Historical records suggest that the Paliwal Brahmins – a community of wealthy merchants, had established this settlement, but later shifted towards the comparative safety of Jaisalmer town. Kuldhara is situated along the northern bank of an ephemeral stream, the village has been declared as a protected State heritage/ historical monument. One can see temples, roads, houses, stone-lined steps-wells (Fig. 16), wooden structures used in the roof, water storage devices, and some of the utensils marking the way people lived amidst a dry and desert environment. It provides an interesting insight into contemporary land use, town planning, and civic layouts. Although the sacred deity is not preserved here under the *sanctum sanctorum*, the abandoned Hindu temples found in the village show tantric inscriptions and carvings of *Shaivite* affinity. A visit to this place is truly awe-inspiring.



Fig. 14 A&B. Abandoned ruins at Kuldhara village of over 400 years old, ancient settlements of Paliwal merchant clan near Jaisalmer.



Fig. 15. The 16th century Shaivite Temple with tantric carvings in stones – the fossiliferous Jurassic Limestone in the ancient city, over 400 years old, the settlement at the Kuldhara, Jaisalmer Basin.



Fig. 16. Traditional rainwater harvesting structure - A step well [recently renovated] leading to the deep-water table in the middle of the desert environment at Kuldhara, Jaisalmer Basin, Thar Desert.

Another interesting aspect is the construction of traditional man-made scanty rainwater runoff harvesting along sandy slopes and depressions, locally called as the ***Khadins***. Traditionally the Khadin system of runoff farming was designed and developed by the Paliwal Brahmins of Jaisalmer, Rajasthan in 15th century. A network of these seasonal water harvesting structures – the Khadin farming systems – are being practiced even now for dryland agriculture in the region around.

Besides the prevalent traditional water harvesting practices, the application of modern geotechnical knowledge in the dryland setting of western India has facilitated the

inter-basin transfer of perennial Himalayan fresh-water of the Himalayan Sutlej River through *Indira Gandhi Nahar Priyojna* – a system of canals and distributaries. These modern practices address issues affecting sustainable regional development and taming the desert environment for conservation of biodiversity, sand dune stabilization, improved agricultural productivity besides ensuring the availability of potable quality water for the human settlements in the Thar Desert. These are worth visiting and offer a great learning experience.

Recently, efforts have been made by the government to harness clean and renewable resources of energy in the hot, windy, and sunny Jaisalmer region. Accordingly, Wind-mills (Fig. 13) and solar Photo-Voltaic panels have been installed at various vantage sites that are an added attraction for the tourists.

6. CONCLUDING REMARKS

1. The Jaisalmer Basin in the Thar Desert has various integrated cultural, historical, biodiversity, and geoheritage sites and desert landscapes – all the necessary ingredients and the vibrant built-in infrastructure that are existing to utilise its potential for developing Geopark in west Rajasthan, India. The traditional bazaars, relaxed easy-going and remote natural ambiance, etc., showcase ideal palaeo-environmental settings in time and space and offer interesting themes for geoscientific research, education, training, and recreation. Therefore, it has immense scope and connectivity for the growth of geotourism that needs to be promoted for sustainable socio-economic development of local community and the region.
2. A comforting situation in the case of the Jaisalmer Geopark would be that many of the geosites are located well within the protected Desert National Park. The Rajasthan State Forest Department has been catering to the protection of bio-diversity ensured regulated entry of the public can also promote conservation of geodiversity.
3. There is an urgent need to improve and expand the prospects, identify, elaborate, and better manage Jaisalmer's geoheritage through geoconservation for comprehensive preservation of natural heritage, and promote utilisation of its potential through organised geotourism. Application of multi-disciplinary approach will necessarily entail a better informed geoconservation of abiotic nature attributes unique geoheritage and preserve pristine beauty of the desert landscape.
4. A formally declared Geopark has the potential to stimulate local socio-economic and socio-cultural development by attracting an increasing number of visitors. Therefore, there is a need to increase public awareness through setting up of interpretation centres, placing attractive signages and distribution of publicity material - through printed folders, hand-outs, booklets, guide books, *etc.*, through attractive TV shows and documentaries about geodiversity; producing informative web pages and, above all, training of geo-guides and DNP guards and field staff.
5. A well-stocked Geoheritage Museum with explanatory notes needs to be housed and fortified at the Akal Fossil Wood Park, Jaisalmer. Documentary films and video-talks can be screened for dissemination of geoscientific information about fossils and other elements of geodiversity. It provides value addition and the needed third dimension strengthened through conjunctive utilization of geodiversity together with biodiversity and the cultural heritage prevalent within the allocated resources.

However, a viable management plan with dedicated trained geoscientific personnel has to be put in place for regular maintenance and application of geoconservation practices.

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VISAKHAPATNAM: A POTENTIAL GEOPARK OF INDIA

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INTRODUCTION

Visakhapatnam District with its headquarters at Visakhapatnam is one of the North-Eastern Coastal districts of Andhra Pradesh. It is believed that the King of Andhra Dynasty built Visakheshwari temple near Lawsons Bay and named the place as Visakheshwaripuram, which subsequently came to be known as Visakhapatnam. The temple is supposed to have been submerged under the advancing sea. The District in the present form came into existence in 1979. It is bounded on the North partly by the Orissa State and partly by Vizianagaram District; on the South by East Godavari District, on the West by Orissa State and on the East by the Bay of Bengal. Visakhapatnam is well connected by road, rail, and air with all major cities of India.

Visakhapatnam is the largest city in Andhra Pradesh with an area of 550 km². It is an industrial and port city. It is also home to the Eastern Naval Command. The city is popularly called Vizag and is nicknamed as the ‘City of Destiny’. It is also referred as “Jewel of the East Coast of India”. It is endowed with rare natural splendour and is the only place in the Eastern Ghats where the sea and the hills meet. Visakhapatnam has a tropical wet and dry climate. The annual mean temperatures range between 24.7–30.6°C, with the maximum in the month of May and the minimum in January. Near the coast, the air is humid and moist, but gets warmer towards the interior and cools down in the hilly areas helped by elevation and dense vegetation. The months of April to June are the warmest. The Visakhapatnam District receives an annual rainfall of 1202 mm, of which south-west monsoon accounts for 72.0% while north-east monsoon contributes 13.9%. Visakhapatnam becomes quite unbearable in the summers because of its hot climatic conditions. The best time to visit Visakhapatnam is from October to March. During this time, the weather of the region is more pleasant and comfortable. December to February is the duration of winters in this region. In 2020, the district’s population was 45,74,261 while the Visakhapatnam city’s population is reported to be 21,75,000.

The Visakhapatnam District abounds in sites of scientific and historical significance. It is often called the best tourism destination in Andhra Pradesh. From lakes to cool beaches, from beautiful hill ranges to caves and valleys, Visakhapatnam has them all. Visakhapatnam District’s geological diversity ranges in age from recent to more than 1500 million years. Due to its archaeological and cultural tourist sites, Visakhapatnam has a great potential to become a member of the Global Geoparks Network (GGN) of UNESCO as discussed below.

GEOMORPHOLOGY AND GEOLOGY OF VISAKHAPATNAM DISTRICT

The District presents two contrasting Geographic divisions, viz. the Plains Division consisting of the coastal strip and the interior, and the Agency Division consisting of

the hilly area towards North and West. The Agency Division consists of the hilly regions covered by the Eastern Ghats with an average altitude of about 900 meters and is dotted by several peaks exceeding 1200 m. Armakonda or Seethammakonda, with an elevation of 1680 m, is the tallest peak not only in Visakhapatnam District but also in the entire Eastern Ghats.

A variety of geomorphic features are distributed in the hinterland and coastal plains of the Visakhapatnam District. The land systems can be classified as hills and hillocks, rolling plains, fluvial plains, and coastal zone (Raghavswamy and Vaidyanadhan, 1980). Visakhapatnam area is covered with denudational hills ranging between 30 and 594 m above mean sea level. In Visakhapatnam city, two hill ranges extend in the E-W direction (deviating from the general NE-SW trend of Eastern Ghats) viz. the Kailasa range (maximum height 506 m) which limits the city towards the north and the Yarada range (maximum height 356 m) is located on the southern side. These two ranges, separated from each other by a vast tidal basin, a few scattered hillocks, and portions of low land, terminate into the sea as promontories. The Dolphin's nose, famous for its shape resembling the fish Dolphin, is a promontory formed by Yarada.

High-grade metamorphic migmatite complex of the Eastern Ghat Mobile belt with rocks of the Precambrian age, characterized by meta-sediments and intrusive meta igneous bodies, occurs in Visakhapatnam District (Fig. 1). The chief rock types of the Eastern Ghats Supergroup, viz. Khondalites (Garnet – sillimanite – biotite gneisses), Charnockites (hypersthene granites), Leptynites (garnetiferous granites), quartzites and pegmatites, occur as bedded and banded as well as massive formations in the District. The Khondalite and Charnockite groups are exposed in the central part of the upland area. Besides these rocks, the area also consists of recent sediments such as red sediments with calcium carbonate calcretes, dune sands, and beach sands with economically important black sand concentrations in the coastal plains.

The District comprises a variety of mineral resources including quartzite, graphite, manganese, titanium, silica sand, and 1,000 MT of bauxite reserves.

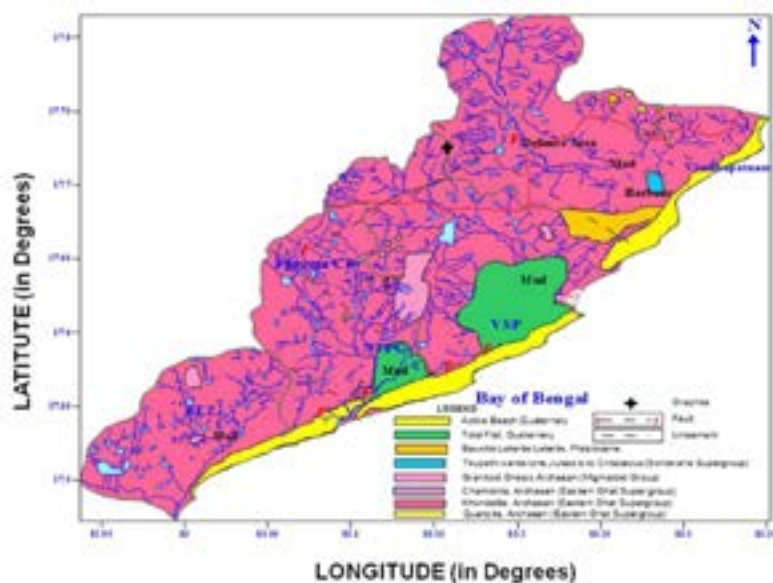


Fig. 1. Geological map of Visakhapatnam District (Ratnakar et.al., 2015).

IMPORTANT GEOLOGICAL AND GEOMORPHIC SITES

The important geological and geomorphic sites in the district are Erra Matti Dibbalu, Coastal geomorphic features including Natural Arch, beaches, *etc.*, in the Visakhapatnam sector and Borra caves, Bauxite deposits, Araku valley, Araku ash bed, *etc.* in Borra - Araku sector. The satellite map of Visakhapatnam is presented in Fig. 2.



Fig. 2. Satellite Image of Visakhapatnam (Resourcesat-1: LISS-III).

1. Erra Matti Dibbalu – The National Geoheritage Site: Coastal red sand dunes, popularly known locally as “Erra Matti Dibbalu”, are a prominent feature occurring over 10 sq. km in the coastal area (Figs.3&4), located about 20 km northeast of Visakhapatnam city and about 4 km southwest of Bhimuniapatnam (King 1886). This is a highly picturesque and popular tourist spot, and many movies have been shot in this area. Such sand deposits are rare and have been reported only from three places in the tropical regions in South Asia, viz, Teri sands in Tamil Nadu and Erra Matti Dibbalu in Visakhapatnam from India, and one from Sri Lanka. They do not occur in equatorial regions or temperate regions due to many scientific reasons (Gardner, 1995).

These red sediments are a part of the continuation of the evolution of the earth and represent the Late Quaternary geologic age. With a height of up to 30 m, they exhibit badland topography with different geomorphic landforms with features including gullies, sand dunes, buried channels, beach ridges, paired terraces, the valley in the valley, wave-cut terrace, knick point, and waterfalls. (Vaidyanadhan, 2012).

These sediments are unfossiliferous and deposited over the khondalite basement. The dunes comprise a light yellow sand dune at the top followed by a brick red sand unit, a reddish brown concretion bearing sand unit with yellow sand at the bottom. The earlier studies indicate that the bottom-most yellow sand unit is fluvial while the other overlying three units are aeolian in origin. The thickness of these sand units is variable in the area (Rao *et al*, 2006). At the initial stages of their formation, the mineralogy of these sediments was similar to the modern dune sands which subsequently underwent chemical alteration by leaching of unstable iron-bearing minerals like garnet, because of which the sediments got reddened. The top light-yellow sand unit, estimated to have been deposited around 3000 years ago, could not attain the red colouration as the sediments were geochemically unaltered.

Calcareous concretions recorded in the red sediments are dated to be 5840 +/- 170 and 5810 +/- 120 years (Rao *et al*, 1982). The studies indicate that the area was tectonically active during the 2.5 million years to 11,000 years ago (Madabhushi, 2003) and the sediments are mainly derived from the khondalite suite of rocks from the hinterland Eastern Ghats (Reddy, 2015). Geologically these red sand dune sediments are very important as they are the result of the combined effect of numerous factors including global climatic changes, sea-level variations, monsoonal variability, etc., and thus serve as valuable paleoenvironment indicators.

Two National workshops were organized during February 2012 and May 2013 by the Geology Department of Andhra University and INTACH in which the scientific significance of the area was highlighted, based on which an appeal was made to the Geological Survey of India (GSI) for declaring the area as a 'National Geoheritage Monument' (Reddy and Sarma, 2012; Reddy, 2013). The GSI declared the area as National Geoheritage Site in 2014 and Andhra Pradesh State Government notified the area as a Protected Geoheritage Site in 2016. (Reddy, 2020).

The area is important from an archeological point of view also. Archaeological studies of artefacts in the compact dark yellow coloured Erra Matti Dibbalu indicate an Upper Paleolithic horizon and on cross dating assigned to Late Pleistocene Epoch c. 20,000 BCE. It is interesting to note that the region was also the home to the pre-historic man as the excavations dug at several places in the region revealed stone implements of three distinctive periods and also the pottery of the Neolithic man (Reddy *et al*, 1999).

2. Coastal tract of Gangavaram - Visakhapatnam - Bheemunipatnam: The beautiful 40 km coastal stretch between Gangavaram (about 10 km south of Visakhapatnam) and Bhimili (about 30 km north of Visakhapatnam) is endowed with a variety of marvellous beaches (Fig. 5) viz. sandy, rocky, bay, pocket beaches with diverse landforms, such as, sand dunes, promontories, wave-cut platforms, stacks, natural bridges, *etc.* in different sub-environments of the beaches viz. foreshore, backshore, berm, and sand dunes. The beach sands comprise minerals of different

colors, such as quartz, garnet, sillimanite, monazite, rutile, zircon, *etc.* derived from the khondalite suite of hinterland eastern ghat rocks. The proportion of these minerals imparts different hues to the beaches at different places and they change in space and time and make the beaches look more beautiful.



Fig. 3. Panoramic view of Erra Matti Dibbalu.



Fig. 4. Erra Matti Dibbalu showing deep gully erosion of stabilized aeolian sands.

2a. Natural Arch (Fig. 6) developed in the Mangamaripeta beach by the action of waves and currents on the khondalite rocks has a very high educational value in understanding the process of development of such features several hundred million years ago like the Natural Arch on Tirumala Hills – a declared National Geological Monument. It is a classic example of a Geologic Dictum – Present is a Key to the Past.

2b. Wave cut Platforms/wave cut benches (Fig. 7), which are the result of continuous wave action on the rocky cliffs and promontories of the headland, occur in the areas near Rushikonda, Ramadri, and Thotlakonda. There are paleo wave-cut platforms at Gangavaram and near Tenneti Park at about 10 m higher than the

present-day sea level, indicating that they might have formed either due to uplift of the coast or subsidence of the sea basin or a combination of both the processes.



Fig. 5. Visakhapatnam Beach (Source: Google images – industrialtours.com).



Fig. 6. Natural Arch at Mangamaripeta Beach, Visakhapatnam, a product of marine erosion.

A variety of coastal geomorphic features such as sea stacks, sea caves have been formed at many places along the rocky coastal stretches at Gangavaram, Rushikonda areas.



Fig. 7. Wave Cut platform at Thotlakonda.

2c. Serpentine Hood Structures (Fig. 8): These structures are formed by the continuous pounding of sea waves causing concave snake hood like structures. (Garner 1974). These structures occur along the coast at Gangavaram, Rushikonda, etc. both at the present-day sea level indicating their recent formation and at about 15 m above MSL indicating their formation in the past when the sea levels were higher.



Fig. 8. Serpentine Hood structures near Thotlakonda beach.

2d. Promontories, a long narrow area of highland that goes out in to the sea: A number of promontories are observed in Kailasa hill, Yarada hill, and Thotla Konda hill.

3. Wind Gap: About 1.5km wide wind gap occurs along the Kailasa hill range at Venkojipalem, which is believed to have been formed by a river that some time back lost its waters to a stream flowing east, probably by headward erosion.

Borra – Araku Sector

4. Volcanic Ash deposit (Fig. 9): Volcanic tephra recorded in the Patal River in the Araku valley is supposed to have been transported from the Indonesian Toba volcanic eruption that took place 74000 years ago. The feature is scientifically exciting because the youngest volcanic Toba Tephra (YTT) travelled thousands of kilometers crossing the Bay of Bengal and got deposited in the Indian river valleys and is preserved. It is one of the biggest volcanic eruptions of the past two million years. The global environmental impact of the ash and gas clouds from this ‘super-volcano’ – known as Toba – is considered by some scientists to be the most catastrophic event the human species has ever endured. It had an estimated volcanic explosivity index of 8 (maximum). At least 2800 cubic kilometers of volcanic material was ejected during this super eruption. The erupted mass was 100 times greater than the largest eruption in the world. This is called Youngest Toba Tuff (YTT). The YTT explosion instantly destroyed all life in its immediate area with intensely hot flows accompanied by deafening noise and powerful tsunamis. When the ash began to fall, it covered the Indian subcontinent. Its effect on climate and human evolution needs to be investigated in detail, particularly in India. The Toba eruption has been linked to a genetic bottleneck in human evolution about 50,000 years ago, which might have resulted from a severe reduction in the size of the total human population due to the effects of the eruption on the global climate.



Fig. 9. Volcanic Ash layer, Patal River, Araku valley, from the Indonesian Toba volcanic eruption, 74,000 BC.

5. Borra caves and Araku valley: Borra caves and Araku valley are very popular tourist sites at a distance of 90 and 115 kms, respectively, by road from Visakhapatnam. The train journey to Borra and Araku Valley is the most enjoyable as the rail passes through tunnels, hillsides, and streams. It is better to go to Araku by train and return by road. The Borra caves were discovered by William King, of GSI in 1807 and are believed to be about 150 million years old.

The **Borra Caves** (Fig. 10) are located in the Ananthagiri hills of the Araku Valley. The caves, one of the largest in the country, at an elevation of about 705 m, are deep and aphotic. They are basically limestone drained by the Gosthani River resulting in a variety of karstic limestone structures extending to a depth of 80 m. These are considered the deepest caves in India and exhibit speleothems stalactites, stalagmites, and columns.

Archeological studies have unearthed stone tools of middle Paleolithic culture dating back to 30,000 to 50,000 years, which confirm human habitation.



Fig. 10. Borra caves entrance (Source: Google images – Wikimedia commons).

6. Araku valley (Fig. 11) is splendid with scenic beauty and a famous tourist hill station owing to its excellent climate. The best time to visit the Araku Valley is in the winters from December to February when the temperature drops down to five degrees Celsius. The Valley is doubly enchanting amid the magic of the winter air. With pleasant days and cool nights, all sightseeing activities are best done during this time of the year. From June to October Araku gets extensive rainfall during the monsoon.

Besides being a hill station, Araku is also famous for coffee plantations and Dhimsa, a tribal dance. There are many interesting tourist spots in Araku which include Katiki,

Chaparai and Tadimada waterfalls, Matsyagundam, Tribal Museum, Padmapuram gardens, etc. One of the main attractions is treetop cottages located in the middle of the green surroundings of the Araku valley. These tree hanging cottages are ten feet above the ground level and one can experience rare swing along with trees. Tyda nature camp located at a distance of 75 Km from Vizag on the way to the Araku valley is the right place for bird watching, rock climbing, trekking, and overnight stay.

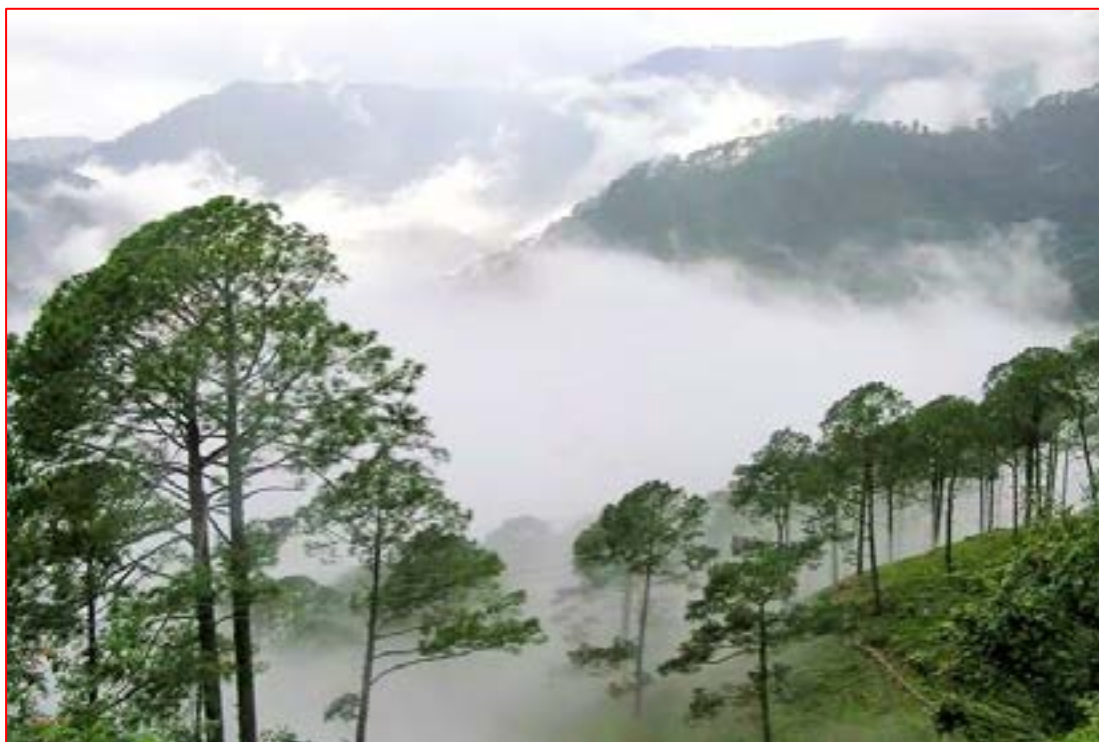


Fig. 11. The enchanting Araku valley– a tourist paradise (Source: Google images – lbb.in).

7. Bauxite deposit (Fig. 12) in Andhra Pradesh is one of the largest bauxite deposits in the world and an indicator of paleoclimatic and paleogeographic influence in the geochemical alteration of various minerals resulting in the enrichment of aluminium hydroxides. It is reported that the bauxite deposit is post Mio-Pliocene age. Though the host rocks of bauxite occur in the entire Eastern Ghats, the bauxite deposits are formed only in selected areas due to various other controlling factors like geomorphology, climate, etc. It is interesting to observe and study the bauxite profile from the bottom fresh/unaltered host rock to the top bauxite capping with various intermediate stages of geochemical alteration.

Bauxite cappings of variable extent and thickness occur on several hilltops. The important Bauxite deposits are in the areas of Galikonda, Chittamgondi, Araku and at Gudem and Sapparla, and in the Chintapalle area. The alumina in the ore ranges from 45% to over 51 %. Some more cappings are also reported in Minimuluru and Anantagiri areas. In 2019, the Andhra Pradesh Government banned the mining of bauxite in the state due to local tribal agitations on environmental concerns.

IMPORTANT ARCHAEOLOGICAL SITES

The archaeological value of the Visakhapatnam district is manifested in various recognized Buddhist sites such as Thotlakonda, Bavikonda, Pavurallakonda, and Bojjannakonda. Coastal Andhra Pradesh has perhaps the maximum number of Buddhist sites in the country. The Andhra Pradesh State Archaeology Department has carried out excavations which brought to light Buddhist Sangharamas that flourished from 3rd Century BCE to 3rd Century CE. These finds have great importance for the study of Buddhist remains in India as they are distinctly different from the Buddhist finds elsewhere in the country.



Fig. 12. Bauxite Mining (Source: Google images -fresherslive.com).

8. Thotlakonda

Thotlakonda (17°49'33.82"N, 83°24'37.68"E) Buddhist Complex (Fig. 13) is situated about 15 kilometers from Visakhapatnam near Bheemunipatnam, on a hill (128 m above MSL) overlooking the sea. The Telugu name Thotlakonda is derived from the presence of a number of rock-cut cisterns hewn into the bedrock of the hillock. Thotlakonda was well within the influence of ancient Kalinga, which was an important source of dissemination of Buddhism to Sri Lanka and various parts of Southeast Asia. It provides an insight into the process of transoceanic diffusion of Indic culture, especially Buddhism.

Excavations conducted by the State Archaeology Department of Andhra Pradesh during the period from 1988 to 1993 established the existence of a Hinayana Buddhist complex which flourished 2000 years ago. The excavations reveal nine Satavahana dynasty lead and five Roman silver coins indicating foreign trade; terracotta tiles, stucco decorative pieces, sculptured panels, miniature stupa models in stone, and Buddha footprints, twelve inscriptions in the Brahmi script. Thotlakonda complex is beautifully constructed with a magnificent structural design having circular Chaityagriha (prayer hall), a congregation hall, Viharas (cells for monks), a Bhandagara (store room), Kappiyabhumi (kitchen), and dining hall to tender peace and harmony to monks.

Thotlakonda's peak activity was between the 2nd BCE and the 2nd century CE and declined by the end of the 3rd century CE. Thotlakonda came into existence along with nearby sites in Visakhapatnam like Bavikonda and Pavurallakonda. There are rock-cut cisterns in various sizes, obviously for the storage of water to meet the requirements of the monks. Thotlakonda might have accommodated more than 100 *bhikkhus* with required facilities and served as a religious-cum-academic centre. Nikaya Buddhism appears to have been practiced here, including the worship of Gautama Buddha. The Buddhist monks arriving from China, Burma, and many other countries would stay at this site for months before finishing their learning.

The government of Andhra Pradesh is taking steps to spruce up the Buddhist heritage site without disturbing its sanctity.



Fig. 13. Thotlakonda Budhist Monastery (Source: Google images: Wordpress.com).

9. Bavikonda

Bavikonda (17°49'3.71"N, 83°23'27.46"E) Buddhist Complex (Fig. 14) lies about 16 km from Visakhapatnam, on a hill about 130 meters above mean sea level. The term Bavikonda in Telugu means a hill of wells. As per its name, there are wells for the collection of rainwater on Bavikonda. It flourished as a Buddhist monastery between the 3rd century BCE and 3rd century CE.

The Andhra Pradesh State Archaeological Department has unearthed a large Buddhist complex at this site with remnants, such as, a piece of bone stored in an urn supposed to be one of the remains of the Buddha, inscriptions, Maha Chaitya, several Votive Stupas, Chatiya Grihas, a Congregation hall, a Kappiya Bhoomi, a Bhandagara, several manmade ponds, and a few rock cut cisterns. Among the important finds were three Roman silver coins and one Satavahana lead coin, indicating trade relations between the East coast of India and the Mediterranean coast.

The Bavikonda Buddhist site is an extremely important site not only in Andhra Pradesh but in the entire country. The Buddhist sites of Thotlakonda and Pavuralla Konda are situated close by to Bavikonda.



Fig. 14. Bavikonda Buddhist complex (Source: Google images– Native Planet.com).

10. Pavurallakonda

Pavurallakonda (17°53'19.94"N, 83°26'16.25"E; about 150m above MSL) (Fig. 15) is the local name of a hill, popularly known as Narasimhaswamy Konda, near Bheemunipatnam, about 25 km north of Visakhapatnam. Pavurallakonda consists of a ruined hill-top Buddhist monastic complex dated to be between the 3rd Century BCE and 2nd century CE. It is one of the largest Buddhist Monasteries of the North Coastal Andhra Region featuring Hinayana Buddhism.

Excavations at this site by the state Archaeology Department yielded many relics. Two Brahmi label inscriptions, foundations of Viharas, circular chaityas, votive stupas, halls, *etc.* are located among the ruins. Coins, polished ware, beads, *etc.* were also recovered from the site. Sixteen rock-cut cisterns are carved on the hill for the storage of rain water. Presently the Excavations and Restoration Programme are under progress at Pavurallakonda.

11. Bojjannakonda

Bojjannakonda (17°42'37.07"N, 83° 0'57.62"E) (Fig. 16) and Lingalakonda are two Buddhist rock-cut caves on adjacent hillocks, situated near a village called Sankaram, which is 3 km away from Anakapalle and 40 km from Visakhapatnam. The double

storeyed cave on Bojjannakonda was originally known as Buddina Konda. The hills contain numerous monolithic stupas, rock-cut caves, chaityas, and monasteries forming one of the most remarkable Buddhist establishments in Andhra Pradesh. It is believed that the site was a place of worship 2000 years ago. It is visited by Buddhist monks and tourists from Sri Lanka, Vietnam, Kampuchea and some other countries.



Fig. 15. Pavuralla Konda Buddhist remains (Source: <http://wikimapia.org/>).

Bojjannakonda was excavated in 1906. Interestingly this site features all three phases of Buddhism i.e. Hinayana, Mahayana, and Vajrayana. During excavations from this area pottery, seals, terracotta inscribed tablets, terracotta beads, and terracotta figures, one gold coin belonging to Samudra Gupta of the Gupta dynasty who ruled Magadha from 340 to 375 CE, some copper coins belonging to the Eastern Chalukya king Vishnuvardhana (633 CE) and one lead coin belonging, perhaps, to the later Satavahanas, were recovered. Based on these evidences, the Buddhist settlements here are believed to date between the 2nd and the 9th century CE when Buddhism was the majority religion of Sankaram (Sangharam as it was called then).

The Indian National Trust for Arts and Cultural Heritage, (INTACH), has appealed to the authorities for better protection of Buddhist sites and for pursuing UNESCO for the declaration of Bavikonda, Thotlakonda, Pavurallakonda, and Bojjannakonda as heritage sites.

12. Lingala Konda

The western hill or the Lingala-Konda (Fig. 17) is covered with a large number of rock-cut stupas. Numerous antiquities were recovered during the excavations

conducted during 1907-08 on both the hills. Pottery, coins of gold, copper, and lead; seals, terracotta inscribed tablets, terracotta beads, and terracotta figures, a stone image of Hariti, one gold coin belonging to Samudra Gupta of the Gupta dynasty were recovered from this site. Some copper coins belonging to the Eastern Chalukya king Vishnuvardhana surnamed Vishamasiddhi (633 CE) were also obtained. One lead coin was also found. It is on the evidence of these antiquities that it has been possible to date the Buddhist settlement here to be between the 2nd and the 9th century CE.

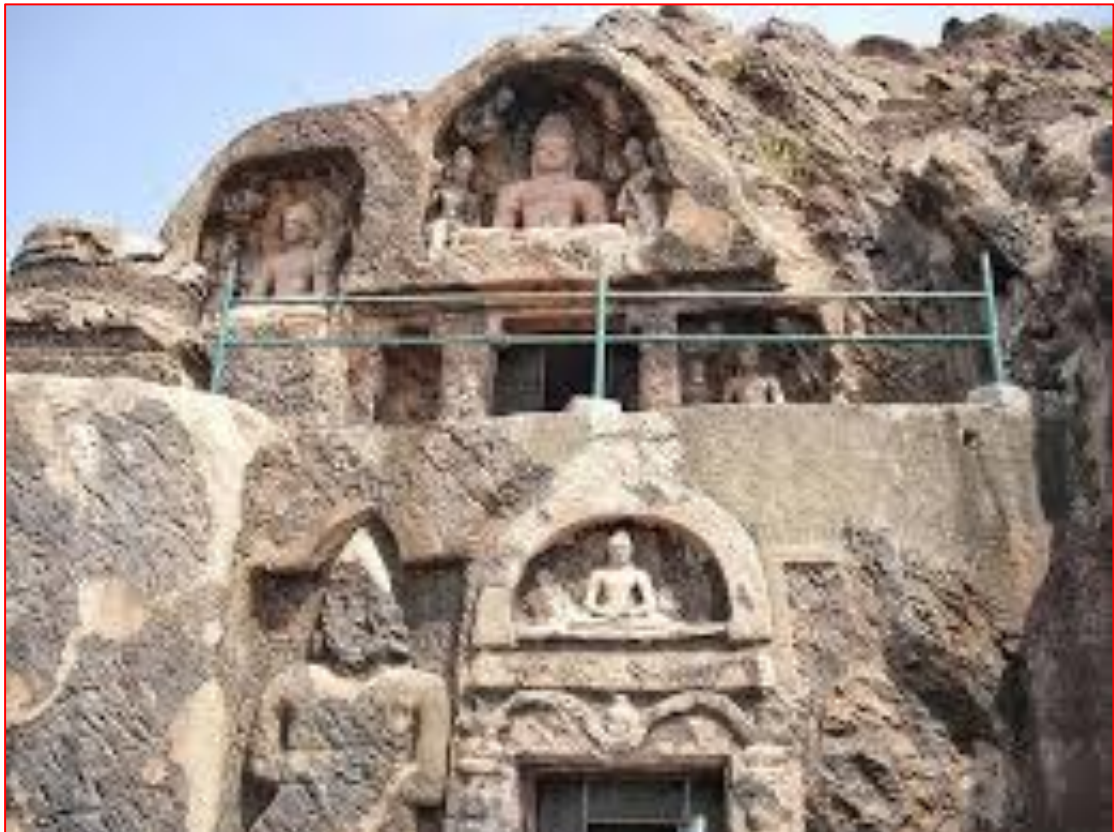


Fig. 16. Bojjanna Konda Buddhist site (Source: Google images Ethno travels.com).

WILDLIFE SANCTUARY

13. The Kambalakonda Wildlife Sanctuary (17°49'34.78"N, 83°18'15.19"E) (Fig. 18), is a popular tourist attraction near Visakhapatnam. Wildlife sanctuaries are protected areas established by IUCN category IV. The Kambalakonda Wildlife Sanctuary is situated in the heart of Visakhapatnam City and is spread over an area of 71.39 sq. km. Eco-Sensitive Zones (ESZs) are areas notified around Wildlife Sanctuaries by the Ministry of Environment, Forests and Climate Change (MoEFCC), Government of India. The Eco-sensitive Zone around Kambalakonda wildlife sanctuary extends up to 4.33 kilometer from the boundary and is spread over an area of 30.51 square kilometers in Visakhapatnam District

The Sanctuary harbours a large variety of flora and is characterised by a scrub jungle. The major tree species of the area are *Ficus banghlensis*, *Acacia lucophloea*, *Acacia chundra*, *Sapindus emarginatas*, and *Wrightia tinctoria*, etc. The Sanctuary maintains

very rich bio-diversity comprising a number of species of trees, herbs, shrubs, climbers, bamboos, and grasses. The area harbours a rich faunistic diversity which includes panther, bear, wild boar, sambhar, barking deer, mouse deer, spotted deer, jackal, wild dog and birds.

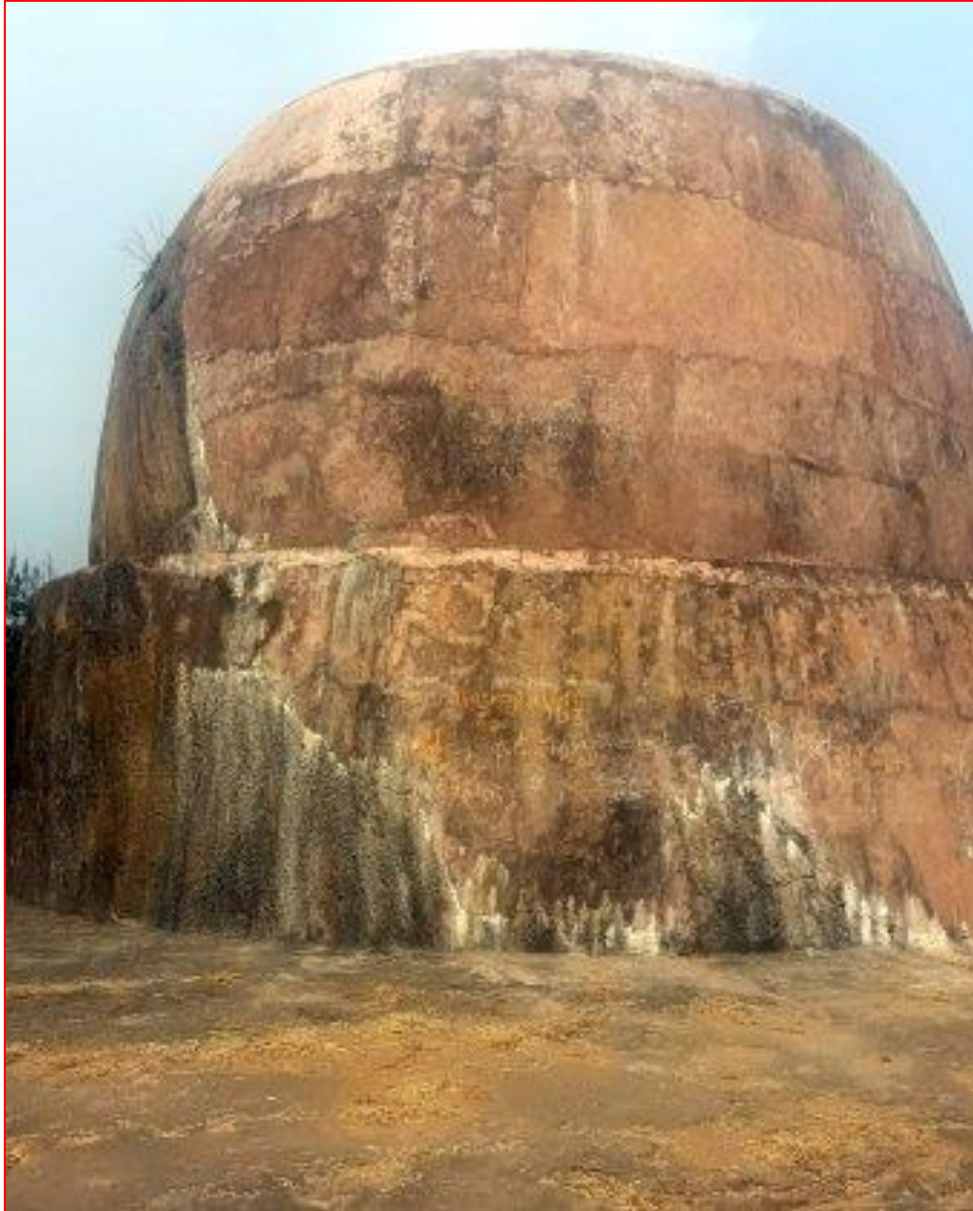


Fig. 17. Lingala Konda Budha Stupa (Google images – tripadvisor.in).

HISTORICAL CULTURAL SIGNIFICANCE

14. Old Cemetery at Visakhapatnam - A testimony to the first ever Naval war and First Sepoy Mutiny of India in 1780 at Visakhapatnam: Old records refer to this cemetery as “Old cemetery” or “European Cemetery”. It is sometimes, mistakenly called a Dutch Cemetery. There are no Dutch Tombs in this cemetery. The grave stones bear inscriptions ranging from 1699 to 1833. The cemetery has the tombs of some of the Chiefs of Vizagapatam Factory, soldiers who gallantly laid down their lives fighting for their country. Patrick Lawson, a wealthy sailor-merchant

after whom the coastal bay near Waltair is named as Lawson's bay, was buried here. More importantly, this cemetery bears testimony to two historical events in the history of Visakhapatnam. The first event was the first ever "naval war" on the coast of Visakhapatnam that took place on 18th Sept' 1804 between the British and the French. The British could successfully defend Vizagapatam by defeating the French but lost one brave officer named John Dykes whose body was buried in the Old Cemetery.



Fig. 18 A watch-tower in Kambala Konda Wild life sanctuary to admire its biodiversity (Source: Google images – vizagtourism.org).

Native Sepoy Mutiny is the other important event that took place on 3rd October 1780, at Vizagapatam Fort, much before the famous Indian Mutiny of 1857. This was the first ever Sepoy Mutiny that took place anywhere in India where the Native Sepoys took arms against the British and killed their officers. This 1780 mutiny took place in Vizagapatam when Hyder Ali of Mysore invaded Carnatic. To fight against him the English East India Company requisitioned the troops from Visakhapatnam. The local native sepoys were asked to embark a ship to sail for Madras. The native sepoys refused to undertake the sea voyage, saying that it was against their religious sentiments to cross an ocean. Three British officers were killed and many were injured in this mutiny. The inscription on one of the British cadet's tombstone records the event. To quote a few lines; "Mr. Kingsford Venner cadet in the 1st Circar Battalion of Sepoys was precipitated to an untimely grave at the age of 19 in a Mutiny of Grenadier Sepoys ordered for embarkation from this Port on 3rd October 1780".

The cultural value of the district is manifested in various religious monuments and harmony among different religions in the Visakhapatnam sector and also in the form of pristine tribal culture in Borra – Araku sector.

15. Visakhapatnam - Three Holy Hills Promoting Religious Harmony

As a unique testament to communal harmony, and the peace-loving nature of Vizagites, there are three picturesque hillocks, each with its distinctive religious

significance along the channel that leads to the inner harbour. There is The Venkateswara Temple on the Sringamani Hillock, The Ross Hill Church on the Ross Hill, and The Baba Ishq Madina Dargah on the Dargah Konda (Fig. 19). Each of these shrines has added to the glory and history of Vizag. These are the finest examples of communal harmony and are witness to the growth of the small towns into what Vizag is today. While the Dargah is about 700 years old, the temple is more than two centuries old. The Ross Hill Church too is more than a century old, emphasising the quaint essence of spiritualism, that all religions are but the branches of the same tree.



Fig. 19. Religious harmony at Visakhapatnam with Temple, Mosque and Church on adjacent hills (Source: Courtesy Edward Paul).

16. Simhachalam: At a distance of 15 km from Visakhapatnam, the very famous Simhachalam temple (Fig. 20) is situated on the Simhachalam hill range at an elevation of 300 m above MSL. The exact age of the temple is not known, but it contains an inscription dated as far back as 1098 – 99 CE of the Chola king Kulottunga-I who conquered the Kalinga territories. The deity of Varaha Lakshmi Narasimha at Simhachalam, the boar incarnation of Lord Mahavishnu, appears like a Shivalinga when covered with a sandal wood paste. The original shape of the deity in the tribhanga posture has two hands with the head of a boar on a human torso. The Simhachalam temple faces the West, unlike so many others which face the East. An east-facing entrance, according to religious belief, brings prosperity while the west-facing one brings victory. Kalyanotsavam and Chandanotsavam (Nijaroopa Darshanam) are the two major festivals celebrated in the temple.



Fig. 20. Simhachalam Temple (Source: Google images – newindianexpress.com).

17. Terracota – Araku style: The clay is solidified and wedged to the frame into the desired shape and size on the potter wheel. This is followed by hand craft for decoration and design like inlay, handle making, etching, *etc.* After drying, the product is given finishing by sand paper and sponging and then the initial firing is done followed by glazed firing in the kiln. Meticulous care is taken to retain the natural grace and feel of the products.

18. Dhimsa dance (Fig. 21): The tribals of Araku celebrate spring, heralding the new year and Deepavali festival through the popular group dance Dhimsa in which men and women sing in their Savara language as the others provide stimulating musical support with bugles, wooden sirens, and sticks. The picturesque Araku valley that provides a perfect backdrop reverberates with the sound of music and rhyme of the tribal dance. Eight forms of the dance are presented with men on the right side and women on the left forming a chain with each holding the waist of the other as they sing and shout in praise of their deity. It is a colourful celebration of hope and joy over their hard-earned produce.



Fig. 21. Dhimsa Tribal Dance at Araku (Source: google images – in.pinterest.com).

POSSIBLE THREATS TO GEOHERITAGE SITES

There are a number of threats to the sustainable development of the geoheritage sites in the area. The tourism activity is uncontrolled that causes pollution and unhygienic conditions. The beaches at certain places are getting eroded which requires immediate protection. Due to the pressure of tourists, places like Erra Matti Dibbalu, Borra caves, *etc.* are in danger of losing their scientific and aesthetic value. Important sites like Erra Matti Dibbalu are facing the problem from real estate developers. Sometimes, to develop tourism some of the important geological sites are destroyed. It is necessary to carry out an impact assessment of any ongoing / proposed activity on the existence of important and vulnerable features like beaches, Erra Matti Dibbalu, Borra caves, *etc.* as geological sites once lost are lost forever.

GOVERNMENT ACTION REQUESTED

The Government needs to protect the valuable geological, archeological, and cultural sites by designating them as Geopark following the guidelines of UNESCO.

The State Government should establish the Visakhapatnam Geopark by bringing all important geological sites, including Erra Matti Dibbalu, Natural Arch, Kailasa Hill, Borra caves, Volcanic ash deposit site, Bauxite deposit site, and the archeologically important sites like Thotlakonda, Bavikonda, Bojjannakonda, Pavuralla gutta under one integrated Geopark Management Authority (GPMA) and nominate the members of GPMA. The management authority should oversee policy making and provide guidelines for proper upkeep of the tourist sites. The GPMA should open an exclusive website for the geopark, oversee the establishment of facilities like tourism information centres, trained guides, signage boards, amenities and facilities for tourists at the sites. The government should identify and promote marketing of the local products based on the native skills as souvenirs of the area that will help improve the economy of the local people. If it is done, Visakhapatnam will be one of the finest geoparks in the country and thus can be a leader in guiding other states as well as get a chance to be recognized by UNESCO. This will greatly enhance international tourism and boost up the economy of the region.

CONCLUSIONS

Visakhapatnam is already a very popular tourist destination on the east coast of India with a number of excellent coastal and highland tourist spots. It is well connected by all means of transport and has accommodation facilities of high standards, including hotels and guest houses, which cater to domestic as well as international tourists. Keeping in view the important and popular geological, archeological, and cultural sites in the area, as enumerated above, Visakhapatnam has boundless potential to be developed as a Geopark on the UNESCO model.

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RAMGARH CRATER: A BLOW OF A "STAR" ON THE EARTH

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INTRODUCTION

The elements that life is composed of were cooked in a star. The stars break off into planets, asteroids, satellites, comets, interplanetary dust, and gases. These space debris collide with each other or crashes onto larger bodies forming craters due to impact. Ramgarh (pronounced as Ramgadh) is one such crater formed on the Earth in Rajasthan, India. There are only three such terrestrial meteorite impact craters in India. The number of terrestrial impact craters reported to date from all over the world is only 200, amongst all these impact craters, Ramgarh Crater enjoys some unique features: one, this impact happened on a target submerged in water; two, it has a visually appealing shape offering a rich cultural (archaeological and historical) heritage.

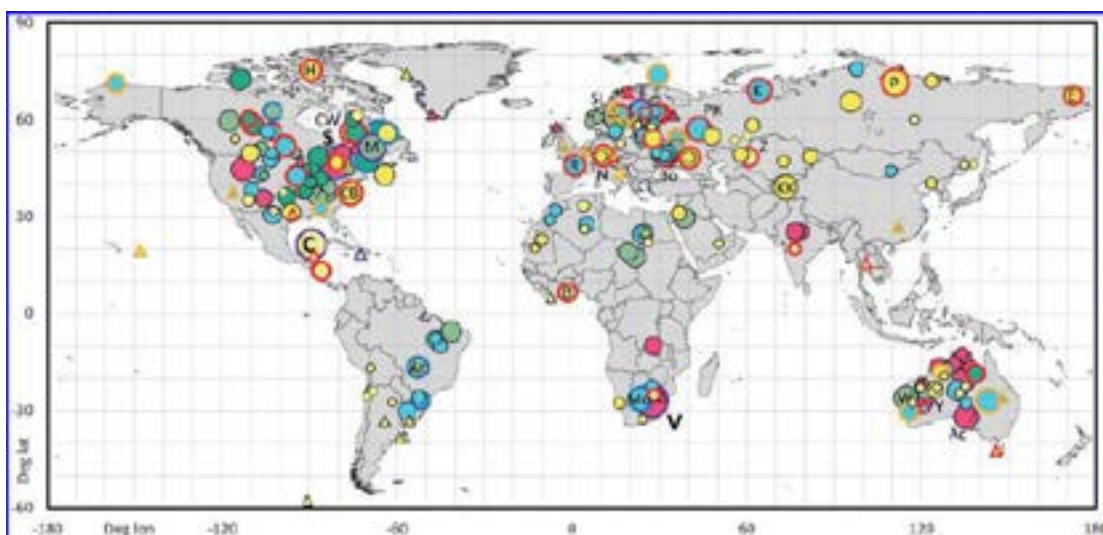


Fig. 1. Map showing confirmed terrestrial impact craters in the world. Note the three confirmed craters in India viz., at Lonar, Maharashtra; Dhala, Madhya Pradesh; and Ramgarh, Rajasthan. (After Schneider and Kring, 2020).

LOCATION

The Ramgarh Crater is located in the Baran District in southeast Rajasthan, India ($25^{\circ}20'N$, $76^{\circ}37'E$), about 110 km northeast of Kota city. It is excavated in sandstone and shale and also minor limestone horizons of the Bhandar Group of Vindhyan Supergroup. The moderately oblique impact occurred into a shallow water regime on the horizontally lying 1000-1070 million years old, upper Vindhyan sedimentary rocks. The impact is supposed to have occurred during the middle or upper Jurassic, about 165 million years ago.

GEOLOGY

The Ramgarh Crater is a complex crater of about 10 km diameter with an uplifted central peak or a peak ring and a typically broad, shallow crater floor and terraced

walls. The central peak ring is very prominent, visible from a very far distance, and is quite obvious in the imageries while the rest of the crater is buried under the sediments. The central peak rises blatantly $\sim 200 - 250$ m above the surrounding plain as a continuous ring that has an approximate diameter of ~ 3.5 and 4 km in the east-west and the north-south directions, respectively. The inside of the central peak/ring again is a flat shallow floor formed due to the collapse of the peak or dome from the center. (See figure 3).

Ramgarh Crater is formed in the flat-lying sediments and is situated in the center of the Vindhyan Basin of the Bundelkhand craton of the Proterozoic age. The domal uplift shows the Upper Rewa Sandstone of the Upper Vindhyan group of Proterozoic age exposed at its geographic center and shows vertical dips.

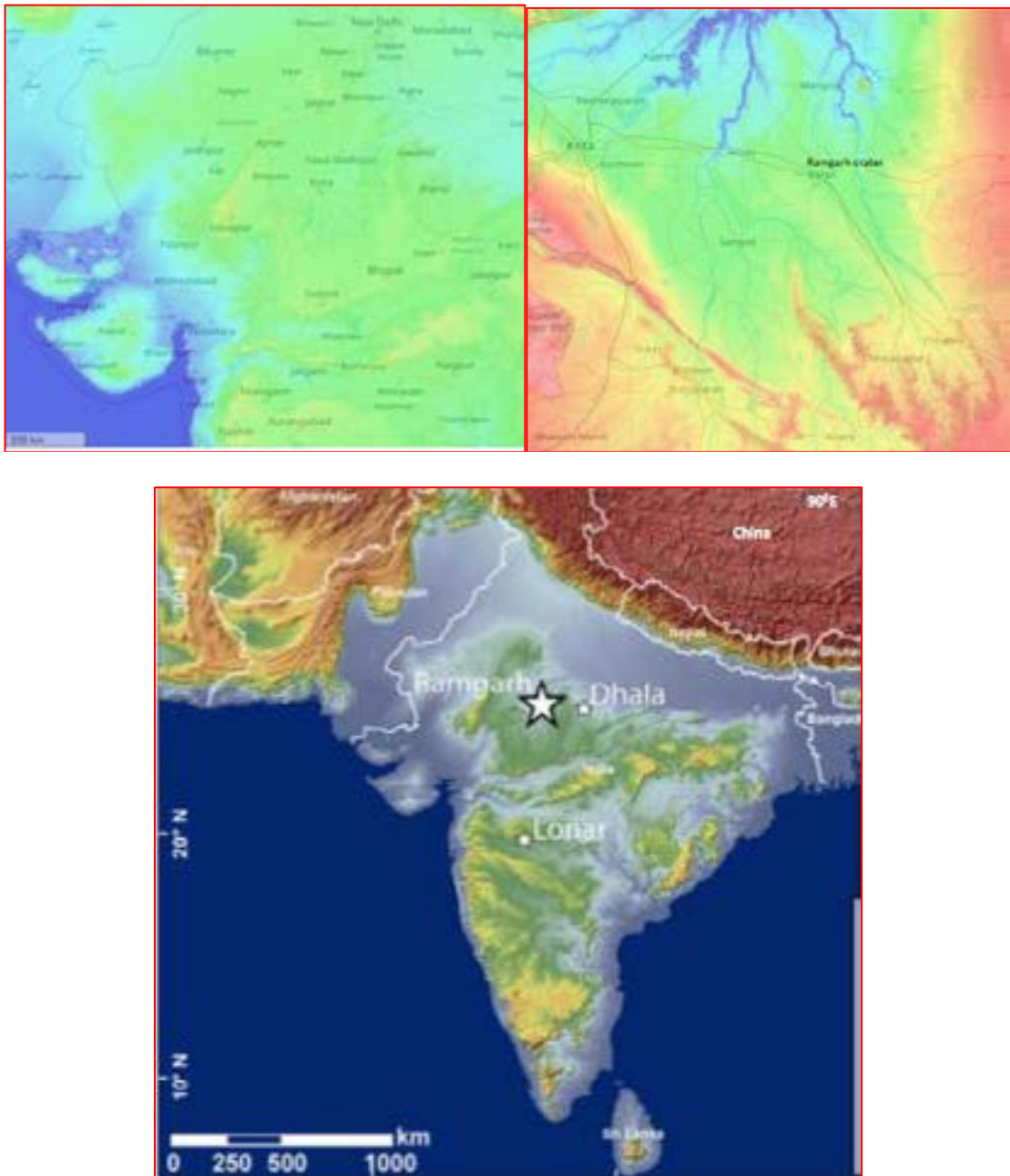


Fig. 2. Location of Ramgarh Impact Crater. (Relief map after Kenkmann *et al.*, 2020).

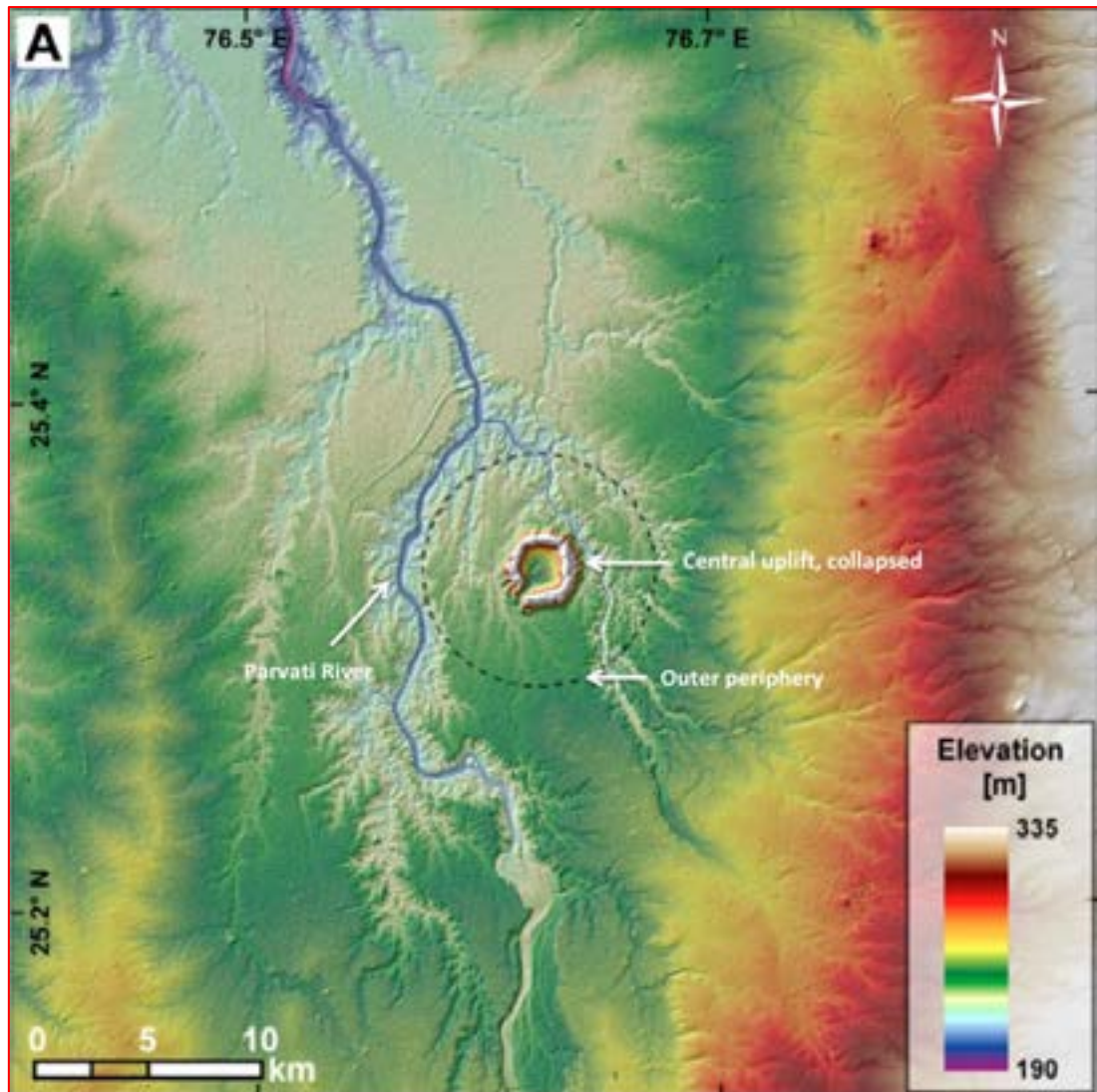


Fig. 3. Map showing wider region of the Ramgarh Crater and surrounding area with elevation data. (After Kenkmann *et al.*, 2020).



Fig. 4. The central peak ring of the Ramgarh Crater; visible from about 32 km away from the Crater.



Fig. 5. Three-dimensional view of the central depression formed due to collapse of the Central Uplift of the Ramgarh Crater.

The central depression comprises heavily deformed shales, sandstones, and limestones, which are partly disintegrated into fault-bounded mega blocks belonging to the younger Ganurgarh Shale Formation. Lower Bhander Sandstone of the Upper Vindhyan group is exposed at the neck of the dome.

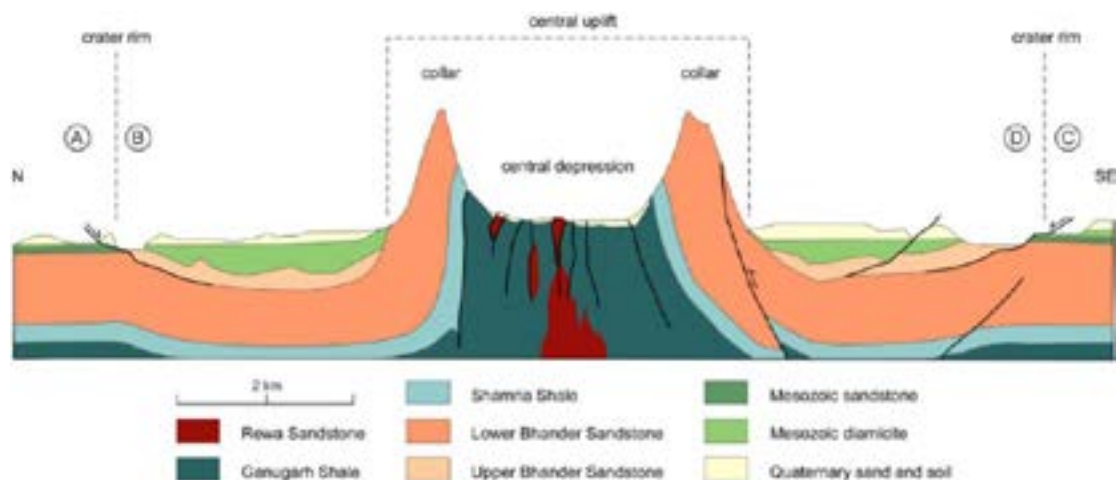


Fig. 6. Schematic cross-section showing Geology through the Ramgarh Impact Crater. (After Kenkmann *et al.*, 2020).

The Ramgarh Crater as compared to Meteor Crater in Arizona, U.S.A. or Lonar Crater, Maharashtra, India is in a more degraded state. The other comparable terrestrial asteroid impact craters on sedimentary target-rocks of equivalent diameter

are B. P. structure, Libya (25°19'N, 24°20'E); Goyder crater, northern Australia (13°9'S, 135°2'E), and Gusev crater, Russia (48°26'N, 40°32'E). (See Earth Impact database (<http://www.unb.ca/passc/ImpactDatabase>) or a paper of 2020 by Schneider and Kring). Most importantly, Ramgarh Crater is special in the sense that it reveals an impact on a water-submerged target and therefore has a huge scope for the researchers who study Impact Cratering. It is the sole crater to date that shows an impact in a water-filled regime. Different opinions were proposed for its origin but it has been proved that it was formed due to asteroidal impact on the basis of the following observations: impact spherules, diaplectic glasses, specific crater morphology, brecciation, multiple striated joint surfaces, swinging strike, radial folds, deformed central uplift particularly in the absence of any igneous activity, planar fractures along crystallographic planes, irregular extinction and mosaicism, toasted quartz, isotropic grains, and patches as well as planar deformation features (PDFs) and decorated PDFs with occasional ghost traces of original PDFs, accretionary lapilli, high Ni content and also anomalously high percentage of Cr and Co.

IMPACT CRATERING

Impact cratering is a fundamental process operating on all the celestial bodies of the Universe including the Earth. It is one of the primary mechanisms responsible for planetary accretion in shaping the planetary surfaces. Small and big extraterrestrial bodies have continuously hit the Earth since its formation, similar to other planets, but the dynamic processes operating on the Earth have mostly obliterated the impact signatures. In contrast to the planet Earth, the tectonic processes and erosion are not extensive on other planets and satellites, hence the morphology of impact generated craters, their sharply circular pits, widespread ejecta deposits, impact melt flows and the terraces and cliffs formed during crater development have been preserved.

ARCHEOLOGICAL MARVEL

The central peak ring of Ramgarh Crater is very high and being placed in an otherwise flat terrain, it provided a naturally built naturally built protection for the erstwhile rulers and their subjects from attackers and invaders. Jhala Zalim Singh (1730-1823), a brave, fearsome fighter, appointed as 'faujdaar' by the rulers of Kota got constructed a fort, an archaeological marvel, that had a heavily guarded gate on the entry side of the strategically placed hills and a wall on the crater rim. These constructions provided safety to the inhabitants from the attacking invaders during the eighth century.



Fig. 7. The ruins of the fort on the rim of the collapsed central peak of the Ramgarh Crater. (Note: The heavily built entry gate, watch tower, and the palace).

The masonry walls constructed for the underground step well, which was a source of drinking water for the then residents in the fort still stand majestically intact.



Fig. 8. A step well in the plains of the collapsed Central uplift of the Ramgarh Crater.

Looking at the ruins, it becomes obvious that this magnificent place has suffered complete negligence from all the responsible departments. It is pertinent that this old archeologically important fortress be renovated to its original shape so that the present generation could learn about the living style and customs of the older generations.

CULTURAL HERITAGE

Right in the centre of the crater stands the ruins of a temple with exquisite carvings and erotic sculptures akin to the famous Khajuraho temple. The decapitated remains of this temple reveal that it was magnificent during its glorious past. This temple is called as Bhagn-Devra Temple, dedicated to the “Tantric tradition of Shaivism”. In the Garbh Griha or sanctum of the temple is a Shiva Lingam (but it seems this lingam is not the original; the original sculpture of the deity must have been destroyed or stolen).



Fig. 9. Bhagn-Devra, Shiv Temple located in the middle of the Ramgarh Crater. There are ornately carved pillars depicting erotica, music, dance, ashtadikpalas, saptamatrikas and also Ganesh, Vishnu and other avatars. Surprisingly, it also shows

sculptures of Shiva in the form of “Bhairav”. The information board setup by the State Department of Archaeology and Museums, says: the inscriptions found on the site indicate that the temple was built in the 10th century CE by Raja Malaya Verma of Nag Dynasty from Malwa, and was renovated in 1162 CE by Raja Trisna Verma of the Med Dynasty. It is believed that the Bhagn Devra Temple is no ordinary tantric temple, but it is a yogini temple. There used to be sculptures of the 64 yoginis at the temple. All these sculptures have been removed. However remains of one such sculpture in its majesty can still be seen.

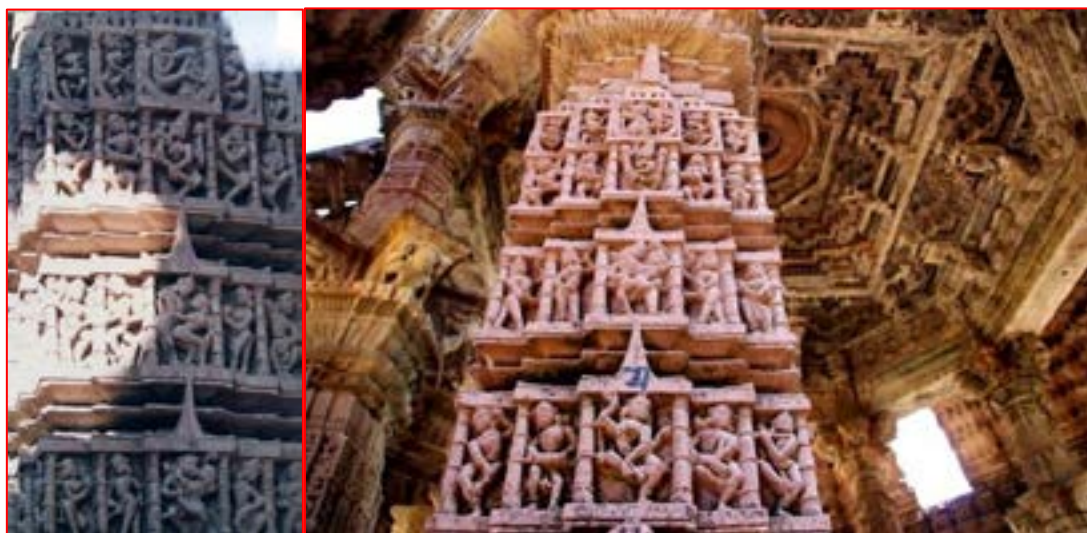


Fig. 10. Ornate carvings on the temple pillars of Bhagn-Devra.

The advanced state of ruins of this elegant and magnificent temple epitomizes disregard and neglect at its worst. It looks as if the temple will fall any minute. Profuse growth of vegetation has worsened the state of the temple. Some devotees have done a patchwork but that looks like a blot on its elegance.

LOCAL IMPORTANCE

There are two lakes in the crater and there is a flight of white washed steps leading to the top of the dome visible from this temple. The steps lead to a natural cave and two temples built during the reign of Jhala Zalam Singh. These two temples are dedicated, respectively, to two local deities ‘Kisnai’ and ‘Annapurna Devi’. Interestingly, offerings to both temples are different. Kisnai is offered meat and alcohol while Annapurna Devi is offered vegetarian items/sweets. A fare is organised annually at these temples and thousands of devotees from the vicinity and far off places visit the temples during this time.

POTENTIALITY OF RAMGARH CRATER AS GEOPARK OF INDIA

It is essential that Ramgarh Crater be preserved and promoted as a National Geoheritage Site, the reasons being : (i) It was formed by a star (meteorite) impact that is a very rare phenomenon and therefore scientifically suitable site to understand star processes. (ii) It provided a nature-built protection for the erstwhile rulers and their subjects; in addition, it is adorned with an eighth-century built fort and a Bhagn-Devra temple with exquisite carvings, which is an archaeological marvel. (iii) There are hill-top-temples of Annapurna Devi and a local deity in the craters that are visited regularly by local devotees.

The Natural Heritage Division (NHD) of INTACH and its Udaipur Chapter have carried out detailed development study of this potential Global Geopark that is published in detail through a Monograph (Sisodia, M. S. & Ranawat, P. S., August 2020). Its map is reproduced below for ready reference. (Fig. 11.)

Salient points of the proposed development of this natural-cum-cultural heritage site are:

1. Biodiversity Survey
2. Buffer zone around Ramgarh Crater
3. An attractive Gateway
4. Interpretation Complex
5. Parking Area
6. Bicycle Pickup Point and Bicycle Stand
7. No-noise Zone
8. Lake Circumference Development
9. Restoration of the Ancient Temples and Fort
10. Hill-top Temple Stepped Route Development (halt-points, drinking water and toilet facilities).
11. Trekking Route-2m wide along with 3 camping sites.
12. Attractive Signages with QR-Code for concise spot description. (See Fig. 11.)



Fig. 11. The proposed development plan of Ramgarh, Geopark area, by NHD-INTACH, from Sisodia, M. S. & Ranawat, P. S., 2020.

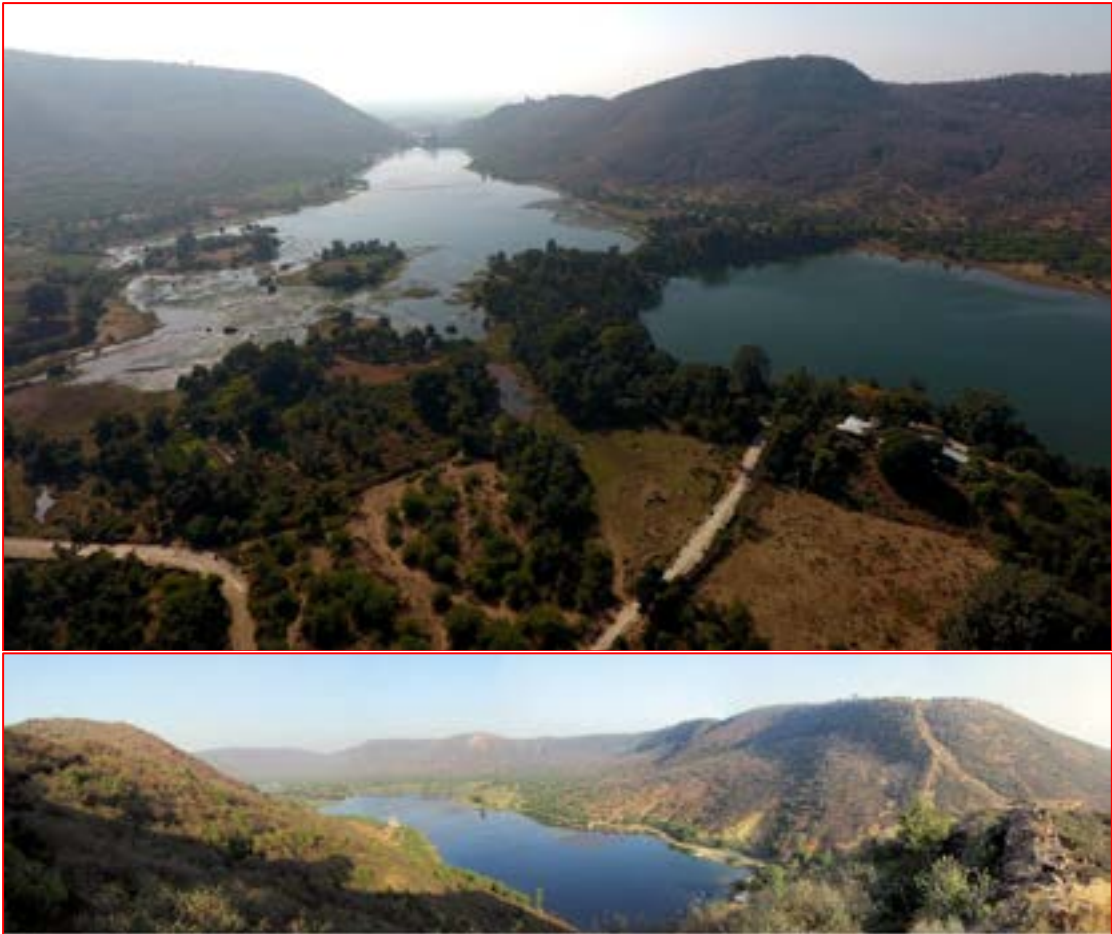


Fig. 12. Panoramic view of the inside of the collapsed dome of the Ramgarh Crater showing two lakes and a close view of the lake. Photo by INTACH team, Baran, taken from Drone.



Fig. 13. View of the Annapurna Devi temple and a cave with steps leading to this temple, built at the far end of the Ramgarh Impact Crater. Photo by INTACH team, Baran, taken from Drone.

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THE PIN VALLEY, HIMACHAL PRADESH: A POTENTIAL GEOHERITAGE SITE AND GEOPARK

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1. INTRODUCTION

Geologic Heritage encompasses the significant geologic features, landforms, and landscapes characteristic of our Nation. The Geoheritage sites are conserved as a legacy for posterity and offer enormous potential for scientific studies. These sites serve as outdoor classrooms and also promote and stimulate scientific curiosity in laymen together with cerebral enjoyment. Geoheritage sites are fundamental to understanding dynamic earth systems, the succession and diversity of life, climatic changes over time, the evolution of landforms, and the origin and localisation of mineral deposits. The Pin Valley is one such site.

The Pin Valley is located in the Lahaul and Spiti district, Himachal Pradesh (India), within the Cold Desert Biosphere in the Himalayan region. Lahaul and Spiti district (Fig. 1) is a high altitude terrain surrounded by passes that provide access to a magical geomorphologic marvel (Bhargava et al., 2010). The Pin Valley National Park was established on 9th January 1987. A large portion of the park remains snow-covered for several months in the year providing a natural habitat for a number of endangered animals including the snow leopard and Siberian ibex. It is a tribal area having approximately 17 villages with a total population of about 1500-1600. Most of the locals follow Tibetan Buddhism.

Only the south-eastern part of the Spiti Valley can be approached, without crossing any pass, along the Sutlej Valley up to Khab and thereafter following the Spiti river (Hayden, 1904; Bhargava and Bassi, 1998). The Rohtang, Kunzum, and Baralacha are the important passes in the district. The Rohtang Pass situated in the Pir-Panjal range, connects Kullu district to the Lahaul Valley, while the Baralacha Pass connects Lahaul to Ladakh. The Kunzum Pass is a gateway between the Lahaul and Spiti valleys. Most of the time the passes remain open (around 20th May to 5th June) and close by 15th October. Lahaul and Spiti district falls in the rain shadow area of the Great Himalayan Range, which has rendered it a cold desert.

The annual rainfall varies from about 10 to 40 cm. In the Lahaul Valley snowfall varies from less than 1 m to 6 m and may be more at higher altitudes. The maximum temperature at Keylong (headquarters) ranges between 7° C and 23° C, while the minimum can be as low as -10° C during the winter months. As per the 2011 census, the entire Lahaul and Spiti district falls under rural areas.

The Pin Valley (the Pin river is a tributary of the Spiti river), occupying an area of 675 km² within the latitudes 31°45'-32°11'N and longitudes 77°45'-78°06', forms an important sector of the Lahaul and Spiti district (Fig. 1).

The Pin Valley (Fig. 2) provides access to the geological sequences ranging in age from Neoproterozoic (~800 Ma) to Lower Jurassic (~200 Ma) (Hutton, 1841; Stoliczka, 1865; Griesbach, 1889; Hayden, 1904; Reed, 1910; Srikantia, 1977; Fuchs, 1982; Bhargava and Bassi, 1998). The Palaeozoic (542-250 Ma) and Triassic (250-200 Ma) sequences of this valley are globally known on account of their fossil contents (Blanford, 1863; Diener, 1908; Krystyn and Orchard, 1996; Krystyn et al., 2007; Brühwiler et al., 2010; Romano et al., 2016; Singh et al., 2017). This is the only place in India where more or less complete Palaeozoic and Triassic sequences are exposed. This feature prompts us to suggest it as a National Geoheritage and Geo-Park.

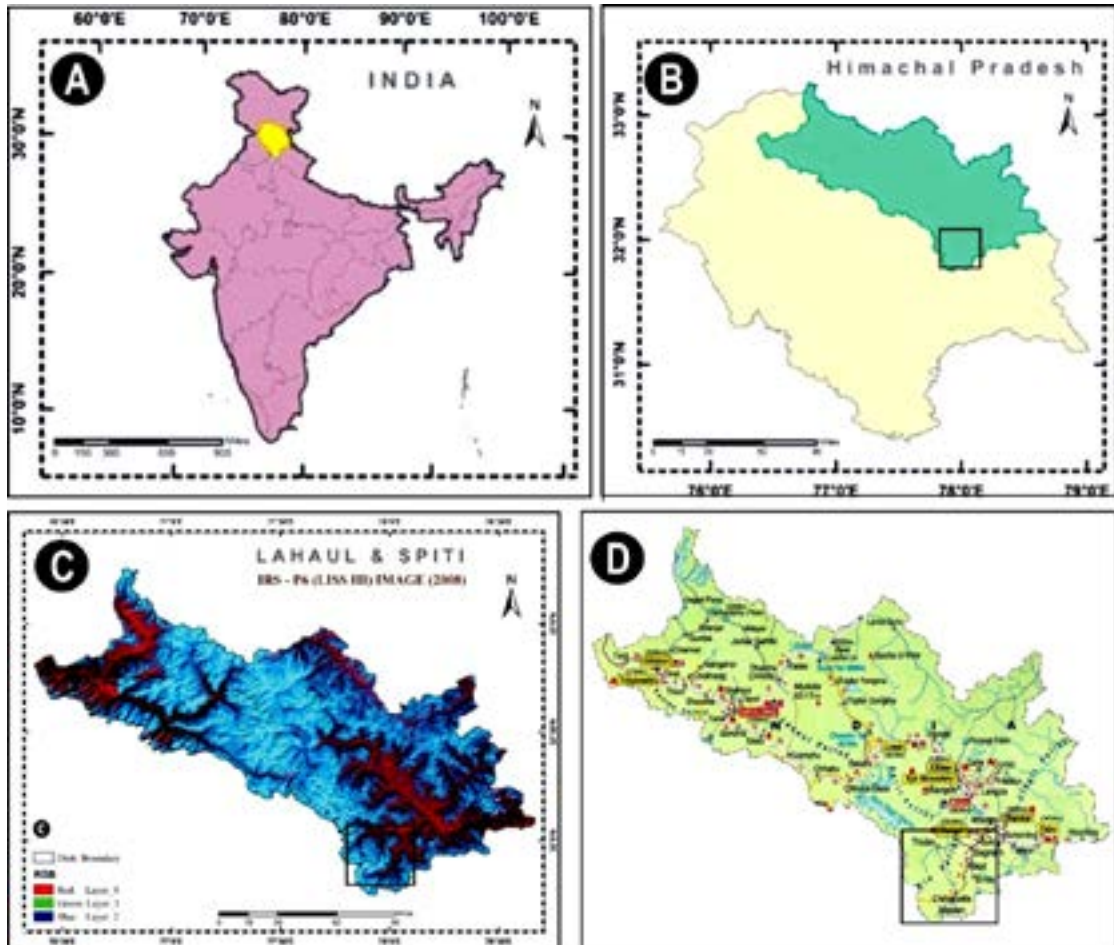


Fig. 1. (A-D) Location of the Pin Valley (inset) in the state of Himachal Pradesh (India) (Krishnanand and Raman, 2019).

2. PHYSICAL AND HUMAN GEOGRAPHY

The Pin Valley forms part of the Tethyan Himalaya, located north of the Higher Himalaya. The Pin River originates from the eastern side of the Pin-Parbati Pass (Fig. 3), while the Parbati River, one of the main tributaries of the Beas River, takes off from its western slopes (Bhargava and Bassi, 1998; Bhargava et al., 2010). The Pin River is joined by the Parahio River at Khar. It finally debouches in the Spiti River, downstream of Atargoo. The altitude of this valley ranges from ~3,500 m (11,500 ft) near Ka Dogri to more than 6,000 m (20,000 ft) at its highest point. The Pin-Parbati Pass in the east and the Bhabeh in the south separate the Pin Valley from the Parbati and the Sutlej valleys respectively. In the north exists the Ratang Valley separated by an un-named major divide, towards the west the Pin Valley joins the Spiti Valley, the Spiti river being an important tributary of the Sutlej river. The Mantalai group of glaciers occur along the Pin-Parbati Pass Range. Smaller hanging valley glaciers exist all along the high altitude terrain. Structurally, partly lithologically controlled matured topography co-exists with rare first order topography. The wide Pin Valley (Fig 4) originally was a glacial valley, which during post-12 ka glacial maxima was modified by fluvial agencies. The river is fed by glacial and snow melts. Freshwater springs are the source of potable water.

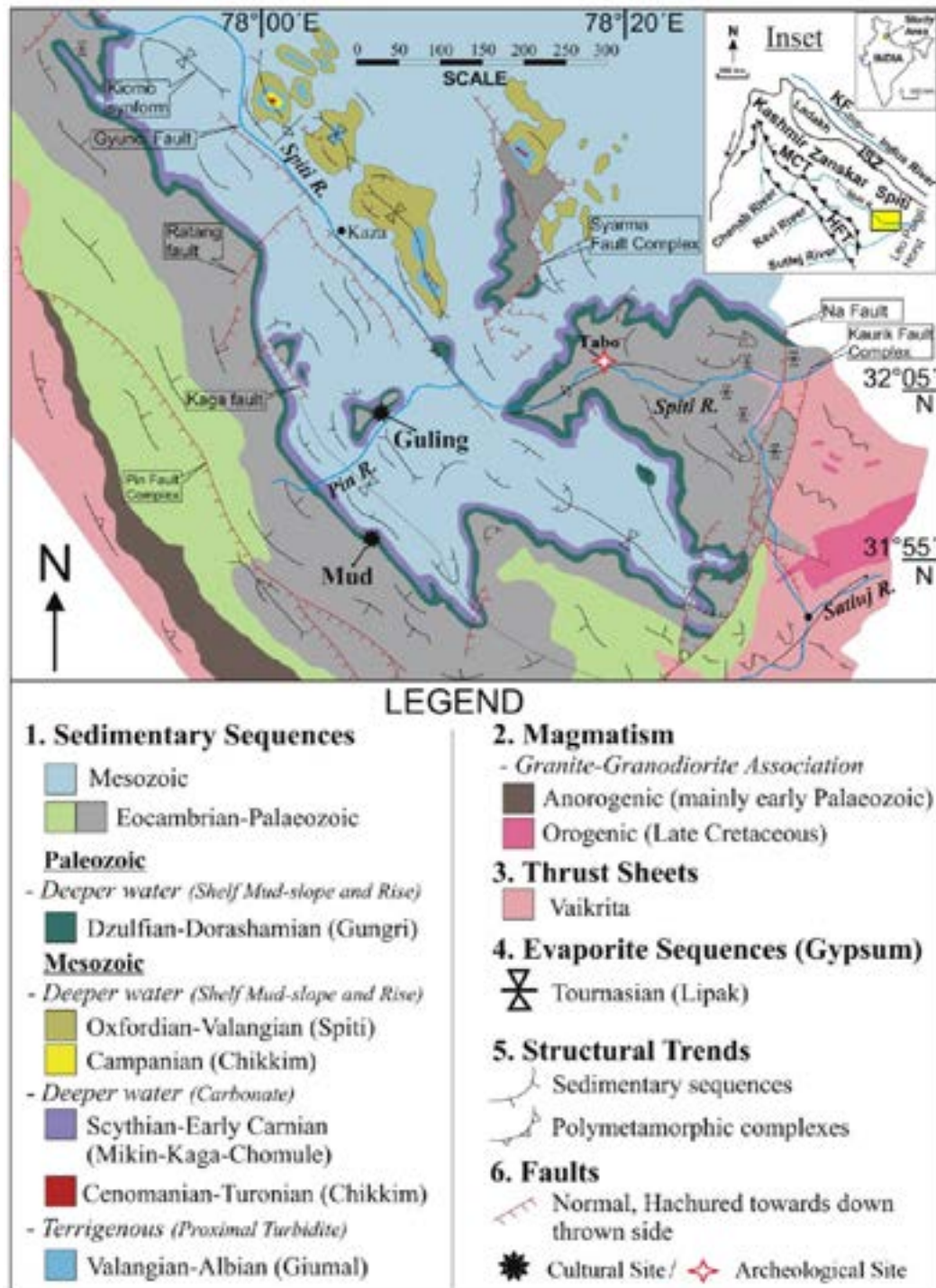


Fig. 2. Generalised Geological map of the Lower Spiti Valley, including the Pin Valley.



Fig. 3. Pin-Parbati pass viewed from western side.



Fig. 4. View of the valley and the Pin-Parbati Pass from the eastern side.

3. PROPOSED GEOLOGICAL SITES

3a. Spiti Confluence:

Near the confluence Late Triassic (Middle Norian) coral reef is exposed (Fig. 5) The builders are coral, stomatoporoids, and algae (Bhargava and Bassi, 1998). It is overlain by the Late Norian and Rhaetian sequence, including *Megalodon* bearing fossil beds. Probable Triassic-Jurassic boundary can also be studied in this stretch.

The reef and the overlying sequence are of global interest for reconstructing the Triassic paleogeography and history.



Fig. 5. View of Norian coral reef.

3b. Guling village:

Just before the village, the Permian/Triassic contact (Black shales of the Gungri Formation overlain by a ferruginous layer succeeded by the carbonates of the Mikkin Formation) is exposed along the road (Fig. 6). Further upstream along the road, disconformity between the Lower Permian sandstone of the Gechang Formation and the Late Permian black shales of the Gungri Formation can be studied. Up the hill, a gradational contact between the quartz arenite of the Middle Devonian Muth Formation and siliciclastic-carbonate of Givetian-Tournasian Lipak Formation is exposed. On the opposite bank, “anticlinal hills and synclinal valleys” representing First order topography can be viewed. The P/Tr boundary along which about 96% of marine life became extinct can be studied. Also, exposures of the Muth Formation denoting the paleo beach of the Devonian age are of great interest.

3c. Mud (old spelling Muth):

Excellent section of the Muth Formation, believed to be a beach /barrier island deposited is developed. Farther up, the Muth-Lipak sequence is overlain by the Lower Permian Gechang Formation, marking the absence of a major part of the Carboniferous (Po and Ganmachidam formations). It is followed by the Late Permian Gungri Formation and the Triassic sequence with a disconformity (Fig. 7) (Ghosh et al., 2010). World's best Induan-Olenkian boundary section where excellent ammonoid (Fig. 8)-conodont integrated biostratigraphy has been established in this section (Krystyn and Orchard, 1996; Bhargava et al., 2004).



Fig. 6. The Permian-Triassic boundary at Guling village, Pin Valley.

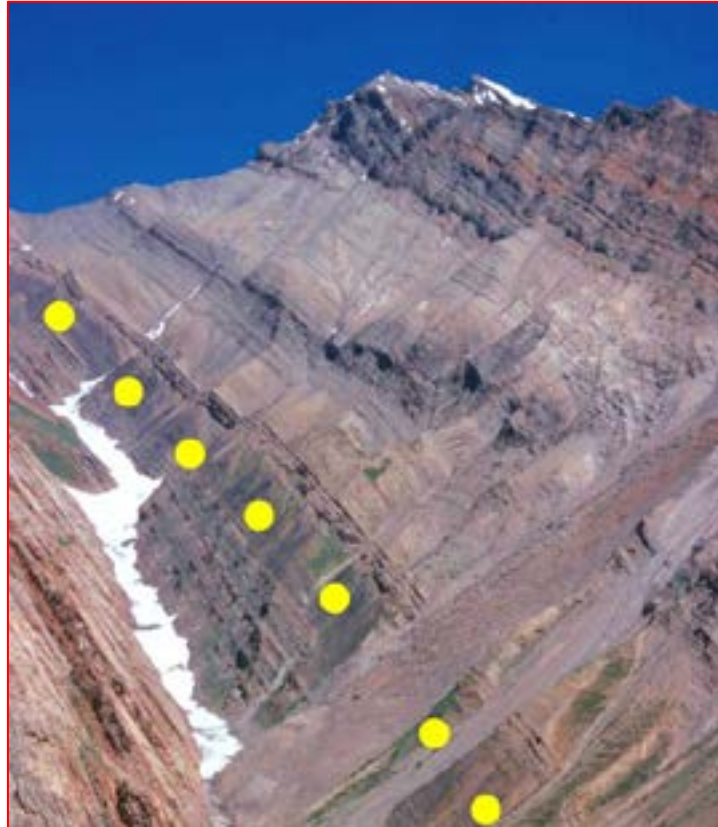


Fig. 7. Permian (black shale) disconformably overlain by Triassic (dominantly carbonate).



Fig. 8. Ammonoid *Flemigites bhargavai*.

Further upstream, opposite Farraka Ordovician-Silurian carbonate buildup (Takche Formation) is exposed, which is overlain disconformably by the Muth Formation (Bhargava, 1997, Bhargava and Bassi, 1998). Late Silurian and a part of Devonian is absent along this contact (Fig. 9). The Palaeozoic carbonate buildups evoke global interest.

Opposite Shian the Ordovician conglomerate (Thango Formation) (Fig. 10) is developed in full force.

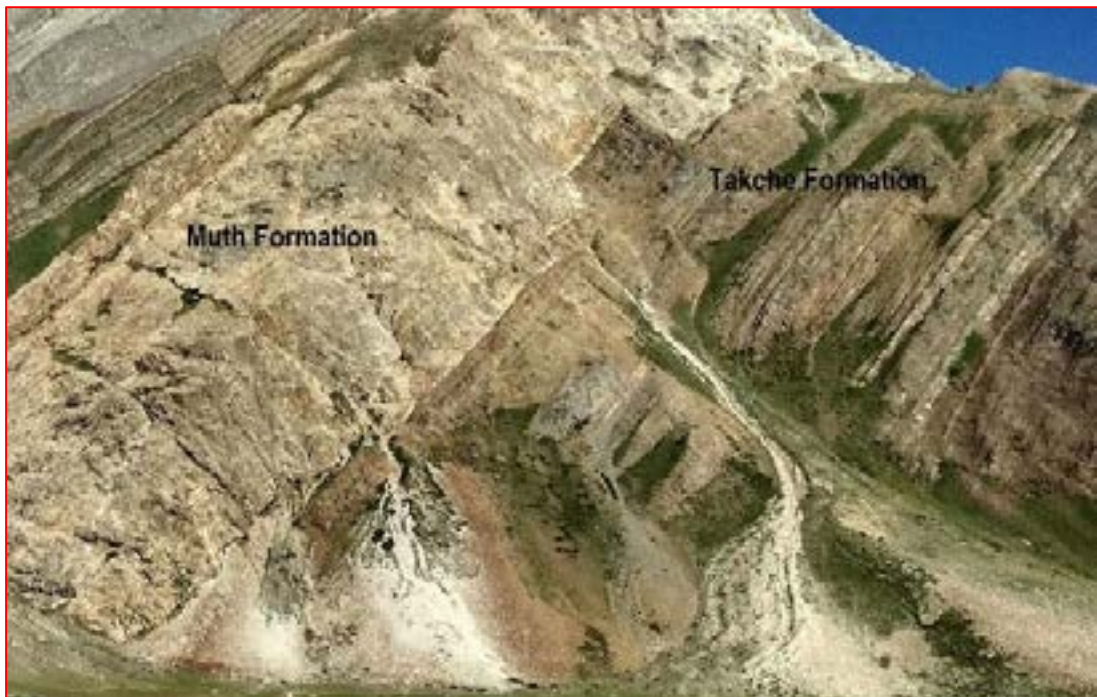


Fig. 9. Disconformable contact between the Takche and overlying Muth formations.



Fig. 10. Ordovician Conglomerate (Thango Formation).



Fig. 11. The angular unconformity between the Middle Cambrian Kunzam La Formation and the Ordovician Thango Formation.

The conglomerate marks a hiatus covering Late Cambrian, caused by the Kurgialkh Orogeny, which is denoted by an angular unconformity between the Thango and Middle Cambrian Kunzam La Formation (Fig. 11). Evidence of late Cambrian orogeny, which now has been encountered throughout the Himalaya is best available here. It was a major event in the history of the Himalayas, which is now receiving worldwide attention.

3d. Tariya:

From Tariya towards the Bhabeh and Pin-Parbati passes, the nonconformable contact between the Batal (Ediacaran-Lower Cambrian) and the underlying Precambrian Vaikrita Group sequence is exposed. Towards the Pin-Parbati Pass, Lower Palaeozoic granitoid, which are the manifestation of the Kurgialkh orogeny, are conspicuous.

4. POTENTIAL THREAT TO THE GEOFEATURES

The main threat to the features mentioned is by road building and civil construction. Trace fossils of the giant scorpion, besides the Spiti, so far found only in Antarctica and Australia, and the best exposure of the coral reef in the Ratang *nala* has been already destroyed. The best P/Tr section at Atargoo in the Spiti Valley has been covered by a road wall. No preventive measure has been taken despite several requests made to the local administration.

5. SUGGESTED REMEDIAL MEASURE

It is necessary that while planning the road alignment the State Geological Wing and the Geological Survey of India (GSI) are consulted. The GSI, after seeking information from various concerned agencies, should prepare an exhaustive list of the geological monuments that need preservation. Where erection of a wall to arrest the landslide is unavoidable, transparent material should be used, through which the geological features can be observed.

6. ARCHITECTURAL AND CULTURAL ASPECT OF THE PIN VALLEY

The old constructions are adobe houses built with sun-dried mud blocks. The local inhabitants have Mongoloid features. The people of Spiti share an ancient culture and mainly follow Buddhism. The language spoken by the locals is a dialect of Bhotia, closely related to those of Western Tibet. Several centuries old gomphas (Buddhist monastery) are situated in this district. The Tabo Monastery, situated a little downstream of the Pin-Spiti confluence, comprises more than a 1000-year-old cluster of Buddhist temples (Figs. 12-14). Perched at an altitude of 3050 meters, this Monastery is often referred to as the 'Ajanta of the Himalaya'.

The Tabo Monastery was founded by Richen Zangpo during the 10th century. The monastery houses more than 60 lamas and possesses a rare collection of scriptures, pieces of art, wall paintings, Thankas and Stucco. Petroglyphs (rock carvings) have also been discovered near Tabo (Fig. 14-15). In general, the lower Spiti Valley boasts of one of the densest concentrations of rock carving, pictographs, and bas relief carvings of ancient *Chortens* (stūpas).

These sites are located in close proximity to the Spiti River, straddling well-treaded pathways. The entire population is of rural background, main means of livelihood for the people being agriculture, animal husbandry, weaving and allied activities, daily wage earning as labourers in government projects, regular government service, and small business (main shopkeeping). The Pin Valley is a major source of fresh green peas. Some enterprising individuals are engaged in the travel and tourism business, which provides seasonal livelihood.



Fig. 12. Tabo monastery (Source: www.tabomonastery.com).



Fig. 13. Artwork in Tabo monastery (Source: www.tabomonastery.com).

6a. Wildlife:

It is home to a variety of rare animals like woolly hare, Tibetan gazelle, and snow leopard. Other faunal species present here are: fox (*Vulpes vulpes*), wolf (*Canis lupus*), ibex (*Capra ibex*), bharal (*Pseudois nayaur*), and Himalayan marmot (*Marmota bobak*), Indian porcupine (*Hystrix indica*), blue sheep (*Pseudois Nayaur*) red billed chough (*Pijrrhocra grackles*), partridge (*Aleetoris choker*), snow Partridge (*Lerwa lerwa*), blue rock pigeon (*Columba livia*), snow pigeon, Himalayan snowcock (*Tetraogallushim alayensis*), woolly flying squirrel (*Eupetaurus cinereus*), Himalayan brown bear (*Ursus arctos*), mouse hare, Indian wolf (*Canis lupus*), Yaks and dzos roam across the wild Lingti plains. Over-hunting and a decrease in food supplies have

caused depletion of the population of these animals, placing them under “endangered species”.



Fig. 14. Murals inside Tabo monastery (source: www.wikiwand.com).



Fig. 15. Petroglyphs Dancing figures, Tabo. Early Historic period (Bellezza, 2017).

Flora includes dry alpine and dwarf junifer scrub, which are the major forest types found in this region. Major floral varieties available in the park are bhojpatra (*Betula utilis*), bhutal (*Juniperus mecropoda*), *Populus* spp, and *Salix* spp.

Some plants within the park have significant medicinal properties. Twenty Two rare and endangered medicinal plant species have been reported in and around the Pin Valley National Park. These are *Aconitum rotundifolium*, *Arnebia euchroma*, *Ephedra gerardiana*, *Ferula jaeschkeana*, and *Hyoscymus niger*.

Common wild flowers are *Causinia thomsonii*, *Seseli trilobum*, *Crepis flexuosa*, *Caragana brevifolia*, and *Krascheninikovia ceratoides*.

7. CURRENT TOURISM STATUS

The Pin Valley has been declared a National Park due to its unique fauna and flora. It is a popular trek for tourists, particularly European and Americans. Small hotels have come up at Guling and Mud. Tent accommodation too is provided by various tourist agencies. However, the tourist season, owing to high altitude, is restricted from June to September. An ancient Gompha at Gungri is a tourist attraction. The Gomphas at Ki, Lalung, and Dhankar in the Spiti Valley are most frequented.

8. COMMUNICATION ROUTES

Two main trekking routes are available between mid-July and late September. One option is the route from Kulu in the West, via the Pin Parvati Pass (5,100 m.). The other route is from Kinnaur in the South via the Bhaba Valley and Tari Khango Pass (4,866 m.). Trekking at these heights is a fascinating experience. Spiti Valley is full of jhoolas, like the rope bridge across the Parahio river, a tributary of the Spiti where one crosses a steel wire rope of 12 mm. suspended from abutments on either side. Using a rope made of yak hair (that is tied around one's legs with special knots) one can crawl across. With heart in the mouth, one just marvels at the towering snow peaks with glaciers and the river coursing beneath. There is a bridge near Attargo village connecting to the Pin Valley; the road goes slightly beyond Mud. Local guides, porters, and the famous Chhumurti horses are available for hire.

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JODHPUR, RAJASTHAN - A POTENTIAL GEOPARK OF INDIA

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INTRODUCTION

The proposed Jodhpur Geopark is located in Jodhpur city of Rajasthan, north-western India. It is a compact area covering 7.86 sq. km mainly in the old Jodhpur city surrounded by a strong sandstone wall. Jodhpur Geopark aims to highlight the geological sites and promote geotourism for the general public, as well as support the sustainable economic development in the region through Geopark. Jodhpur Geopark is endowed with a variety of igneous rocks of Malani Igneous Suite (MIS) and overlying Jodhpur Group (JG) of rocks of Marwar Supergroup (MSG) of international significance. MIS is the third-largest acidic terrestrial volcanism of the world and first in India which significantly witnessed Pan African orogeny. Due to the rarity of pyroclastics of MIS and its interface with JG, both have been declared as National Geological Monuments (GSI, 2001 a & b). Interestingly, this region of the Greater Indian Plate (India, Madagascar and Seychelles) was unimaginably under intense volcanism of MIS, active for a longer period in Cryogenian history of Earth (750 to 680 million years ago). Subsequently, Jodhpur experienced an aquatic environment of the sedimentary system of the significant Ediacaran period (635-541 Mya). The Ediacaran Period spans 94 million years from the end of the Cryogenian Period to the beginning of the Cambrian Period. It also marks the end of the Proterozoic Eon and the beginning of the Phanerozoic Eon. It is named after the Ediacaran Hills of South Australia. Rocks of MIS and JG built four ridges and valleys which represent two significant periods of Earth history (Cryogenian and Ediacaran) in Jodhpur. Historically, the old Jodhpur city started its journey in 1459 CE to become the second-largest city of Rajasthan. During this period, the Geopark area also witnessed other geological and historical highlights including exotic sandstone mining, construction of historical-cultural buildings (fort, palaces, *havelies* and temples). Additionally, traditional groundwater bodies of the Geopark area are unique in the world showcasing a water conservation and harvesting system of more than 550 years old patronage in this arid zone of Thar Desert.

Recently developed Rao Jodha Park near Mehrangarh Fort is an outstanding example of modern day's geotourism site, showcasing rich geodiversity and biodiversity of the region. Under such a remarkable geological scenario, thirty-three geosites have been identified representing five geoheritage types of regional, national and international significance. Accordingly, these are i. Geological, ii. Geomorphologic, iii. Hydrogeologic, iv. Geo-historic and Geo-cultural v. Archeologic. The combination of all these geoheritage types in one complex type geosite with existing tourism facilities and well managed compact tourism site puts the proposed area in a strong position to develop a dynamic and successful Geopark in Jodhpur.

LOCATION AND EXTENT OF GEOPARK AREA

Culturally vibrant Jodhpur city, also referred to as the “Blue City” and the “Sun City”, is a gateway to the Great Indian Thar Desert. It is situated in the *Marwar* region of western Rajasthan in north-western India. It is well connected to major Indian cities by railways/airways. The proposed Geopark area is covering about 7.86 sq. km unified area mainly within the city wall and rocky land of Mehrangarh ridge in old Jodhpur city (26° 14'20.04''N, 73° 01'27.48'' E; Fig. 1). All the identified geosites are connected with tar roads. A visitor centre, big halls, geological museum, library, café's, restaurants, souvenir shops, public amenities and large parking space are available at and near Mehrangarh Fort in a compact building. All these facilities are managed by the Mehrangarh Museum Trust (MMT) and can be the location of the interpretation centre for the proposed Jodhpur Geopark.

PHYSICAL AND HUMAN GEOGRAPHIC CHARACTERISTICS

Jodhpur was the capital of the former princely state of *Marwar* of Rajputana. It yet retains its identity because of its glorious history and culture. Historically, Jodhpur (Mandore, capital of *Marwar* Kingdom) was first ruled by the *Nagas* in the 4th to 5th century and then from 6th to 13th century by the *Pratiharas*, the *Chahamanas* and the Muslim Sultans of Delhi, from whom it was wrested by the Rajputs in the 14th century. Later on, Jodhpur city was found in the 1459 CE by the *Rajput* king *Rao Jodha* as a new capital of the kingdom of *Marwar* under the *Rathore Rajput* dynasty until Indian independence. After that, it was rapidly developed to become the second-largest city of the Rajasthan state with many touristic destinations. The population of Jodhpur was 1,033,918 in 2011 showing an increasing trend since the last one decade (<https://en.wikipedia.org/wiki/Jodhpur>).

GEOLOGICAL ATTRIBUTES

The geology of Jodhpur has been studied in great detail with its various aspects – Lithology, stratigraphy, structure, tectonics, paleontology and paleogeography. Geomorphologically, Jodhpur is endowed with four prominent NNE-SSW trending ridges and old Jodhpur city is situated around the foothills of these ridges. Rocky outcrops within the city wall area comprise of the spectacular landscape of igneous rocks of MIS and overlying fluvial to marine sedimentary rocks of JG of MSG (Fig. 1 and 2).

Basement rocks of Malani Igneous Suite (MIS)

MIS represents the world's third and India's largest acidic and terrestrial volcanism of 779 – 681 Ma age. MIS display two volcanic stages in Jodhpur: 1. Pyroclastics phase (welded tuff, ignimbrite and minor ash beds) and 2. Lava phase (rhyolite and rhyolite porphyry). Both these phases constitute an “igneous cycle”. (Bhushan, 1973) and are the reflection of the ‘Pan-African Event’ in India.

Jodhpur Group

Jodhpur Group (JG) is a distinct succession of basal MSG in Jodhpur city. Rocks of JG are divided into Basal conglomerate; Umed Bhawan Formation (UBF), Soorsagar Formation (SSF) and Motisar hill Formation (MHF) in chronological order (Mathur et al., 2019 a & b).

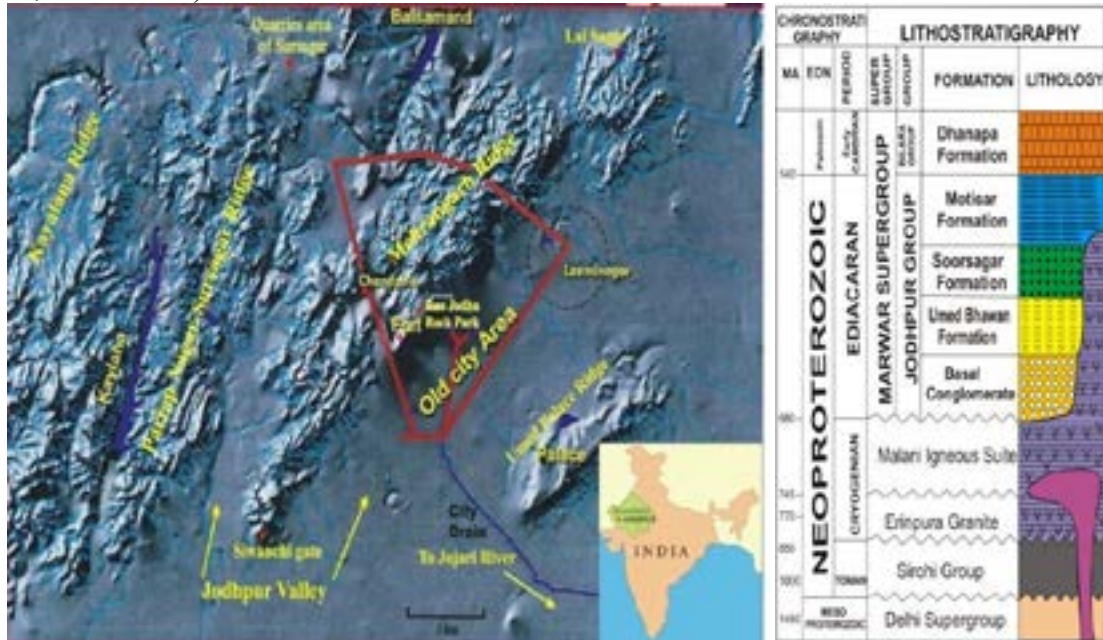


Fig. 1. DEM of Jodhpur city showing four prominent ridges and proposed Geopark area. **Fig. 2.** Lithostratigraphy of Jodhpur (Modified from Mathur et al., 2019b).

GEOHERITAGE OF JODHPUR

The above mentioned local geology reveals that thirty-three geoheritage sites in Jodhpur Geopark can be recognised (Fig. 3). Based on Ruban, (2010), these geosites can be categorised into five significant geoheritage types: geological (seven geosites), geomorphologic (four geosites), hydrogeologic (seventeen geosites), geo-monumental-cultural (four geosites) and archaeological (one geosite) in the proposed Geopark area along with additional nine geosites of spectacular rock outcrops. It is evident that hydro-geological type geoheritage is more dominant and provide a high rank to Jodhpur Geopark because of their number and uniqueness; architectural design and civil engineering works. These geosites display water harvesting and conservation systems of more than 550 years of antiquity. Additionally, geo-monumental and cultural types geoheritage represent the brilliant history and rich culture of the region built by indigenous world fame Jodhpur sandstone (heritage stone resource). Jodhpur Geopark with all these specialties is a vivid example of a perfect combination of geoheritage and historic-cultural place of great educational values. More specially, the newly developed Rao Jodha Park is a good example of recent efforts by a private stack holder (MMT) for conserving the rich geodiversity and biodiversity of the region. It is a an ambitious and successful pilot project of MMT so as to develop a Geopark at Jodhpur in the future. Jodhpur Geopark with its variety of geological sites of regional to international significance will certainly provide opportunities to create a more balanced development between geoheritage conservation, public education and socio-economic development in the region.

Thirty-three geological sites of five geoheritage types are selected in the proposed Jodhpur Geopark. The numbering of geosites are mentioned at Fig. 3. These geosites of regional, national and international significance are discussed below with their various important characters.

1. GEOLOGICAL TYPE GEOHERITAGE (Fig. 3):

It includes geosites (1, 4, 6, 20 and 21) of Pyroclastic rocks and their interface with rocks of JG. These outcrops are significantly designated as National Geological Monuments (NGM; GSI, 2001a & b) in the proposed Jodhpur Geopark area. Pyroclastic rocks of MIS are endowed with the following remarkable and unique geological features in their various geosites:

a. Pyroclastic rocks

Forty to 50 meter thick pyroclastics and rhyolite are exposed in a beautiful landscape which is represented by volcanic agglomerate, volcanic breccias, welded tuff/ignimbrite, minor ash laminations and Welded Tuff covering a vast area of eastern, western and central part, respectively, of MGR (Fig. 1). Pyroclastic rocks are characterised by aphanitic volcanic ash and sand forming about six flows. Various geosites of pyroclastic rocks can be observed all along the road from Nagori gate, near Jaswant palace to Mehrangarh Fort and also in *Hathi* Canal. Purple to ash coloured laminated ignimbrite is primarily composed of a matrix of volcanic ash (tephra) which is composed of shards and fragments of volcanic glasses, pumice fragments, and crystals deposited as pyroclastic flows.



Fig. 3. Locations of various geosites of the proposed compact area of Jodhpur Geopark.

i. Columnar Joints (geosite 1; Fig. 4.):

Beautiful columnar joints have developed in welded tuffs/ ignimbrite. They are rectangular to hexagonal straight columns, attaining a length of about 30 - 40m or more on the roadside going to Mehrangarh fort from Nagori gate. The best sites of columnar joints can be seen near the cenotaphs of Jaswant palace area (Fig. 3).

ii. Volcanic Flows (geosite 4; Fig. 5.):

As many as six pyroclastic flow can be observed all along the road that goes to Mehrangarh Fort from Nagori gate and around Gol Nadi areas. All geosites of volcanic flows are well connected by a tar road. All protected sites mainly occur near Gol Nadi, Jaswant palace, Mehrangarh Fort and Rasolai pond and are endowed with significant textures, structures and features of educational value. Among these, the main gate of Jaswant palace site has become a popular selfie point with beautiful surrounding landscape of pyroclastics, core stone with the statue of Rao Jodha, Singhoria hill, Mehrangarh Fort, Jaswant palace and blue city view in the background.



Fig. 4. Columnar Joints (NGM).



Fig. 5. Pyroclastics (NGM) near statue of Rao Jodha.

b. Interface of MIS and JG (geosite 21; Fig. 6):

Contact between basement rocks of MIS and Jodhpur Group of NGM are variable i.e. with conglomerate at Singoria hill, sharp contact with ferruginous sandstone at Gol Ghati (way to Naya Bass). At the foothill and near the entrance to Mehrangarh Fort, along with best outcrop at inside the Fort (near the lift) are the remarkable sites of NGM.



Fig. 6. NGM of sharp contact between MIS and JG at Mehrangarh Fort.

c. Rao Jodha Desert Rock Park (RJDRP); (geosites 6, 7, 16, 17 and 18; Fig. 7-10): RJDRP is located on a road that goes to Chandpole from Mehrangarh fort covering 72 ha of rocky land displaying geodiversity and biodiversity. The objective of the development of RJDRP was to conserve geodiversity around Mehrangarh fort by Mehrangarh Museum Trust (MMT) as a pilot project. Additionally, ecological restoration of Desert plants and to increase greenery on the barren landscape on MGR was another prime objective of RJDRP (Mathur and Pradip, 2016). The park is divided into three main segments (geosite 6, 7 and 16; Fig. 3).

1. Visitor's Centre is housed in a historic sixteenth-century old building near Singhoria gate. Ticket cabin, a small library and a geological museum displaying rocks, minerals and fossils from western Rajasthan are available for the visitors to look at. From the main gate of the park, the pathway that leads to the visitor centre is floored by large slabs of rippled pink Jodhpur sandstone (Fig. 7 and 8). It is a pleasant surprise to see almost all varieties of ripple marks occur in Jodhpur sandstones outside a geology laboratory in the open for visitors to notice and admire (Fig. 8).

2. Sandy Plot: One can observe how plants live in rocks and can witness their ecological restoration around the Mehrangarh fort. Today, the Rock Park reportedly has over 300 species of trees, grasses, shrubs, herbs and climbers, adapting to desert rocks. We use a special term 'lithophyte' to describe the plants that have found ways to survive in rocky or coarse pebbly habitats (Mathur and Pradip, 2016).



Fig. 7. Visitor Centre of RJDRP and Singhoria Gate. **Fig. 8.** Geological Museum at RJDRP.

3. Walking trail (Hathi Canal): From the sandy plot, steps take you down into the ancient rock-cut Hathi Canal (Elephant Canal). It is a rocky canyon that gradually opens up to reveal Mehrangarh Fort and then to beautiful water bodies Ranisar-Padamsar for a distance of about one km. The walking trail gives an excellent opportunity to observe various volcanic rocks and their features in the walking trail: i. volcanic Breccia, ii. Agglomerate, iii. Rhyolite, and iv. Rhyolite porphyry.

i). Volcanic Breccias:

Volcanic breccias consist of angular to sub-angular fragments of pyroclastics, mostly unsorted lapilli, embedded in a groundmass of fine ash and rhyolitic lava. Physically, it looks like tephra. Its excellent outcrops can be observed at beginning of the walking trail (Fig. 9).

ii). Volcanic Agglomerate:

The coarse accumulations of sub-angular to sub-rounded large pyroclastic material are set in tuffaceous matrix. The outcrop is highly jointed and fractured probably due to stresses generated by the flow of pyroclastics and is filled with melt material (Fig. 9).

iii). Rhyolite and Rhyolite porphyry:

Pink, maroon, brown and grey coloured fine-grained rhyolite in the walking trail display numerous small to large rounded to elliptical cavities/ vecicles on top of its outcrop. Beautiful flow bands and flow structures in rhyolite give a spectacular view of this site and is an attractive site for visitors. Sometime rhyolite in the walking trail is porphyritic in nature. Rhyolite porphyry is composed of euhedral to subhedral small and large phenocryst of quartz and orthoclase feldspar which are set in the devitrified quarzo-felspathic matrix that gives an attractive look to the outcrops (Fig. 9).

iv). Welded Tuff:

Hard, tough, light to dark brown coloured welded tuff (Fig. 10) occur at the middle part of the walking trail and is characterised by its aphanitic to fine grained nature. It is dominantly composed of volcanic ash and fine sand which are mixed with hot gases that were ejected rapidly down from source vent to deposit massive welded tuffs. The outcrop is highly jointed (dominantly vertical joints) which may have developed due to stresses generated at right angle by the flow of pyroclastics.



Fig. 9. Volcanic agglomerate in Hathi canal. **Fig. 10.** Welded Tuff in Hathi canal in walking trail.

2. GEOMORPHOLOGIC GEOHERITAGE

a. Siliciclastic Plateau (geosites 10, 12, 13 and 14):

The rocks of the Jodhpur Group forms spectacular landforms of siliciclastic plateaus at Ghoda Ghati, Soorsagar, Keru, Arna-Jharna, Kabir Nagar and Masuria areas. In these plateaus, the Umed Bhawan Formation (UBF) of JG forms a sequence of shale at the base followed by sandy shale, shaley sandstone, fine to coarse grained and pebbly sandstone at the top. The coarsening upward sequence and abundant presence of cross-beds with other structures indicate a typical deltaic environment for UBF in these sandstone platuae. Recently, a landslide which occurred at Masuria hill of UBF damaged such elements. Hence, there is urgent need of conservation and also similar sites in Jodhpur (Mathur et al, 2020, in press). Overlying Soorsagar Formation (SSF) at Ghoda Ghati and Soorsagar platuae comprises minor siltstones, fine, medium and coarse-grained sandstones with excellent preservation of Ediacaran fossils and sedimentary structures represent beach environment. These rocks also endowed with significant sedimentary structures of geoheritage values viz: 1. Ripple marks

(wave, current and mega ripples), 2. Cross beds (festoon and trough), 3. Graded bedding, and 4. Other structures (Rain prints, Rill marks and Scour marks). These profusely occur in mining areas of these plateau having great scientific and educational values are under great threat to destruction. Hence, the geoheritage elements of both UBF and SSF need urgent conservation (Fig. 11,12,13 and 14).



Fig. 11. Ghoda Ghati sandstone plateau.



Fig. 12. Soorsagar sandstone plateau (mining area).



Fig. 13. Kali Beri sandstone plateau (mining area).



Fig. 14. Kabir Nagar sandstone plateau.

b. Hill of Wireless station/ Singhoria Hill (geosite 5; Fig. 15):

The 310 M thick highest peak in surrounding areas of Mehrangarh fort is known as Hill of Wireless station or Singhoria hill. This hill showcases pyroclastic deposits, rhyolite and rhyolite porphyry all along its base and up to base of the temple at top. It is a remarkable geomorphological landscape of the area. Top of this hill is marked by rocks of the Motisar Hill Formation (Fig. 2). It is represented by fining upward sequence of conglomerate at the base to fine grained sandstone at the top. This hill has great aesthetic, cultural and strategic values because at top of this hill there is a famous temple of Goddess Ma Durga and the wireless station of the Army.

3. HYDROGEOLOGIC GEOHERITAGE

Spectacular, natural and traditional water bodies, locally known as *Sagar*, *Baori*, *Jhalra*, and *Kund* are the most significant entity of this Geopark. From old times, these water bodies were used for various purposes by local peoples. However, due to prolonged negligence and lack of maintenance, a few water bodies need urgent conservation. Old history, construction, architect, technologies, hydrogeologic conditions and part of the water supply network of old Jodhpur city make them excellent sites for education. These water bodies are unique in the world and are of hydrogeo tourism significance (Singh and Mathur, 2014) showcasing the water conservation and harvesting system of old times. These water bodies are classified as (a) natural and (b) traditional water bodies.

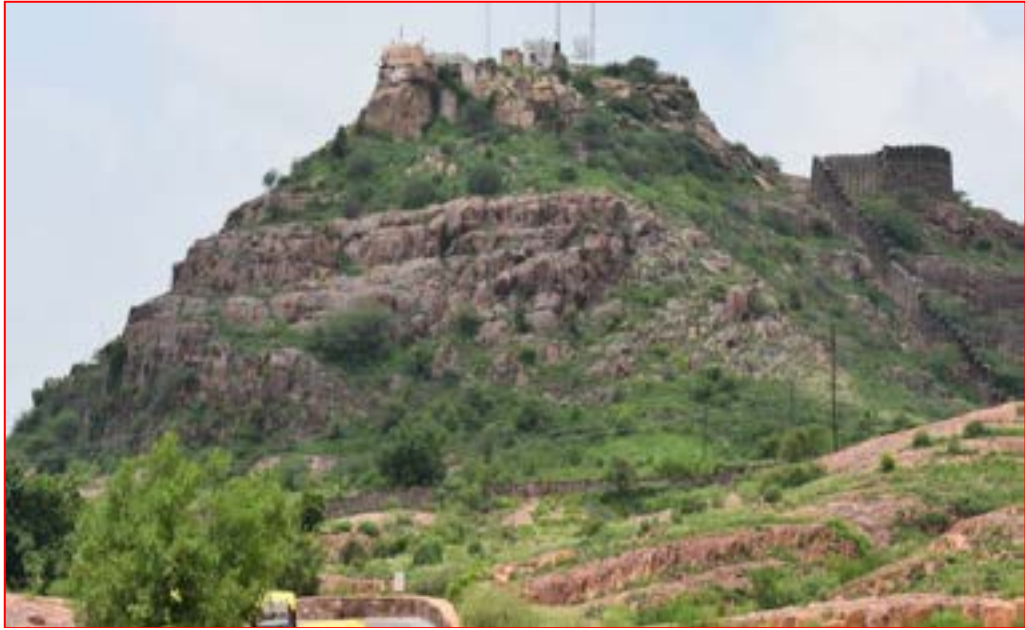


Fig. 15. Singhoria Hill.

a. Natural water bodies (geosite 3, 11, 19 and 23; Fig. 3):

Spectacular natural water bodies are natural depressions in rocks of MIS and JG were places of the water reservoir, recreational and worship activities from old time. These geosites are (i) Dev Kund, (ii) Rasolai Talab, and (iii) Soorsagar Talab, and (iv) Chamunda Mata Talab (Fig. 16, 17, 18a and 18b).



Fig. 16. Dev kund.



Fig. 17. Rasolai Talab.



Fig. 18a. Soorsagar Talab.



Fig. 18b. Chamunda Mata Talab.

i. Dev Kund: (geosite 3; Fig. 16)

Dev Kund (pond of God) is a beautiful natural water body located near Jaswant palace. It is surrounded by rocks of MIS on three sides and one side is of well designed platform of ferruginous sandstone of JG. The platform and banks of Dev Kund were built along with the construction of Jaswant palace in the year 1899. Several beautiful marble cenotaphs were built near this pond. Dev Kund has great significance as various traditional rituals of royal family were performed here.

ii. Rasolai Pond: (geosite 19; Fig. 17)

Rasolai pond is situated near lower parking on the road that goes to Mehrangarh Fort. It is surrounded by pyroclastic rocks from all sides. This geosite with outcrops of small columnar joints in Pyroclastic rocks with its beautiful banks and steps make it a spectacular and relaxing site for local people and tourists coming to Mehrangarh Fort. This pond, with a temple, is also used for religious and swimming purposes since old times.

iii. Soorsagar Talab: (geosite 11; Fig. 18a)

Soorsagar Talab is one of the largest water bodies of Jodhpur. It was constructed in 1595 by Sawai Soor Singh in Rawati area on Ghoda Ghati road. On its bank, beautiful palaces with Mughal and Rajput style architecture, gardens, library and museum are located. Now, these have turned into ruins and need urgent conservation. Significantly, three baories in which Kharbuja Baori was famous with two wells were part of old water supply in Jodhpur city, which now has a day-fed water supply system to nearby colonies and the Mandore garden (one of the famous tourist attractions of Jodhpur).

iv. Chamunda Mata Pond and Temple (geosite 23; Fig. 18b)

Chamunda Mata Talab is one of the most important water bodies of Jodhpur. At this site pig and goat are sacrificed during *Navratra* by the kings of Marwar to pay homage to Ma Chamunda as per old traditions. Spectacular Chamunda temple is situated just upstairs on western most part of Mehrangarh Fort. The small pond, surrounded by sandstone, fed water to the temple, staff quarters of the Mehrangarh Fort and Jail (in old time) situated on Pachetia hill. Religiously, this hill is very significant for local people as it is endowed with three famous temples viz: Shiv Kundia (temple and pond), Jwalaji temple and the unique Panchmukha Hanuman temple.

b. Large Traditional Water Bodies (geosites- 17, 18, 26 and 28; Fig. 3):

These are larger groundwater bodies with a dimension of more than 50 X 50 M length and width made through human interaction in old time (Singh and Mathur, 2014). These are mainly: (i) Ranisar - Padamsar, (ii) Gulabsagar, (iii) Fatehsagar.

i. Ranisar - Padamsar: (geosite 17 and 18; Fig. 19 and 20)

The oldest twin water bodies of Jodhpur, Ranisar and Padamsar are located in RJDRP in the backyard of Mehrangarh Fort. Both are large traditional ground water bodies. They also receive rain water from surrounding rhyolite hills. Ranisar was built in 1516 CE by Jaswada Hada, queen of HH Rao Jodha. It has a 67m depth with a surrounding wall of 78m length with beautiful steps in different levels and verandas constructed of Jodhpur Sandstone. It has five wells so in absence of rain water it can act as a ground

water body. Its water was lifted by the old technique of Arhat to Mehrangarh Fort. It is connected with the Bhogi Ranisar outlet with Padamsar. Padamsar was built by Seth Padhain in 1520 CE. From old time to the present, its water is used for religious purposes by local communities. It is surrounded by rhyolite hills from three sides and on one side there are steps and pump house for water supply. Both water bodies are protected by the order passed recently by the Honourable High Court of Rajasthan.



Fig. 19. Ranisar.



Fig. 20. Padamsar.

ii. Gulab Sagar:

Gulab Sagar was built by Gulab Rai, a concubine of HH Vijay Singh, from 1780 to 1788. It is 150 x 90 M in dimension with a depth of 10 M. There is a small pond named Gulab Sagar ka Baccha that was also constructed to commemorate the son of Gulab Rai. There is a small and beautiful bridge between both water bodies having heritage lights, pillars and benches. The rampart, steps, verandas, each with statues of Gods and Goddesses on three sides of Gulab Sagar are made of splendid red sandstone with recreational facilities. Hence, it attracts tourists in large number as it is situated near the clock tower in old city.

iii. Fateh Sagar:

Fatehsagar was built in 1845 by Shekhawati, queen of HH Vijay Singh in memory of their prince Fateh Singh. Fatehsagar is located half km eastward to the Gulab Sagar near Neel Kanth Hill. Fateh Sagar is 140 x 75 M in dimension with 25 M depth. To recharge it with water, a canal from Gulab Sagar was linked to Fateh Sagar. A canal from Balsamand and Kaylana Lakes was also linked to it to drain water in it.



Fig. 21. Gulab Sagar.



Fig. 22. Fateh Sagar.

c. Small Traditional Ground Water Bodies (geosites- 8, 9, 15, 24, 27, 29, 30, 31, 32 and 33; Fig. 3):

a. Jhalras:

Jhalras are human-made heritage groundwater bodies that are larger than Baoris having a rectangular design with steps on three or four sides; these are essentially meant for community use and religious purposes. These are (i) Sukh Dev Jhalra, (ii) Rajmahal Jhalra, and (iii) Toorji ka Jhalra (geosites- 8, 15 & 29; Fig. 23, 24 and 25).

i. Sukh Dev Jhalra (Kriya ka Jhalra)

It was built by Sukh Dev Tiwari in the reign of HH Ajit Singh Ji in 1718 CE near Singoria gate. This Jhalra with a beautiful structure of carved sandstones having steps at three sides: on one side it has a beautiful veranda. It has statues on all four sides i.e. in the east sun, in the south Goddess Durga, in west Shiva and in the north Kamal and Ganesha. At one side there is a room for ritual purposes. Presently, its condition is pathetic and needs conservation (Fig. 23).

ii. Raj Mahal Jhalra (Mahilabagh Jhalra):

It is located near Gulab Sagar, constructed by Gulab Rai, queen of HH Vijay Singh, in the year 1775 CE. It has a remarkable design with steps at various levels from all sides with spectacular verandas, domes and arches represent with rich architect and civil engineering of old time (Fig. 24).



Fig. 23. Sukhdev Jhalra.



Fig. 24. Rajmahal Jhalra.

iii. Toorji Ka Jhalra or Tunwarji ka Jhalra: (Fig. 25).

Tanwar Kanwar queen of HH Abhay Singh constructed this Jhalra in the year 1740 CE at Makrana Colony near Gulab Sagar. It is a spectacular ground water body with beautiful architectural design having steps on four sides at various levels, and verandas with carved pillars and domes. It has a gaumukh (Cow Mouth) in the northern side from which water flows throughout the year showing knowledge of our ancestors to identified paleo-conduit system and indicating rich knowledge of subsurface geological structure. Recently, Rajmahal and Toor Ji ka Jhalra was cleaned by Mr. Caron, 70 years old Irish with the local residents. Now, both have become the centre of attraction for tourists. Many guest houses and restaurants with roof top bars have opened in the surrounding area which shows how such geosites can contribute to the economy.

b. Baories (geosites 9, 15, 30, 31 and 32):

Baories are also magnificent human-made groundwater bodies of old time. These are smaller than Jhalras in dimensions but have three to seven levels of steps only in one direction. Each level is constructed with verandas pillars, arches and sandstone statues of Gods and Goddesses. These water bodies were constructed at places where the water table was very high so that people could reach the lower water table to get water easily. These are also religious places similar to Jhalras of old times. These are: (i) Navi Baori, (ii) Raghunath Baori, (iii) Gorinda Baori, (iv) Tapi Baori and (v) Najjar ji ki Baori.



Fig. 25. Toorji Ka Jhalra.

i. Navi Baori or Malan ki Baori:

Navi Baori is located in the courtyard of Rameshwar Temple near the Chand Pole area. It was constructed by Indira ji in 1871 CE during the reign of HH Takhat Singh. Architecturally, it is constructed of pink Jodhpur sandstone. It is a large, L-shaped structure with beautiful steps and verandas. A canal linked with Balsamand Lake (out side Geopark area) was constructed to drain water in it. Presently, it is full of polluted water and needs urgent conservation (Fig. 26).

ii. Raghunath Baori:

It is located near Chand Pole. It was constructed by Deewan Bhandari in 1705 CE. It is 30M in length, about 7 M wide and 30 M deep. It has beautifully carved pillars, arches and verandas with four floors. On three sides, a statue of Ganesha, Govardhan and Shiva are placed, indicating its religious importance for local residents. Recently, it was renovated by Govt. under the Jal Swavalamban scheme (Fig. 27).

iii. Gorinda Baori:

This Baori is situated in busy Tripolia Market near Sojati Gate at the foot hills of Mehrangarh Fort (Fig. 3). It is a small Baori with about 20m length and 5m width with 25m depth having three beautiful floors, supported by carved pillars and arches.

Presently, due to high ground water problem of Jodhpur city and to get the water table lowered, its water is supplied to Public Parks. Recently, it has also been renovated by Rajasthan Govt. under Jal Swavalamban scheme (Fig. 28).



Fig. 26. Navi Baori.



Fig. 27. Raghunath Baori.

iv. Tapi Baori:

This Baori is situated near the Jalori gate (Fig. 3). It was built by Nathoji Vyas to commemorate his father Tapoji Vyas in 1675 CE. The water of this Baori was light and sweet and hence, supplied to inhabitants residing up to Sojati Gate. It is 30m in length, 8m wide and 30m deep having five floors with verandas, carved pillars and arched temple. It was renovated under Jal Swavalamban scheme recently (Fig. 29).



Fig. 28. Gorinda Baori.



Fig. 29. Tapi Baori.

v. Najarji ki Baori:

This Baori is located between Jalori Gate and Sojati Gate (Fig. 3). It was constructed in the reign of HH Takhat Singh in the year 1859 by Nazir Altmas. It has four floors supported by beautifully carved pillars and arches with verandas and steps on all floors. It is constructed by red Jodhpur sandstone and has been renovated recently (Fig. 30).

c. Wells:

Surprisingly, in old Jodhpur city more than 500 wells existed on the name of a person or a community. Among them, two wells (Jeta and Nimbla wells) are very important for having medicinal water. During old time, water from these wells were allowed to be used only by the royal family. For others, rationing of water was enforced and

only a bucket of water was permitted for the general public by deputed guards with the permission of officials (Singh and Mathur, 2014).

i. Jeta Well: (Fig. 31)

It is one of the oldest well located in the premises of lord Shiva temple near Chandpole. It was built by Mootha Jaita at the time of Rao Jodha in 1488. In the reign of Aurangzeb from 1680 to 1690, efforts were made to demolish it. Hence, to protect this well, guards were deployed for its safety and also because of the quality of its water.

ii. Nimbla Well:

It is oldest well of Jodhpur located inside of Jalori gate (Fig. 3). It was built by Shrimali Neemba in 1459 with the Mehrangarh Fort. There are beautiful arched varandas and a temple for worship. The water of this well was considered medicinal and the importance of this well is still maintained. (Fig. 32).



Fig. 30. Najar ji ki Baori.



Fig. 31. Jeta Well.



Fig. 32. Nimbla Well.

4. GEO-HISTORICAL- CULTURAL HERITAGE MONUMENTS (geosites 2, 22, 23, 25):

These represent magnificent buildings of more than 550 years old patronage of Jodhpur represented by the unique Mehrangarh Fort, its seven palaces, Havelies and temples constructed by Jodhpur sandstone and beautiful Jaswant palaces of Marble. Folk music, literature, painting, pictures and handicrafts of the old time are well displayed in Mehrangarh Museum. Ancient art, sculptures and carving in Jodhpur sandstone are also displayed in windows (Jharokha), balconies and on walls of royal palaces. These royal Geo-historical and cultural heritage monuments are unique heritage attracting tourists from India and abroad in Jodhpur. These are: (i) Mehrangarh Fort, (ii) Chamunda Temple, (iii) Jaswant palace, and (iv) Clock Tower.

i. Mehrangarh Fort:

Mehrangarh Fort is one of the largest Forts in India. It was founded in 1459 as the site of Rao Jodha's new residence in the capital of Marwar state. It occupies the entire top of a 150 to 240 m high and 0.5 km long Pachetia ridge with commanding views all around. About three km of massive rampart built around the Fort by Jodhpur sandstone with intricate carvings and expansive courtyards inside. There are seven gates to enter the Fort boundary. Several brilliantly crafted and decorated palaces give a royal sense to Mehrangarh Fort. These include Moti Mahal (Pearl Palace), Phool Mahal (Flower Palace), Sheesh Mahal (Mirror Palace), Sileh Khana Fateh Mahal (victory palace) and Daulat Khana (Treasury). It is managed and maintained by Mehrangarh Museum Trust with HH. Gaj Singh ji II, as its custodian (Fig. 33).

ii. Chamunda Temple:

On the south-western tip of Mehrangarh Fort, an ancient temple of Chamunda Mata is situated on Pachetia sandstone Hill. On Pachetiya hill, famous temples like Shiv Kundia (temple of Shiva with small pond), Jwalaji and Panchmukha Hanuman (rare) temples are situated. The idol of Devi Chamunda was brought to the fort from Mandore in the year 1460 by Rao Jodha being Kuldevi (family Goddess) of Rajput Rathores (Fig. 34).



Fig. 33. Panoramic view of Mehrangarh Fort.

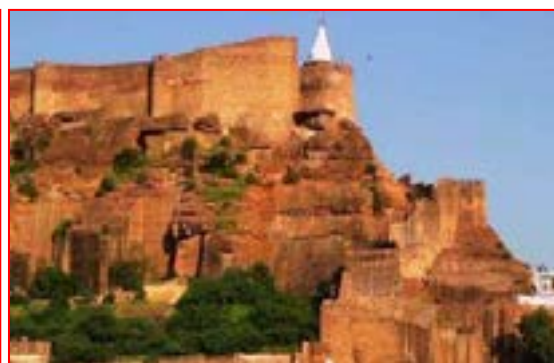


Fig. 34. Chamunda Temple and Pachetia hill.

iii. Jaswant Palace:

Magnificent and beautiful Jaswant Palace is located about one km downhill from Mehrangarh Fort. It is a cenotaph built by Maharaja Sardar Singh in 1899 in memory of his father. It is built out of intricately carved sheets of marble (Fig. 35). These sheets of marble are extremely thin and polished so that they emit a warm glow when

illuminated by the sunlight. A cenotaph nearby serves as the cremation ground for the royal family since the old time (Sinha, 2007).

iv. Clock Tower (Ghantaghar):

It was built by HH Sardar Singh in the year 1890 from whom the surrounding market takes its name Sardar market. It is an old city landmark surrounded by the vibrant sounds, sights and smells of traditional foods. It displays a magnificent blend of modern architectural concepts with old Rajput traditions. It has triple gateways with narrow and winding lanes of the old city that spread out in all directions. Selling of vegetables, spices, sweets, handicraft, amusing or annoying chaos with tiny shops on both sides of the narrow lanes attract tourists, specially foreigners (Fig. 36).

5. ARCHAEOLOGICAL GEOHERITAGE

The excavations carried out in 1909-10 by Archeological Survey of India yielded two elaborately carved monoliths of Krishna-Leela scenes found at Mandore Fort. These are placed at the nearby museum (Fig. 37). On stylistic grounds, these monoliths could be dated to the early fifth century CE. The Ghatiyala inscription of 861 CE reveals that the Jain temple and Jeevan Mata temple of Pancholi, Kayastha were constructed during king Kukuka of the Pratihara period. These temples, with one mosque sharing a common wall at Mandore near Ghoda Ghati sandstone plateau (geosite 10) just outside the Geopark boundary reveal secularism and harmony among communities during ancient time (Fig. 38). This evidence also reveals that Rajputs and Pancholi were two main ancient local communities of Jodhpur. Additionally, Chhatris (cenotaphs; Fig. 39), hall of heroes, palaces, temple of Kala Gora Bheru ji, museum of archaeological significance with Nagadari Lake, are the major attraction in the eighty-hectar area of lush green Mandore garden surrounded by sandstone hills. Among six beautifully carved sandstone cenotaphs with collection at Mehrangarh Museum of old record (Khyats), inscriptions and books on Pratihara and Rajput dynasty (6th to 13th centuries) and later history since 1459 CE of Rajput dynasty represent glory, gallantry, rich traditions and culture of Jodhpur.



Fig. 35. Jaswant Palace.



Fig. 36. Clock Tower.



Fig. 37. Mandore Fort and museum.



Fig. 38. Common walls of - temples and mosque showing secularism of the old time.



Fig. 39. Cenotaphs of Mandore

CURRENT STATUS OF PROTECTION AND MANAGEMENT

Most of the geoheritage sites of Jodhpur Geopark are managed by Mehrangarh Museum Trust (MMT). Hence, geosites of NGM and RJDRP along with geo-historical sites are well protected and conserved. However, most of hydrogeological geosites are managed either by state Govt. or religious trusts need their conservation. Five types of geoheritage sites of Jodhpur Geopark discussed above reveal that these are undoubtedly of great educational and geotourism values having national and international significance. Looking to these specialities, the UG, PG and research students of Earth Science, Botany, Geography and Arts of many Universities conduct their educational tours every year. Similarly, because of historical and cultural geosites Jodhpur is popular nationally and internationally as tourist place. It is a proved fact that the spectacular scenic landform, NGM and RJDRP geosites with their geoheritage elements also attracting tourists to a large extent. Under such tourism scenario, to promote geotourism through proposed Jodhpur Geopark, required infrastructural facilities are also available at Mehrangarh Fort premises developed by MMT. These include a visitor centre, ticket counter, money exchange counter, a big hall, audio commentary facilities, restaurant, souvenir shop, brochures and sign boards (details of NGM, various rocks and their features, flora and fauna) and guides, etc. Similarly, other geosites of scenic and educational values can contribute to tourism as most of these geosites are near Mehrangarh Fort and can be easily accessed through tar roads on the suggested route map (Fig. 3). However, few geosites which are unclaimed or are under Govt. management need conservation, especially siliciclastic plateaus which are under threat to anthropological activities and rapid urbanization. These need to be covered under proposed Geopark. For promotional activities, many videos of tourist places of Jodhpur are available on YouTube. An audio-video describing many important geological sites, prepared for international participants of IGC field trip (WR004), a web site of MMT and RJDRP are available for details. Besides all these aspects, Jodhpur Geopark satisfies the requirements of UNESCO as five type's of geoheritage of the proposed Geopark are undoubtedly of national and international significance. Most of the geosites are unique and representative of educational, aesthetic, historical, cultural and geotourism values. Since majority of geosites are well-managed by MMT, a legal body should be established under the esteemed leadership of the chief of MMT (HH Gaj Singh ji), geoscientists working on these geosites, representatives of INTACH and local community, to achieve the goal of Jodhpur Geopark. This body may also include partnership and involvement of academic bodies, local, state Govt., and all stakeholders with a firm conservation and management plan. After fulfilling these criteria, a document (dozier) should prepared with details of geodiversity, biodiversity and cultural aspects of international

significance of Jodhpur Geopark. A national body should evaluate the proposal to provide a national Geopark tag to potential sites to be qualified for the UNESCO global Geopark in future for socio-economic development of the region.

CURRENT OR POTENTIAL THREATS AND REMEDIAL MEASURES FOR GEOCONSERVATION

Geosites of the siliciclastic plateau and few hydrogeological sites, outside the management of MMT are poorly managed and are mainly under serious threat due to anthropological activities, rapid urbanization and various geological processes. To save and conserve these geosites, protected status can help in mitigation of negative anthropogenic influence on them. Among hydrogeological sites (few Baories) which are not covered under the Jal Swavlamban Scheme of state Govt. require maintenance and conservation for which local people and/or NGO's (INTACH, which is active NGO working in Marwar) can do this work for their protection and restoration. Additionally, including these geosites under the Geopark management system under MMT can be a better option for their conservation in the future.

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AN ASSESSMENT OF GEOTOURISM POTENTIAL IN THE KURNOOL DISTRICT, ANDHRA PRADESH, INDIA

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INTRODUCTION

Geotourism is a newly emerging field and in spite of its conceptualisation in the 1990s remains ill-defined. Its definition varies depending on the perception of the promoters with different backgrounds and interests. The differing views and divergent opinions on the same only added to confusion and complexity over the years. There is, however, no doubt that “geology” and “geography” are two vital pillars of Geotourism.

The International Congress of Geotourism held at Arouca, Portugal in 2011 under the auspices of UNESCO declared that ‘Geotourism should be defined as tourism which sustains and enhances the identity of the territory, taking into consideration its geology, environment, culture, aesthetics, heritage and the well-being of its residents’. The Declaration added ‘geology’ to the existing definition promoted by National Geographic (2005).

Irrespective of various definitions in vogue, geotourism seeks to identify and understand various natural heritage and geosites carved on the mother earth by normal geological processes (surface and subsurface) or created by man through his ingenuity from time immemorial, which are recognized as great monuments of rich historical, cultural and religious heritage. Geotourism also promotes such sites as geoparks / natural heritage sites for the present and future generations. Such heritage sites are several and spread all over our country, although some of them have remained obscure.

An attempt is made to compile the available information on the Kurnool District, which has a hoary past in terms of human civilisation, long history of ruling by renowned dynasties, distinct geological and geomorphological features, and contrasting cultural and religious legacies.

THE KURNOOL DISTRICT

Kurnool, one of the four districts of the southern Andhra Pradesh (AP), collectively known as Rayalaseema, is considered as it has a wealth of data on all relevant themes to promote Geotourism and conserve Geoheritage. The district, located in the western part of AP, has borders with two states, Karnataka on the west and Telangana on the north. The northern boundary coincides with the Tungabhadra and the Krishna rivers, the eastern side with Prakasam District, and the southern side with the Anantapur and Cuddapah districts of AP. Kurnool is the second largest district in the State, occupying an area of 17, 617 sq. km and bounded by N latitudes $14^{\circ} 54': 16^{\circ} 18'$ and E longitudes $76^{\circ} 58': 79^{\circ} 34'$ (Fig. 1).

Kurnool, the district headquarters, was originally known as Kandenavolu from the ancient inscriptions and texts. It is popular as the location was a halting place for greasing (grease meaning kandenamu in Telugu) the bullock cart wheels with oils before crossing the Tungabhadra River (TBR) with loads of stones for construction of Alampur temple in the 11th century during the reign of the Chalukyas. The town is located on the banks of the Handri River near its confluence with TBR. It is about 29 km from Sangam, the confluence of TBR with the Krishna River. The place has served as Gateway to the Rayalaseema from medieval times and gained prominence during the rule of King Achyuta Deva Raya (1529-42) of the Vijayanagara Empire.

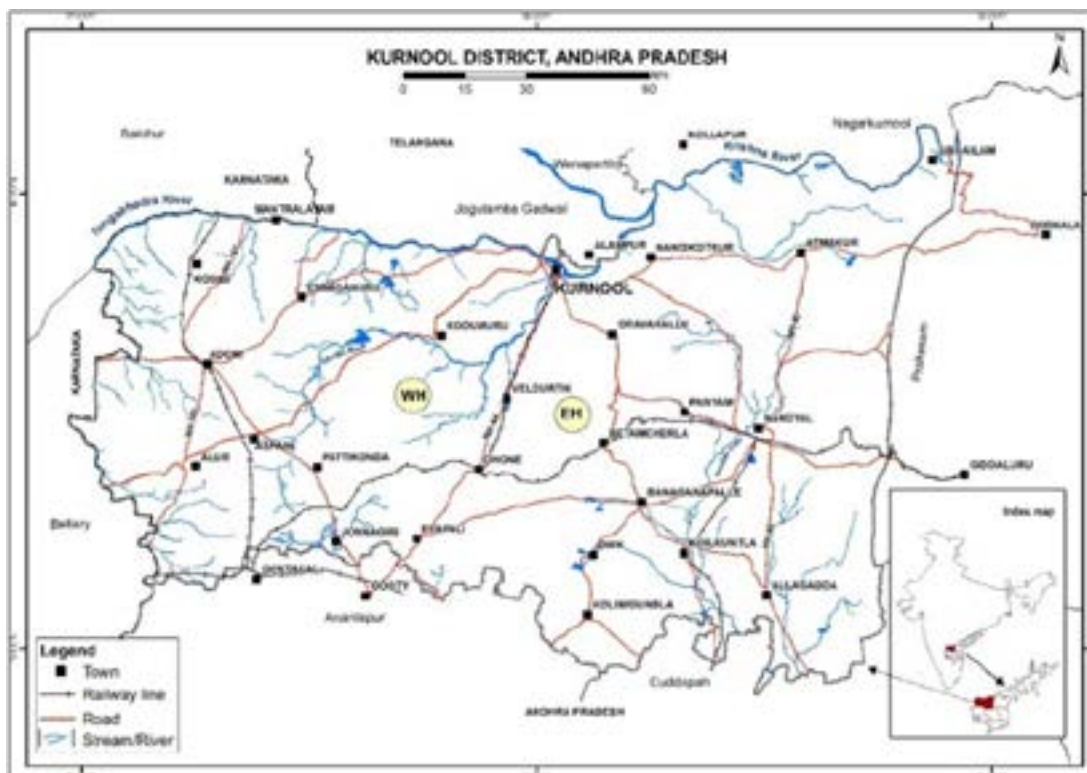


Fig. 1. Base map of the Kurnool District, Andhra Pradesh

The N-S NH 44 broadly divides the rectangular shaped E-W oriented district into two halves, the Western Half (WH) and the Eastern Half (EH). The two areas, apart from having different geologic and geomorphic settings, possess distinct historical, archaeological, cultural, ethnological, and botanical attributes.

General Information

The district is well served by N-S, E-W, and radial State Highways (SH) and National Highways (NH 44, 40 & 167) and four railway lines, linking Kurnool with other places in the district / State and important places in the neighbouring states (Fig. 1). It has the distinction of the presence of the longest national highway NH 44 (3,745 km long) in India that transects in N-S corridor through 11 states and union territories from Srinagar to Kanyakumari, passing through the central part of the district.

Climate is normally hot with April and May as very hot months. November to February is relatively cool. The area, in general, falls under a scarce rainfall zone receiving 500 to 700 mm annually from SW (68%) and NE (22%) monsoons. Forest

cover is nearly 1800 sq. km in area (10% of the total area), and almost all of it is confined to the hill ranges of the EH.

Soils, in general, are not very fertile and are neutral to alkaline (7 to 8.5 pH). Agriculture is the main source of livelihood. About 65% of the area (11,478 sq. km) is under cultivation wherein mostly commercial crops such as groundnut, pulses, cotton, onion, and chillies are grown. The rice produced in the district, popular as ‘Sona Masoori’, is exported to North America, Australia, and Gulf countries. Mango and banana are the commonly grown fruits. The delicious Banganapalle mango often called ‘benisha’, is native to this area. The chief source of irrigation is through bore wells, tanks, and canals. Apart from the 150-year old Kurnool-Cuddapah (K-C) Canal that draws water from the Sunkesula Dam across TBR, the district is served by four other major canals that have come up in the post-independence period drawing water from backwaters of the Srisailem Reservoir across the Krishna River.

Much of the general information on various aspects of the district is obtained from several published government reports, and websites. The Manual of the Kurnool District in the erstwhile Presidency of Madras compiled in 1885 by N. Krishnamah Chetty (the then Deputy Collector) is an important one. Many websites, particularly those of the Government of AP (kurnool.ap.gov.in, apedb.gov.in, aparchmuseums.nic.in) and India (dcmsme.gov.in), Census of India 1961 Volume II Andhra Pradesh (Part VII-B (II) Fairs and Festivities (11 Kurnool District) and District Survey Report of the Kurnool District (2018), prepared by the AP Space Application Centre and submitted to the Department of Mines and Geology, Govt. of AP, contain useful information.

The Land of Contrasting Terrains

The district is marked by distinct but different in several respects, particularly in terms of contrasting physiographic and geologic settings and cultural features.

MAJOR GEOGRAPHICAL FEATURES

The total area from west to east is broadly classified into four geographically distinct divisions, namely the Handri pediplain, the Erramala hills, the Kunderu (Nandyal) plains, and the Nallamala hills (Fig. 2). The WH is an extensive pediplain country with scattered monadnocks in granite-gneiss terrain whereas the EH is dominated by two subparallel N-S trending hill ranges, Erramalas in the west and Nallamalas in the east, with intervening Nandyal plains.

The Erramalas (red hills) form a series of low flat-topped hills and discontinuous plateaus. The hills extend over a length of 130 km, 75 km in the Kurnool District and 55 km in the Cuddapah District. Quartzite, limestone, shale, and volcanic sills and flows are the major rock types. The plateaus, chiefly composed of the Panyam Quartzite, display some sort of pinnacles formed due to differential weathering. The lower beds remain as plateau quartzites. The hills at several places form scarps often dislodging huge boulders (5 m to 10 m size) of the quartzite, that dot the slopes. This formation at many places houses cavernous type hollows, which have been identified as prehistoric sites.

The eastern hills referred to as Nallamalas form the southern continuity of the Eastern Ghats to the south of the Krishna River and join the Tirupati hills further south. They form highly dissected steep hills with deep valleys and exhibit rugged topography with elevation ranging from 900 to 1100 m above MSL. About a third of the total 430 km length of the hill range forms the eastern boundary of the district. The hills act as a major drainage divide to several main rivers, the Gundlakamma and the Sagileru on the east and the Kunderu on the west. The Nallamala rocks, comprising chiefly quartzites and phyllites, are thrown into highly folded subparallel ridges. The highest point in this part of the hills is 1048 m above MSL near Gundla Brahmeswaram, located to the WNW of Cumbum. Gundlakamma, the only significant river between the Krishna in the north and the Penna (Penner) in the south, originates in the Gundla Brahmeswaram area falling in Nandyal and Atmakur divisions.

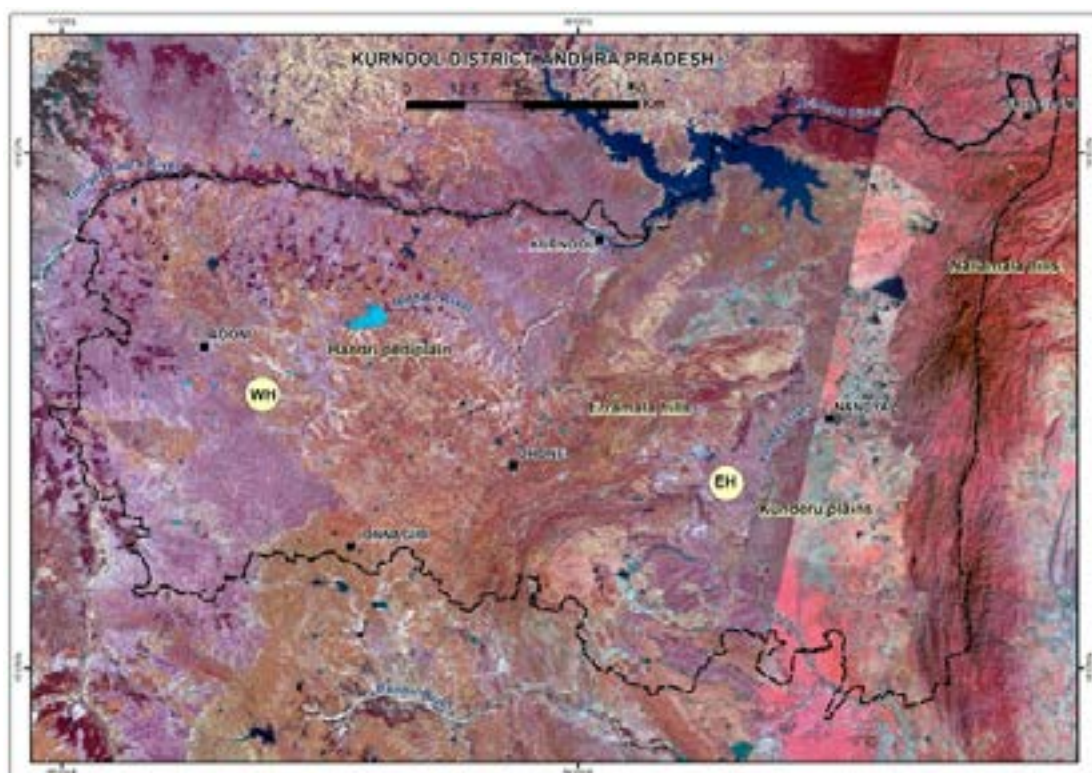


Fig. 2. Landsat image of the Kurnool District and the adjoining area.

Landforms are both denudational and fluvial types, the former is prominent in the WH in the form of pediplain whereas pediment and denudational hills are common in the hill regions of the EH. Fluvial landforms in the form of channel bars and flood plains occupy a limited area. The granitic terrain and the Kundu plains have very gentle slopes. The Erramalas show moderate slopes towards the east whereas the Nallamalas exhibit steep to very steep slopes on either side.

There are five drainage sub-basins that fall into two major basins, namely, the Krishna (9757 sq. km, 55.38%) in the north and the Penna (7859 sq. km, 44.61%) in the south. The five sub-basins, are, i) the Vedavati (a tributary of the TBR) on the west, ii) the Tungabhadra (a major tributary of the River Krishna) in the north, iii) the Handri (also known as Hindri, a tributary of the River Tungabhadra) in the middle, iv) the Krishna in the northeast, and v) the Kundu, a tributary of the River Penner) on the east (Figs.1 & 2). Almost all the streams are non-perennial. Some of them witness flash floods causing a lot of devastation.

There are two major rivers, the Handri in the WH and the Kundu (Kunderu) in the EH, both originating in the district. The former, which originates in a low-rainfall Maddikera area, flows north-easterly to join the TBR. The river is generally dry but occasionally gets flooded during incessant rains. A few legends attribute the origin of the word Andhra to the Handri River. The River Kundu, also known as Kumudvati, has its origin in the Erramala Hills from a spring at Uppalapadu in Oravakal Mandal. The river, which begins its course easterly, turns towards the south later before joining the Penna River near Kamalapuram. During its southern journey, the river receives copious water during monsoon from several streams draining the Nallamala hills. The river often called ‘Sorrow of Nandyal’, is destructive due to unpredictable floods causing heavy damage to Nandyal town and several villages in the valley.

BRIEF GEOLOGICAL HISTORY

The geological history of the region, as outlined from the works of the Geological Survey of India (GSI) and other organizations, is briefly summed up for better understanding (GSI, 2006). The area forms a part of the southern Peninsular Shield, normally referred to as the Dharwar Craton, and is made up of Palaeo to Mesoarchean (3500-2600 Ma age) granitic gneisses with schist bands/enclaves. The present area, which falls in the eastern part of the above-said craton, was an ideal site in the development of intra-cratonic sedimentary basins, namely, the Cuddapah Basin (CB) of Mesoproterozoic age (1600-1000 Ma) and two younger sub-basins, Kurnool and Palnad of Neoproterozoic age (900-600 Ma). The development and configuration of the CB were determined by a series of tectono-thermal events and dilational tectonics that favoured intense basic volcanism, which is pronounced in the lower CB sediments.



Fig. 3. Generalised geological map of the Cuddapah Basin (Source: Jain *et al.* 2020).

The CB is crescent shaped with its convex side towards its west. It is 450 km along its eastern margin and 145 km wide in the central part and occupies 44,500 sq. km area (Fig. 3). Since the early work of Charles Oldham, Bruce Foote, and William King (King, 1872) and their classification of the CB rocks, many primarily from GSI have attempted to revise the basin stratigraphy and structure. The CB is filled with a thick pile of sediments, largely of arenaceous and argillaceous variety with subordinate carbonate components and associated igneous flows, sills, and dykes. The cumulative thickness of the sediments and volcanics is estimated to vary between 6 and 12 km. The CB rocks, grouped as the Cuddapah Supergroup, rests unconformably over the granites and gneisses. The Cuddapah rocks, from bottom to top, is subdivided into i) Papagni Group (Gulcheru Quartzite and Vempalle Formation), ii) Chitravati Group (Pulivendla Quartzite, Tadpatri Formation, and Gandikota Quartzite), iii) Nallamalai Group (Bairenkonda Quartzite, and Cumbum Formation), and iv) Srisailem Quartzite. The Kurnool Group comprises a 500 m thick succession of sandstone/quartzite, limestone, and shale. They generally overlie the Cuddapah rocks with an unconformity but rests at places directly over the Archaean basement. The Kurnool rocks, from bottom to top, are further divided into the Banganapalle Quartzite, Narji Limestone, Awk Shale, Paniam Quartzite, Koilkuntla Limestone, and Nandyal Shale.

The geological map of the Kurnool District (Fig. 4) shows that the WH is occupied by granites, gneisses, migmatites, and schists with several basic dykes and the EH, more or less by the CB rocks overlain by the Kurnool sediments. The Cuddapah rocks occur mostly in the western part of the EH underlying the Kurnool sediments in the Erramalas and again in the eastern part of the EH, occupied by the Nallamalas. The Kurnool rocks are preserved over the Erramala Hills, in the Kunderu plains, and as a few detached outliers over the Nallamalas.

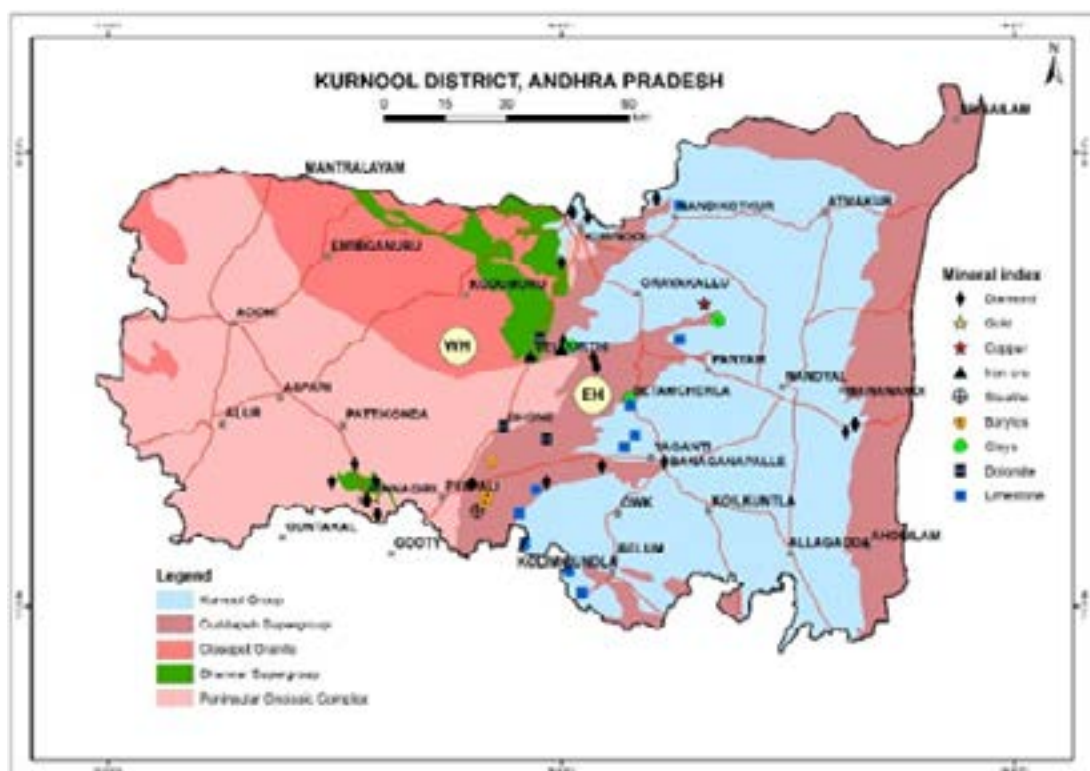


Fig. 4. Simplified geological map of the Study area showing locations of major mineral occurrences. (Source: Quadrangle geological maps of GSI -57 E, I, J & 56 J).

Nearly one-fifth of the CB and more than 50% of the Kurnool Basin lie in the Kurnool District. The west central part of the CB and the central part of the Kurnool Basin are situated in this district.

CULTURAL AND RELIGIOUS HISTORY

The people in the WH bordering Karnataka State have more cultural ties with Kannadigas and came under the influence of Jainism from the 3rd century BC. A few temples dedicated to Jainism were built in Adoni and nearby areas. Apart from Jainism, Lingayatism, founded by Basaveswara or Basavanna, a 12th century saint, philosopher, poet, statesman, and social and religious reformer during the reign of Kalyani Chalukya/Kalachuri dynasty became popular. His writings known as 'Vachanas' have influenced the lives of many in parts of Karnataka, Maharashtra, and Telangana and WH of the Kurnool District. Besides, the 17th century Hindu saints and philosophers Sri Raghavendra Swamy in the WH and Sri Veera Brahmendra Swamy in the EH enlightened the society through their teachings.

The Kurnool region has been under the influence of Islam from the middle of the 16th century as a result of more or less continuous Muslim rule by Bijapur, Qutb Shahi, Mogul, and Asaf Jahi kingdoms. The Muslim population is spread all over the area retaining their culture and mixing up with the local Hindus without any inhibition. They speak Dakhani (Deccani), a variant of Urdu but mixed up with words of Persian and Arabic and local Telugu, Kannada, and Marathi. The rural Muslims are well-versed in Telugu.

The arrival of St. Thomas, one of the 12 disciples of Jesus Christ to the Malabar Coast, Kerala in 52 AD and the preaching of the Gospel has certainly made an impact in the lives of Indians in several respects. The discovery of the sea route to India by Vasco da Gama in 1498 had paved the way for the establishment of the Christian Missionaries and European colonial rule in later years. The missionaries extended their services to the poor and sick, established schools and hospitals, encouraged female education, and initiated many socio-economic activities. The services of the missionaries became widespread in the Kurnool District with the establishment of Missionary Stations in 1873.

Ethnic Tribes

The Banjaras, Yerukulas and Chenchus, the three prominent ethnic groups in the order mentioned, mostly inhabit the EH as the region is suited to their style of living. They constitute nearly 2% of the population and are grouped under Scheduled Tribes (STs). The Banjaras (locally known as Lambadis or Sugalis) are a nomadic Pan-India tribe having roots in the Marwar region in Rajasthan and have settlements mostly confined to the Erramala Hills. Of the 51 Sugali Thandas (Thanda meaning hamlet) recorded, 38 are in the EH. Many of the Sugalis are peasants, hunters, food-gatherers, and small-farmers and knowledgeable about medicinal plants. The Yerukulas (Erukulas) are mostly engaged in pig rearing and are skilful in basket making, mat weaving, etc. The women folk of this community are well known as soothsayers and fortune tellers. The Nallamala hills are home to Chenchus living in about 72 gudems (hamlets). They are an aboriginal tribe, who are hunters and live on forest produce. According to many legends, the Goddess 'Chenchu Laxmi', consort of Lord Narasimha of Ahobilam, was from the Chenchu tribe.

Ethnobotanical Studies

Medicinal plants, known to humans since ages, have become a chief source of inexpensive material for the manufacture of related drugs. The studies by several botanists have brought to light the occurrence of species of different medicinal plants in the Nallamala hills. The knowledge of the Chenchus is immense in using specific plants as crude drugs to treat common ailments. Recent studies have established that crude drugs are found to cure insect and snake bites, fevers, throat infections, stomach disorders, skin diseases, diabetes, paralysis, arthritis, etc. Leaves, stems, bark, gum, seeds, and roots are used mostly in the form of decoction, paste, and powder in conjunction with or without other herbs and spices.

Prehistoric Sites (rock shelters, caves, and megalithic burials)

The Kurnool region has a unique place in the history of human civilisation as revealed by the investigations carried out by many Indian and overseas researchers at several places in the Erramala hills from 1844 till now. Rock arts and paintings and the rock shelters found at Ketavaram ($15^{\circ} 44': 78^{\circ} 09'$) in Oravakal Mandal, Ketavani Kunta (Jurreru valley) near Jwalapuram ($15^{\circ} 19': 78^{\circ} 08'$) (Fig. 5) and Yaganti ($15^{\circ} 21': 78^{\circ} 08'$) caves in Banganapalle Mandal, Nossam in Koilkuntla Mandal, and Kanukuntala ($15^{\circ} 12': 78^{\circ} 00'$) in Owk Mandal, are dated back to 35,000 to 40,000 years. The paintings are in the form of prominent figures of hunting animals and depict the lifestyle of the pre-historic men. Stone implements found at one of the sites are dated at 6,000 years, which indicates that the civilisation in the area is contemporary to that of the Indus Valley Civilisation. The discovery of the largest petroglyph site of Mesolithic-Neolithic age in the State at Kandinati ($15^{\circ} 42': 77^{\circ} 28'$), Yemmiganur Mandal as recent as in 2018 goes well with similar findings in the district.

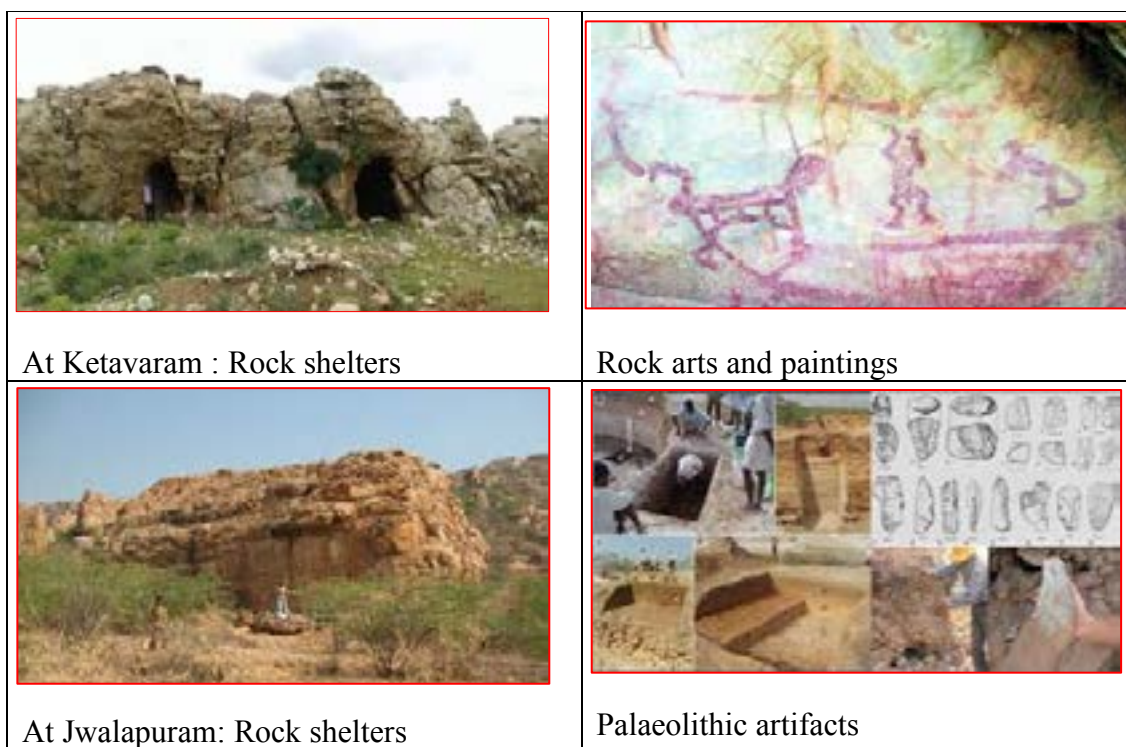


Fig. 5. Rock shelters, rock paintings, and artefacts from Paniam Quartzite (Source: Google).

The occurrence of ash beds in the Jurreru valley, related to the 74,000 years old Toba volcanic eruption from Sumatra, and the associated Neolithic technology and hominin occupation and climatic change towards the glacial environment in this part of the region, indicate Middle Palaeolithic assemblages.

Jain and Buddhist monks are believed to have resided in the historic Belum caves centuries back. The Archaeological Survey of India (ASI) has found relics of pre-Buddhist remnants of vessels and artifacts.

Quite a number of megalithic burial sites have been recorded from the late 19th century onwards in several parts of the district. In the post-Independence period, many sites in the Kosigi and Veldurthi areas in the WH and in the Satanikota, Nandikotkur, Banganapalle, Owk, and Paniam areas in the EH were investigated by ASI and the Andhra Pradesh Department of Archaeology & Museums.

The Past Glory

The Kurnool region in the ancient and medieval times formed a part of the present Andhra Pradesh and Karnataka and has had the reputation of having been ruled by renowned dynasties for more than 2,000 years from 3rd century BC (Mauryans) to AD 1839 (Kurnool Nawabs) before the annexation of the region by the British. The rock edicts found at Erragudi (15° 12': 77° 34') and Rajula Mandagiri (15° 26': 77° 28') north of Pattikonda (Fig. 5), reveal that the area had come under the rule of King Ashoka (274-236 BC). It is said that the Deccan Province of his kingdom was ruled from Suvarnagiri, presently known as Jonnagiri.

During the 1st -11th centuries AD, several kingdoms namely the Satavahanas (221 BC-AD 218), the Pallavas (AD 250-630), the Badami Chalukyas (AD 753-973), the Rashtrakutas (AD 750-975), and the Kalyani Chalukyas (AD 973-1076) ruled different parts of the area. According to one legend, the lesser known Nandana Chakravarthi (11th century?) of the historic Pandava race and expelled from the north, ruled the area with his capital at Nandavaram (15° 22': 78° 16') near Banganapalle. Many place names starting with 'Nand' are linked to his name. Later in the Medieval period (11th-17th centuries), the dynasties that ruled the region were the Velanati Chodas (AD 1118-1206), the Later Cholas (12th century AD), the Yadavas (AD 1210-1317), the Kakatiyas (AD 1163-1323), the Kondaveeti Reddis (AD 1324-1424), Vijayanagara kings (AD 1336-1672), the Adil Shahis (AD 1558-1686), and lastly the Qutb Shahis (AD 1512-1687). In the Modern period (17th century onwards), the area fell into the hands of the Moghuls (AD 1687-1724) and the Asaf Jahis (AD 1724-1947). Kurnool Nawabs (AD 1800-1858) ruled some of the areas in the district, which along with the three more districts were ceded to the British in 1800. The Muslim rule, on the whole, continued for nearly 400 years. Banganapalle remained a princely state and was ruled by the Nawabs (AD 1876-1947) till Independence.

Almost all the famous forts, temples, and mosques were constructed and nurtured by different medieval period kingdoms from time to time.

The Land of Renowned Saints and Modern Champions

The 17th century Hindu saints Sri Raghavendra Swamy (SRS) and Sri Potuluri Veera Brahmendra Swamy (SPVBS) through their teachings had a profound effect on society. Three great personalities of the Modern era (18th-20th centuries), Thomas

Monroe, Narasimha Reddy, and Robert Bruce Foote, carved out niches for themselves in the annals of Rayalaseema in general and the Kurnool District in particular, by their long-lasting contributions in their respective fields.



SRS (AD 1595-1671) and SPVBS (AD 1610-1693) lived in WH and EH of the district respectively. Apart from being saints of the same period, the two have many similarities. Both were born outside the district and state but chose to live in the dry barren areas for a long time, preaching many religious and spiritual aspects. They were believed to be the incarnation of Lord Vishnu, had miraculous spiritual powers, and both entered into Jeeva Samadhi (buried alive) after accomplishing their goals.

Mutts were constructed for SRS at Mantralayam and SPVBS at Kandimallayyapalle in Cuddapah (Kadapa) District by the devotees including local Muslim rulers.



SPVBS, known as Brahman Garu, stayed in the Banganapalle area for a long time before moving to where he had attained Jeeva Samadhi. Brahman Garu, apart from being a saint, was a foreteller, a philosopher, and a social reformer. He became famous for his book titled **Kalagnanm** (Knowledge of Time), a book of prediction of future events or prophecies written in Telugu while staying in a deep pit on Ravvalakonda (Diamond hill) at Banganapalle. His prophetic texts known as Govinda

Vakyas (Statements of Lord Govinda - Vishnu) are sung by minstrels and mendicants. The ballads of Brahman Garu are often compared to those of Nostradamus, 16th century French astrologer, and physician. Brahman Garu remains only one futurologist that the Eastern world had produced.



The history of the Kurnool region cannot be complete without taking the names of 1) Sir Thomas Monroe (1761-1827), a competent administrator from the British East India Company, 2) Uyyalawada Narasimha Reddy (1806-1847), a freedom fighter from the 'Palegars' (military chieftains) clan, and 3) Robert Bruce Foote (1834-1912), a great geologist cum archaeologist from GSI, who put India on the map of world prehistory through his scientific discoveries. The common link between them is that all three were linked to the time of

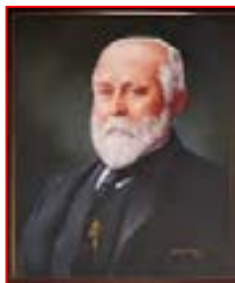
British colonial rule.

Thomas Munro, a Scottish soldier in the East India Company Army, became Principal Collector (1800-07) of the ceded districts (Rayalaseema) and finally the Governor of Madras (1820-27). He was one of the most famous administrators of the Colonial era and established law and order by suppressing violent Palegars. His noble-minded acts, such as the introduction of Ryotwari System, pro-farmer tax reforms, digging of tanks, enforcing reforms in judiciary and administration (in local language), acting against the disgraceful attitude of racial superiority among the British, and supporting religious activities of the Tirumala temple and Mantralayam Mutt through liberal revenue rules, brought him many laurels. Because of his unquestionable deep love for the people of the land, Munro is regarded as a semi-god in the hearts of the people of Rayalaseema. Ballads are still sung in his honour and many boys are named

‘Munrolappa’ as well. He died of cholera on 6th July 1827 at Pattikonda while on an official tour but was buried in the Gooty European Cemetery. A choultry built at Gooty for free poor feeding stands out in the memory of Munro.



Narasimha Reddy (popular as Uyyalawada Narasimha Reddy), a patriot and one of the first Indian freedom fighters, champion of the deprived Palegars, and the suffering peasants of the Kurnool region fought a life-long battle against the British. Born at Rupangudi near Uyyalawada, he became a Palegar of Uyyalawada and Nossam controlling 66 villages. He had fiercely fought the British during 1846-47 before hanged to death in 1847 under public gaze. The tragedy is that his head was hanging on the Uyyalawada fort wall in public view for 30 years. Narasimha Reddy's revolt against the British was a forerunner to the First Indian War of Independence (Sepoy Mutiny) in 1857.



England born Bruce Foote joined GSI in 1858 and served the Department for 33 years before retirement in 1891. His geological findings and mineral discoveries in the Madras Residency are noteworthy. Of equal importance are his archaeological findings of Palaeolithic tools and settlements, mostly in southern India and also in western India. Foote who had also extensively traversed the Kurnool region for geological studies, contributed immensely to enrich the prehistory of the district by discovering the famous Belum caves, stone artefacts in the Bethamcherla (Billa Surgam) caves, rock shelters at Ketavaram, finely polished pottery of Neolithic age in the Banganapalle area and the caved material from the Yaganti area. Bruce Foote, a multi-faceted person - geologist, palaeontologist, archaeologist, anthropologist, museologist, and landscape artist, was rightly called ‘The Father of Indian Prehistory’. Besides, his findings have laid a strong foundation for archaeology in India and gave great impetus to such studies in the future. Foote died in 1912 and was cremated in Calcutta.

Minerals and Mining

The district, although historically famous for diamond and gold mining, is presently known for other valuable mineral wealth in the form of industrial minerals and rocks, polished stones, and building materials. The most important among them are the limestones, dolomites, and granites. The other significant minerals are barytes, copper, iron ore, talc, clays, and ochres (Fig. 4).

The WH comprises granite-greenstone terrain hosting gold bearing quartz zones in sheared meta-basalts and granodiorites associated with the Jonnagiri Schist Belt near Dona in the Jonnagiri area. Detailed exploration by GSI and Mineral Exploration Corporation Ltd (MECL) had proved a viable deposit. This would become the first gold mine in the country to be operated in the private sector. Besides gold, Jonnagiri and its surrounding villages are well-known for several placer diamond-finds by the villagers from top soils.

The EH, which is spanned by the Cuddapah and Kurnool formations, has many economic minerals and rocks useful for different industries. The carbonate rocks,

namely the dolomite, associated with the Vempalle Formation, and limestones of the Narji Limestone and to some extent the Koilkuntla Limestone, are the major sources of revenue to the exchequer. Among them, the Narji Limestone, in particular, extends over a large area forming thick deposits overlying the Banganapalle Quartzite and underlying the Awk Shale. The limestone formation includes flaggy, massive, and fine-grained varieties. Its siliceous variety, which comes in variegated colours, is generally used as flagstone (known as Cuddapah slabs or Bethamcherla slabs) and building material. Exclusive designs, durability, and elegant finish make them popular as flooring slabs for residential, office, and commercial purposes. Bethamcherla with about 400-500 polishing units, over the years, has become a leading center for the production of polished slabs. Thick deposits of massive cement grade variety found at several places support the flourishing cement industry in the State. There are four major cement plants in operation and there is a lot of scope for establishing a few more in the Dhone-Nandyal-Kolimigundla region. The district has become a destination for many top cement majors as it holds many untapped limestone deposits.

The other significant industrial minerals and rocks are the flux and refractory grade dolomites, barytes, and steatite (talc) associated with the Vempalle Formation in Dhone-Pyapali area, fault-controlled iron ore (specular hematite) in the Veldurthi-Ramallakota area, and copper mineralisation in the Gani area, clays and ochres associated with Owk Shale at several places and minor phosphorite and galena associated with Cumbum Formation in the Nallamalas.

The Diamond District

Diamonds are generally associated with primary rocks such as kimberlites and lamproites, and sedimentary rocks such as conglomerates (palaeo placers) and river gravels (Recent placers). They are found in several parts of the Kurnool District (Fig. 4). It is perhaps the only area in the country wherein all the three types of diamond source rocks are discovered. Lamproites (~ 1350 My), emplaced into the Cuddapah Supergroup, are located at Chelima ($15^{\circ}25':78^{\circ}41'$) in the Nallamalas and near Banganapalle ($15^{\circ}19':78^{\circ}13'$) in the Erramalas. These rocks signify the oldest diamond related magmatic activity recorded till now in India. The old workings in the Chelima dykes are generally attributed to the diamonds. The kimberlites, reported in the granitic country near Mantralayam and Kurnool, are of Mesoproterozoic age (~1100 My).

The sedimentary rocks as mentioned above were the well-known source rocks for the placer diamonds during the medieval period and they were mined for a few centuries by the Vijayanagar (1336-1570), Bijapur (1489-1686), and Golconda (1518-1687) kingdoms. The conglomerate occurring generally at the base of the Neoproterozoic Banganapalle Quartzite formation is one of the potential sources for the diamonds. The formation, developed over a length of 225 km along the western margin of the Kurnool Basin, is found to contain several old workings and processed dumps prominently in two belts viz. Banganapalle - Racherla ($15^{\circ}14':77^{\circ}56'$) and Ramallakota ($15^{\circ}34':78^{\circ}00'$) - Yambai ($15^{\circ}33':78^{\circ}07'$), both in the Kurnool District. There were ten important mines, three in Munimadugu ($15^{\circ}16':77^{\circ}58'$) area under the Golconda kingdom and seven in Ramallakota (known as Ravvalakota, meaning diamond fort) - Banganapalle (mine area is known as Ravallakonda, meaning diamond hill) area under the Bijapur kingdom. These mines attracted the attention of the Gujarati and Marwari merchants and others from abroad. (Tavernier, 17th century

famous French traveller), stayed in these areas and carried out diamond trade. GSI carried out detailed exploration for assessment of diamond potential in the Banganapalle-Racherla belt in the 1980s jointly with MECL and National Mineral Development Corporation Ltd.

Besides the conglomerates, river gravels and colluvial material were the other famed sources for diamonds scattered in many locations. In total 15 mines were known in the past, seven under the Golconda and eight under the Bijapur kingdoms. The famous among them were at Jonnagiri ($15^{\circ} 14': 77^{\circ} 34'$) and its surroundings. Here, even today large size, high-quality and high value diamonds are picked up frequently before the onset of SW monsoon by the local villagers and diamond hunters who come from far off places. The area of search is quite wide-spread ranging between 100 and 150 sq. km and covers nearly 20 villages. The exploration of GSI in the 1980s and other organisations later did not reveal any primary source rocks for diamond. The well-known diamondiferous gravel mines in the past are in the Panchalingala ($15^{\circ} 51': 78^{\circ} 01'$) area along the left bank and Satanikota ($15^{\circ} 54': 78^{\circ} 12'$) on the right bank of the TBR, Mettupalle ($15^{\circ} 16': 77^{\circ} 48'$) near Pyapali on the western margin of the Cuddapah Basin, Laxmipuram ($15^{\circ} 45': 78^{\circ} 00'$) on the left bank of the Handri River and Gajulapalle (Basavapur- $15^{\circ} 24': 78^{\circ} 38'$) and Mahadevapuram ($15^{\circ} 23': 78^{\circ} 37'$) in the Kunderu basin.

TOURIST ATTRACTIONS

Though the district is considered a semi-desertic, dry, and hot region, it has many rare sites of repute for promoting Geotourism (Fig. 6). The district is native to several prehistoric settlements and delicious mangoes. It is an abode to several famous temples. The uniqueness of the district is in its geology, geomorphology, biodiversity, ecology, ethnic tribes, pre-historic caves, megalithic burials, historic sites, temples, mosques, churches, and forts, and natural resources like limestones, diamonds, and gold.



The WH has the uniqueness of having spectacular granite landforms in the Mantralayam-Adoni area. Both the places, 50 km apart and well connected by rail and road, were historically linked during the reign of Adoni Nawab Siddhi Masood Khan, an Abyssinian by birth. Mantralayam, the seat of Sri Raghavendra Temple

and Mutt, is located on the right bank of the TBR. It is an important pilgrim center in southern India near the trijunction of AP, Karnataka, and Telangana states, wherein the 17th century saint, theologian, and philosopher Sri Raghavendra Swamy attained Jeeva Samadhi (tomb). To Ashokan rock edicts at Erragudi and Rajula Mandagiri are located in this part of the district.

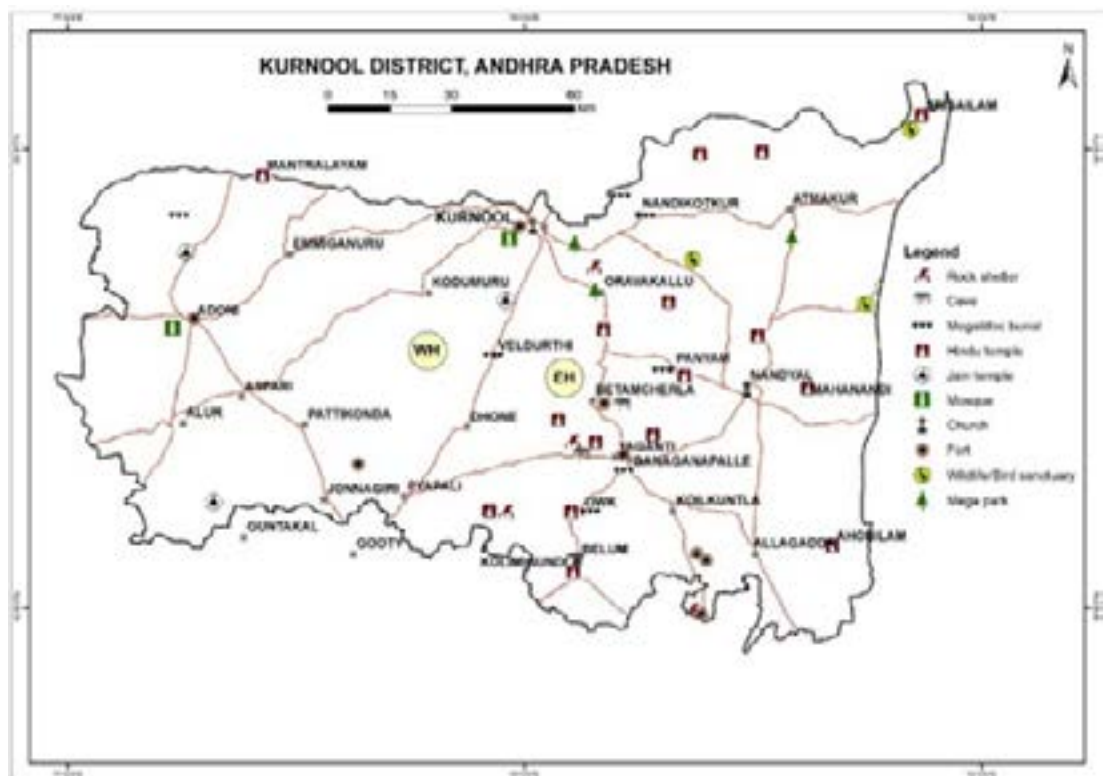


Fig. 6. Major locations of tourist sites in the Kurnool District.

The Nallamalas present rugged physiography with forest cover and form one of the vital ecological zones. For nature lovers, the fascinating beauty of the deep and steep valleys covered with lush green forests is a scene to watch in the hills during the rainy season. Gajulapalli to Giddalur (40 km long SH No.53), Atmakur to Dornala (60 km long SH No.544D), and Srisailam to Dornala (50 km long SH No.765) ghat roads not only showcase the natural beauty of the hills but also provide easy access to the coastal AP. The old railway line between Gajulapalli and Giddalur passes through several tunnels and viaducts of which the Motakamancherla bridge ($15^{\circ} 25'$: $78^{\circ} 45'$) is a breath-taking site.

The EH of the district is picturesque as it comprises Erramala and Nallamala hills and the intervening Nandyal or Kunderu plains. The hills are a boon to the area as they are home to many unique landscapes, prehistoric and historic sites, famous temples, ethnic tribes, and biodiversity. Several places in this part are dotted with natural springs formed along some joints and fractures, which become preferred sites for building several temples in the past as at Kalava Bugga, Mahanandi, Yaganti, RS Rangapuram, Kolanu Bharati, Bandi Atmakur, and Brahmamagundam.

Wildlife Sanctuaries: The Nallamala hill range, together with its dense deciduous forest, offers plenty of room for the wild animals. Rightly, two wildlife sanctuaries are established between Srisailam - Dornala and Nandyal - Giddalur roads. The Nagarjuna Sagar - Srisailam Tiger Reserve, also known as the Srisailam Wildlife Sanctuary, located on either side of the Krishna River in five districts of AP and Telangana is the largest tiger reserve (around 3728 sq. km area) in the country, established in 1984. The core area of 1,200 sq. km of the Tiger Reserve lies in the Kurnool District, south of Srisailam. Another tiger reserve forest in the Nallamalai hills is the Gundla Brahmeswaram Wildlife Sanctuary (1194 sq. km area), located NE

of Nandyal. The tiger population (68 tigers as per 2014 records) is a testimony to the preservation of wild-life in this region. Rollapadu Bird Sanctuary established in 1988 in about 6 sq. km is located 15 km SE of Nandikotkur. The sanctuary is home to the rare and endangered Great Indian Bustard (*Battamaka pitta* in Telugu), and migratory birds and reptiles. The State animal Black Buck (*Krishna Jinka* in Telugu) is also common here.

Caves: The cavernous Narji Limestone and the hard Paniam Quartzite formations exposed in the Erramala hills offer scope for the development of caves in the former and rock shelters in the latter. The important cave areas are at Belum (left), Yaganti (center), and Bethamcherla (right).



Among all, the caves at Belum ($15^{\circ}06'$: $78^{\circ}06'$) in Kolimigundla Mandal, known as Bilam Guhalu, are remarkable in their occurrence. It is the largest cave system formed in agricultural fields and the second largest cave system recorded in the Indian subcontinent after the Krem Liat Prah caves in Meghalaya. The caves, which extend over 3 km, demonstrate speleothems with long and wide passages, galleries, and spacious caverns. The Bethamcherla area is also known for several caves, of which Billa Surgam cave complex is famous for bone artifacts.



Forts: Among all the forts in the district, the Adoni Fort in the WH is a 15th century historic monument constructed during the reign of the Vijayanagar kings and used as a military base. Subsequently it fell into the hands of Bijapur Sultans, Moghuls, Nizams, Tippu Sultan and the British. It is one of the longest forts in India with a wall length of 50 km built over granite hills. Siddi Masood Khan, from Abyssinia (presently

known as Ethiopia), was Nawab (Governor) under the Bijapur Sultans and became a devotee of SRS of Mantralayam after knowing his spiritual values. The Siddis of the African Diaspora were brought to India as slaves during the Arab trade initially in the 11th century and later by the Portuguese during the 17th-19th centuries, settled down mostly in parts of Gujarat, Karnataka, and erstwhile Andhra Pradesh. Some of these East Africans who were recruited as soldiers by the Muslim rulers because of their strong physique and fighting skills rose to occupy higher positions and in course of time became Nawabs too. The A.C. Guards in Hyderabad are actually the African Cavalry Guards, recruited by the 6th Nizam Mir Mahamud Ali Khan in the 19th century.

Chennampalle ($15^{\circ} 18': 77^{\circ} 37'$) fort in Tuggali Mandal in WH is another medieval historic fort built during the Vijayanagar period. Located in more than 100 acres area on a granite hill, it is often subjected to digging for hidden treasures.

There are many smaller forts in the EH namely, 1) Kurnool Fort (left), Bethamcherla fort (middle), and Banganapalle fort (right).



The Kurnool fort was initially built by the Vijayanagar kings during 1530-42. It is popularly known as Konda Reddy Buruju, named after the 17th century, and last, ruler of Alampur who was imprisoned by the Kurnool Nawab in the fort, and 2) Forts at Uyyalawada, Rupangudi, Gutladurthi, Uppaluru, and Giddalur, all built by Uyyalawada Narasimha Reddy during 1805-1847, and 3) the lesser known forts at Nossam, Koilkuntla, and a few other places.

Temples, Mosques and Churches: The district is an abode to several famous and historic temples and pilgrim centres drawing thousands of devotees round the year, particularly during annual festivals. Most of these temples were constructed by the Vijayanagar kings (AD 1336-1570) using the locally available rocks such as granites, quartzites, and limestones. Except for a few, the majority of the temples are dedicated either to Lord Shiva or Lord Narasimha Swamy, the lion-headed avatar of Vishnu.



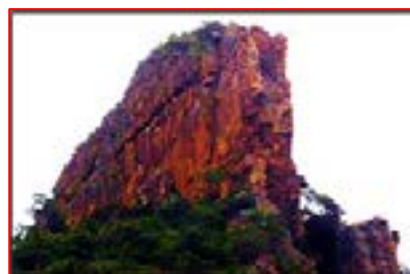
In the western part of the district and the adjacent northern part of Karnataka, several places are found with coexisting Jain and Hindu temples. The Jain temples built by the Western Chalukyas / Rastrakutas are at Pedda Tumbalam ($15^{\circ} 45': 77^{\circ} 15'$) in the Adoni area, Chippagiri (formerly known as Shilpagiri, $15^{\circ} 13': 79^{\circ} 19'$) and Nayakallu ($15^{\circ} 40': 77^{\circ} 57'$). Mantralayam, on the right bank of TBR set in picturesque granite hills, is an important Hindu pilgrimage centre.

There are many famed temples in the EH. Prominent among them and well-known within and outside the State are at Srisailam, Mahanandi, Ahobilam, and Yaganti. The first three temples are in the Nallamala hills and the fourth one is in the Erramala hills. Other notable temples are Rameswara Swamy Temple at Kalava Bugga ($15^{\circ} 36': 78^{\circ} 10'$), Sri Lakshmi Narasimha Swamy Temple at Kolimigundla ($15^{\circ} 04': 78^{\circ} 06'$), Sri Chennakesava Swamy Temple at Owk ($15^{\circ} 12': 78^{\circ} 06'$), Lakshmi Narasimha Swamy Temple at Kambagiri ($15^{\circ} 12': 77^{\circ} 57'$), Sri Chowdeswari temple at Nandavaram, Sri Panikeswara Swamy Temple at Panyam ($15^{\circ} 31': 78^{\circ} 20'$), Maddileti Sri Lakshmi Narasimha Swamy Temple ($15^{\circ} 21': 78^{\circ} 05'$) at R.S. Rangapuram and Sri Omkareswara Temple at Omkaram ($15^{\circ} 33': 78^{\circ} 38'$), east of Bandi Atmakuru.

The Srisailem temple, located on the right bank of the Krishna River in the dense Nallamala forest, is said to have been constructed using the Srisailem Quartzite in the 2nd century by the Satavahanas and renovated during the Vijayanagar period. The temple, dedicated to Sri Bramarambha Mallikarjuna Swamy, is one of the 12 Jyotirlingas of Lord Shiva and one of the 18 Shaktipeethas of the Goddess Parvati. Besides the temple, the Srisailem gorge, Srisailem dam, and the reservoir, and Akka Mahadevi caves on the left bank of the river in the Telangana State are major tourist attractions.

Sri Mahanandiswara Swamy temple at Mahanadi, located near Nandyal at the foothills of the Nallamalas, is said to have been constructed in the 7th century, was under the patronage of Nanda kings (11th century) and Vijayanagar kings later. Mahanandi is a temple complex with nine temples (Nava nandulu) within a radius of 15 km. Spring waters from the temple irrigate a few hundreds of acres.

Ahobilam, like Mahanandi, is a temple complex with nine shrines dedicated to Lord



Narasimha, the lion-headed god. The temple shrines are located in a 5 km radius, at Lower Ahobilam and Upper Ahobilam in the picturesque Nallamala forest and hills comprising the Bairenkonda Quartzite. The Upper Ahobilam can be reached by trekking 8 km along the slopes of a scenic gorge. The temple was initially built in the 8th century by the Chalukyas but major structures were renovated during the 15th and 16th centuries by the Vijayanagar kings. Kakatiya kings also patronised the temple. It



is at the shrine of Jwala Narasimha, the Lord is believed to have killed the demon king Hiranyakasipu coming out of a giant pillar (Ugra Sthambhum) from a mountain behind the shrine to save Prahalad.

Yaganti temple near Banganapalle, dedicated to Lord Shiva (known as Sri Yaganti Uma Maheswara

Temple), is a very ancient temple constructed in the 5th century by the Pallava and Chola kings and renovated by Hari Hara Bukka Raya of the Vijayanagar empire in the 15th century. The Narji Limestone cliff behind the temples with three caves, popular as Yaganti caves, and spring waters add to the scenic beauty of the area. The uniqueness of the temple is a growing Nandi (bull). It is learnt from the studies of the ASI that the Nandi grows at the rate of 1 mm a year.



Kolanu Bharati Saraswati Devi Temple ($15^{\circ} 59'$: $78^{\circ} 31'$), dedicated to Saraswati Devi (Goddess of Knowledge or Learning), is located in the Atmakuru area in the Nallamala hills. The temple, built during the 11th -12th centuries by the Western Chalukyas of Kalyani, is said to be the third of its kind in the Indian continent. Among the other two, one (abandoned) is located along the banks of the Neelam River in Pakistan occupied Kashmir, and the other on the banks of the Godavari River at Basara in Telangana State. Sangameshwara Temple ($16^{\circ} 01'$: $78^{\circ} 20'$), located at Machumari, the confluence of the Krishna and Tungabhadra rivers is accessible only for about 50-60 days in summer. The temple dates back to Mahabharata times and dedicated to God Shiva, was built by the Western Chalukyas.

Among the three Sun temples in the state, two are in Kurnool District, one each at Nandikotkur ($15^{\circ} 51'$: $78^{\circ} 15'$) and Gani ($15^{\circ} 40'$: $78^{\circ} 19'$), and the other better-known ancient temple at Arasavelli is in Srikakulam District. The Nandikotkur temple, known as Sri Suryanarayana Swamy Temple, was built by the Chalukya dynasty in the 11th century. The Gani temple that lies in Gadivemula Mandal is 400 years old and was constructed by Gururaja Acharya who went into *Jeeva Samadhi* about 15 years before SRS.

Sha Jamia Mosque or Jumma Masjid at Adoni (photo left) is one of the famous mosques in the Kurnool district. The mosque is a great heritage, built by Siddi Masood Khan, Governor under Bijapur sultans in the 1670s. The masjid, almost a replica of Jama Masjid of Delhi, was constructed by the Iranian engineers using granite. Roja Dargah Shareef (photo right), built about 500 years before in Roja village on the banks of TBR is another famous masjid. Urs ceremony celebrated here is attended by lakhs of Muslims and Hindus. The tomb of Abdul Wahab Khan or Gol Gummaj built on the banks of the Handri River in Kurnool in 1618 is a marvellous structure. It resembles Gol Gumbaz of Bijapur and was constructed in memory of the first Nawab of Kurnool District.



Nandyal in the middle of the EH saw the arrival of two Christian Missionaries (Arthur Inman and Alfred Briton) in 1881. The local SPG High School was founded in 1893 and the Holy Cross Church (Cathedral) in impressive Gothic architecture was constructed in 1905 (photo left). The town became a vibrant missionary center in later years. Coles Centennial Telugu Baptist Church at Kurnool (photo right), one of the beautiful edifices in south India, was built during World War I through the efforts of the American Dr. Staton, who felt the need for a church for the Christian society. His endeavour became a reality with liberal funding from his friend and benefactor Dr. Auckerman Coles, USA. The construction of the church using the Narji Limestone

was completed in 1918. The church was named after Coles though he never visited India.



CONCLUSIONS AND RECOMMENDATIONS

Geotourism, all over the world, is gaining a lot of importance in societal life because of which efforts for conserving Geoheritage are given priority in many countries. Geoheritage is preserved and promoted based on the nature, history, and culture of each site following the principles of geotourism.

The Kurnool District, with unique geological and geomorphological features, pre-historic caves with rock arts and Palaeolithic tools, historic sites having several medieval period temples and forts built during different ruling dynasties with good ecological and environmental potential, has a distinct place among all the districts in the State. All this bears testimony to the immense scope for developing Geotourism in this part of Rayalaseema. The geological processes that operated over millions of years have sculptured the granite, quartzite, and limestone terrains to form pleasing landscapes. In the Nallamalai hills, the landscapes clad with thick forests, lush green valleys, and cascades during monsoon, long winding ghat roads across the hill ranges, and the rail route running through tunnels, parallel to the road, are quite amazing.

The vast areas occupied by the granite hills in the north-western part of the WH, and limestone hills and valleys and plateau topped pinnacled quartzites in the EH of the district along with the major and minor reservoirs and canals, deserve close study so as to identify suitable places for developing parks. The parks promoted as at Oravakal (Oravakal Rock Garden), Nagaravanam (City Forest), and Nallakalva (Dr. YSR Smruthi Vanam) have already become popular.

The thick pile of sedimentary rocks comprising particularly quartzites and limestones is a boon to the economically backward region not merely for their intrinsic value but because they house several prehistoric sites of Mesolithic age, historic temples and forts, besides throwing light on 'Recent' global volcanic events. Geological outcrops such as the Ulindakonda agglomerate, Gulcheru conglomerate-Granite contact (Eparchean unconformity) at Kurnool, Paniam pinnacled quartzite at Oravakal, Narji Limestone cliffs at Yaganti. Workings / old processed diamond dumps at Banganapalle and Ash beds near Jwalapuram may be identified and developed as 'Geosites' (Fig. 7).

Lakhs of tourists visit many pilgrim centres annually on different occasions. Efforts may be made to convert at least 10% of them into ‘Geotourists’ sites.

Efforts may be made to grow medicinal plants in the Nallamalai forest and improve the traditional knowledge and skills of the ethnic tribes on these plants and their medicinal applications, which will help in biodiversity conservation and the economic development of the inhabitants.

In order to protect the historic Sangameshwara Temple, which remains submerged in the backwaters of the Srisailem reservoir for nearly 10 months in a year, efforts may be made by the government to dismantle and re-erect it at a safer place like Muchumarri on the right bank of the reservoir. The successful transplant of the Kudali Sangameshwara Temple in the 1990s, located at the confluence of the Krishna and the Tungabhadra rivers at Alampur proves this point.



Fig. 7. Geosites suggested for protection and development.

The pioneering contributions of Bruce Foote to the Rayalaseema in general and Kurnool district in particular need to be recognized and acknowledged properly. Installation of his statue at the entrance of Belum caves with a brief write-up is suggested.

Besides the three national highways, the proposed 6-lane road from Anantapur to the new capital of AP at Amaravati passing through the EH of the district is expected to boost tourism. Further, Kurnool is one of the places identified by the Central Government to develop low-cost greenfield airports. The recently constructed airport at Kurnool, if made fully operational, will increase the connectivity along with the tourist circuits and promote tourist inflow to the region

Kurnool and Nandyal, the two major towns in the district may be developed as Geotourism promoting centres for operating one-day, two-day, or three-day tourism packages by including other tourist sites from the adjacent districts.

The region has great potential for promoting Geotourism which will contribute to the economic growth of the rural and backward areas.

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During the course of informal discussions with the first author, Dr. D. Rajasekhara Reddy, Retd. Professor and an active proponent of Geoparks, Geoheritage and Geotourism and a working member of INTACH in Andhra Pradesh has suggested that a write-up on different Geosites in Kurnool District, Andhra Pradesh may help in promoting Geotourism. Following this, an attempt is made by the authors to assess the Geotourism potential in the historic district. We gratefully acknowledge his suggestion and encouragement. Shri T. Sairam, Sr. Geologist, Tecdatum Infoservices Pvt Ltd. is profusely thanked for his help in the preparation of the maps. Many of the photos are downloaded from the Internet.

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ZAWAR, RAJASTHAN - A POTENTIAL GLOBAL GEOPARK OF INDIA

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Based on the INTACH - NHD publication: A Monograph on Zawar Zinc Mines, Rajasthan - A Potential Global Geopark. January 2021. p.31.

1. INTRODUCTION

Zawar area, Rajasthan, represents an ideal case for a UNESCO Global Geopark because of its unique natural as well as cultural heritage attributes of international importance. The American Society of Metals (ASM International) has aptly described Zawar in these words (1988): "At this site are preserved the zinc retort distillation furnaces and remnants of related operation. The village artefacts together with temple ruins attest to the success of this metallurgical technology. This operation first supplied the zinc for making of the brass instrument in Europe, a forerunner of the Industrial Revolution". Earlier in 1983, the British Museum, London, in collaboration with Indian academicians and industry scientists recognized Zawar as the world's first zinc smelting site with thriving social and cultural manifestations. Their C^{14} dating of ancient mining and smelting samples yielded the earliest age of 430 ± 100 BCE and also written proofs of a thriving global trading of the zinc-silver-lead metals that was responsible for the prosperity of the rulers of this area (Warmington, E.H. 1974; Craddock, P.T. 2013.). These natural resources had a great bearing on the cultural and social aspects of this area.

2. LOCATION MAP SHOWING GEOLOGICAL, ARCHAEOLOGICAL AND CULTURAL SITES

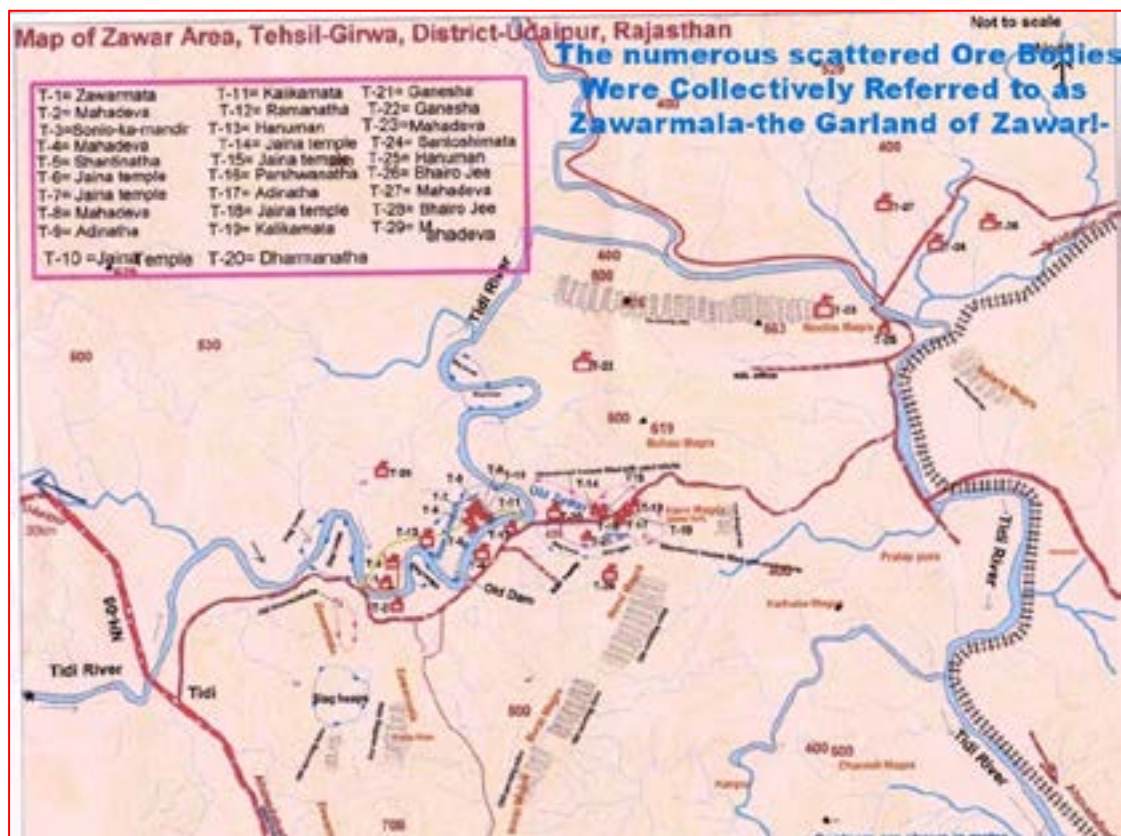
Location: Zawar zinc-lead deposit is located in a rugged and thickly forested area ~40 km south of Udaipur, Rajasthan, approached by a picturesque highway via NH # 48 to Ahmedabad up to Tidi village, thereafter a bifurcation to the left (east) leads to Zawar village. Zawar is also a railway station on the Udaipur-Himatnagar Railway line of NW Railways. Ramanath Temple with its *Kund* (large step-well) near Zawar (spelt Jawar on Google Earth) is an important landmark of the area, its coordinates are $N24^{\circ} 20' 58.1''$: $E073^{\circ} 41' 46.5''$, 396.5 ± 6.4 m while those of the monument of American Society of Metals (ASM International) are $N24^{\circ} 21' 03.8''$: $E073^{\circ} 42' 12.1''$, 415.4 ± 6.5 m. Zawar area is covered in Survey of India toposheet # 45H/11.

2 A. The extent of the Geopark surface area (km^2)

The ancient mines, open as well as underground, heaps of slag and discarded clay retorts, temples, wells, and a fort are found in an area of about 64 sq. km but the major sites of interest are occurring in an area of 16 sq. km that needs to be developed in a systematic manner represented in the following map after Kumar, 2017 and Map 3 of NHD-INTACH. Ramanath Temple and *Kund* of old Zawar village can be taken as the starting point from which the rest of the sites could be visited.

3. SHORT PHYSICAL AND HUMAN GEOGRAPHY CHARACTERISTICS

As mentioned above, Zawar is located in a rugged hilly terrain of Aravalli Hill Range that extends from Delhi in the NE to Ambajee, Gujarat, in the SW for a distance of about 644 km. It attains its maximum width of ~97 km from Udaipur southwards. Zawar is located in this landscape, locally called magra (hill) sub-area, having flat-topped steep-sloped ridges (600-700 m altitude, Zawarmala is 914 m) rising to 100-300 m above the valley level. This location of magra area has seven principal hills (with suffix magra), viz., Zawarmala-, Baroi-, Harna-, Mochia-, Balaria-, Katholia-, and Dhantali-. Presently mining is going on in the first five of these hills. Tidi is the main river that drains this area along with its tributary *nalas*/rivulet and it flows east to southeast to join River Mahi to end in the Gulf of Cambay. The river augments groundwater of the area and hence quite a few old step wells are present to meet the community needs. For metal smelting and industrial use, small masonry gravity dams have been popular in the area for centuries. River terraces 7-30 m high are also characteristically present along the course of this river. Typical sub-tropical flora, mostly thorny bushes, and occasional large trees are present in the hills and valleys that have leopards, hyenas, jackals, peacocks, hares, snakes (poisonous and non-poisonous).



Map 1: Map of Zawar area marked with sites of interest, after Kumar, A., 2017.

Thanks to rock inscriptions and personal records (*pothee*), along with the modern dating techniques, the history of Zawar area can be reconstructed fairly well. As per the Somali inscription of 646 CE of Rajah Shiladitya Guhilot, grandfather of the great Bappa Rawal (734 CE) the first Guhilot ruler of Mewad from Chittaudgad, this region was blessed with a large number of rich mineral deposits that were under production (those of Basantgad, Sirohi, Zawar, Iswal, Chavand, Nathara-ki-Pal,

Rajpura-Dariba, Umerda, Delwara, Agucha, Pur-Baneda belt.), wealthy people lived and visited this prosperous region. Note the name “Shiladitya” (Shila + Aditya) means “Rock Sun” a popular name of those days displaying reverence to rocks and minerals, but some workers believe that the word represent Sheel + Aditya, graceful sun! This trail-blazing historic proof is displayed in the State Government Museum, Ajmer (its replica should be placed at museums of Udaipur and Zawar).

A new town is believed to have been founded here by Mewad ruler Rawal Samar Singh in 1293 CE as Samnagar (after his name) as recorded in Audichya Brahmin *pothee* (memoir), which also records that the area was flourishing for past 1200 years this is also endorsed by C¹⁴ dating. By 1386 CE (Maharana Lakha time) the production of silver was significant with jewelry being made locally and exported at a significant scale (value addition at the production site!). This fact is also recorded in Arab literature, which resulted in the renaming of the town as Jawar after *jewar* / *jewraat*-jewelry in Arabic. As per epigraphic evidence, Zawar was also known as Yoginipur or Yoginipattanam in the early medieval period.

Zawar was a prosperous industrial and trading town that must have had a big population as evidenced by ruins of old huts and houses in the small townships of Old Zawar (*Joonee Zawar*), Singhatwara, etc. in the valleys as well as hilltop dwellings of Harn-Magra (including the fort) and Zawarmala Magra. An interesting aspect is that most of the populace lived in simple huts, but the well-off traders lived in houses that were mentioned with awe in local records (*pothee*) as houses with ‘that many doors’! For example, a local rich cloth trader Vela Baniya is mentioned as living in a house with seven doors! Nearly 6000 remnants of huts and houses have been counted in the area.

Being an industrial trading town, Zawar had a great many category of people living here to take care of the various aspects a typical Indian / Hindu societal structure. There lived, *Rajputs* (defense and administration), *Brahmins* (priests, quite a few temples), *Jains* (traders), *Kumhaar* (potters, mainly to clay retorts, etc. for metal smelting), *Sunaar* (jewelry makers), *Mandli* (mining and smelting), *Teli* (oil extractors, traders), *Kalal* (alcohol distillers), *Bheel-Meena* tribals, and others like bamboo basket weavers, cloth-dyers, Muslims etc.

When the ancient mining stopped here, people migrated out and some of them adopted the surname "Jawariya" (from Jawar/Zawar) to boast of their original place of residence!

4. COMPREHENSIVE GEOLOGICAL DESCRIPTION OF THE AREA (THAT CAN BE UNDERSTOOD BY PUBLIC)

Geology of the Zawar area has been studied in great details, mainly its various aspects- lithology, stratigraphy, complex structures, mineralization, etc., notably the Memoirs of GSI, Heron (#79, 1953) through Straczek & Srikantan (# 92, 1966), down to Gupta *et al.*, (#123, 1997). These and other studies are comprehensively summarized in Craddock, P. T., *et al.*, (2017). Based on these studies it is well established that the rocks of the Zawar area belong to the Proterozoic Aravalli Supergroup of rocks (~1800 Ma), comprising low-grade metamorphosed, but complexly folded phyllite, siliceous dolomite, quartzite, gritty greywacke,

conglomerate sequence that have steep, nearly vertical dips, with frequent vein quartz. Polyphase deformation structures like plunging fold, refolded fold, mullion, boudinage (pinch & swell structures), ladder-veining, foliation, lineation, fault are characteristically present in the rocks of this area. Intrusions of (meta) dolerite are also in the area. A simple ore mineralogical assemblage of sphalerite (ZnS), galena (PbS), and pyrite (FeS₂) with very rare presence of pyrrhotite [Fe(1-x)S (x = 0 to 0.2)], chalcopyrite (CuFeS₂), native silver (Ag), arsenopyrite (FeAsS) is present in this area in contrast to complex ore mineralogy of Rajpura-Dariba area. Mineralization is considered syngenetic that is remobilized along fractures and occurs as enriched structurally controlled ore lenses. The host rock is siliceous dolomite, hence there is no oxidized iron cap (gossan), again as is notably present at Rajpura-Dariba area (an NGM) and the ore at Zawar is exposed on the surface and hence was easily recognized by the ancient prospectors. The host rock is hard and compact, therefore open unsupported mining was possible in it. Being a hilly area, groundwater was not a problem in the initial stages of mining (above water-table).

All these features have scientific, educational, aesthetic values of the national level (but not of international value). Surface and underground mineral exploration work is also going on regularly in this area. Every year pan-India post-graduate earth science students visit Zawar to study these geological features. The area is still being mined for lead and zinc by M/s Hindustan Zinc Ltd. (HZL) by mechanized underground mining methods. Zawar Mines (ZM) are a group of four mines namely Mochia, Balaria, Zawar Mala, and Baroi with an average zinc-lead R&R grade of 6.9%. These are heritage mines where R&R have been regularly added. During the year, the mine produced 99 Kt of mined metal from an ore production of 2.9 million MT as compared to 71 Kt of mined metal from 2.2 million MT of ore in FY 2018. (HZL website, 2019, R&R is Reserves & Resources).

GSI has a permanent Field Training Center (FTC) at Zawar for the mineral exploration and field geology training of its newly recruited officers along with an outdoor museum of rocks and minerals. State Department of Mines and Geology (DMG) grants prospecting/mining lease, the surface area is under the control of the state Forest Department and its rules are observed here. The ancient monuments of the area are under the jurisdiction of the state Department of Archaeology and Museum, which implements the rules for the protection of the cultural heritage.

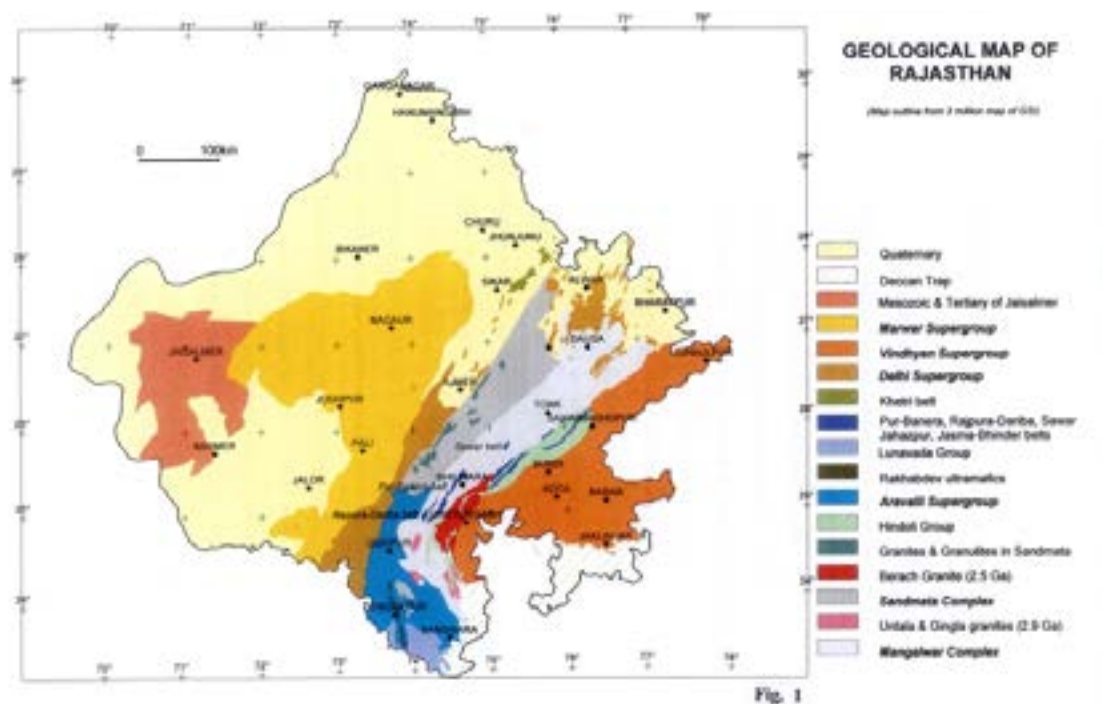
The globally relevant aspect of Zawar is the ancient mining, smelting, and global trading of the metals that were produced from the ores located at Zawar. The ~20 km Zawar mineralized belt has rich zinc-lead mineralization hosted in hard, compact, siliceous dolomite at above mentioned hills that were mined more than 2000 years ago, and the area is globally recognized as the first zinc smelting site of the world (cf. section # 5 below).

5. ARCHAEOLOGICAL, CULTURAL, AND OTHER SIGNIFICANCE OF THE AREA THAT CAN BE INTEGRATED WITH GEOLOGY IN THE PROPOSED GEOPARK GIVING THEIR LOCATION, SIGNIFICANCE, THREATS, EXISTING MAINTENANCE AND MANAGEMENT, AND OTHER RELEVANT DETAILS. (cf. Map 3)

Zinc is a fascinating metal because of its silvery white colour (pseudo-silver/mock-silver) but more importantly because when alloyed with copper it produces eye-pleasing harder golden alloy - BRASS, (pseudo-gold) which has fascinated humans for millennia. Zinc has also been mentioned in ancient Indian literature for its medicinal use in texts like *Charaka Samhita* (900-600 BCE) and *Sushruta Samhita* (~600 BCE) while Kautilya's *Arthashastra* (3rd century BCE) also mentions it and also how to prospect (search) for ores! Zinc-containing dateable ancient coins too attest to zinc's common use in ancient times.

The archaeological study by the British Museum, London, M. S. University of Baroda, and Hindustan Zinc Ltd. (1983) has proved that at Zawar metallic zinc was produced by distillation process for the first time in the world. For a metal, zinc has relatively low melting (419.53°C) and low boiling points (907°C), hence it was obtained by distillation process, possibly inspired by distillation process of local alcoholic drink (hooch)!

The American Society of Metals (ASM International) recognized Zawar as an “International Historic Landmark” in 1988: “At this site are preserved the zinc retort distillation furnaces and remnants of related operation. The village artefacts together with temple ruins attest to the success of this metallurgical technology. This operation first supplied the zinc for making of the brass instrument in Europe, a forerunner of the Industrial Revolution”.



Map 2: Geological Map of Rajasthan, after Cradock, P. T. *et al.*, 2017.

Carbon dating of timber used as support, ladders, baskets, water channels in underground mines (430 ± 100 BCE) and common use of brass (containing $>20\%$ zinc) in Ayad and other archaeology sites of Mewad prove that the area witnessed mineral utilization fairly early in human history. Its recorded and historically impactful use continued at a regular but slow pace essentially because mining was done by chiselling (as explosives and mechanization were not known then).

Mining and smelting activities must have seen ups and downs due to invasions and wars. Record of activity up to the reign of Rajah Shiladitya Guhilot (646 CE) through Maharana Lakha (1382) down to Maharana Raj Singh (1653-1680 CE, an income of Rs. 17, 96,944 is mentioned for Zawar) is present, thereafter due to political turmoil in the 18th century the industry finally stopped altogether.

5 A. Old Mine Workings: A large area of over 16 sq km has numerous verticle shafts (approach to underground mine or for the hoisting of ore or ventilation), inclines, pits, and collapsed roofs of stopes (open mined out spaces), along with a few open pits for mining of ore in the distant past. These are referred to as "old workings", which are of special interest to the adventurous tourists who wish to see the underground stopes dotted with ancient clay lamps, bamboo baskets, timber ladders, a few timber supports, *etc.* Some of these old mines/stopes can be developed for visit by interested tourists, through a jeepable road or cycle tracks.

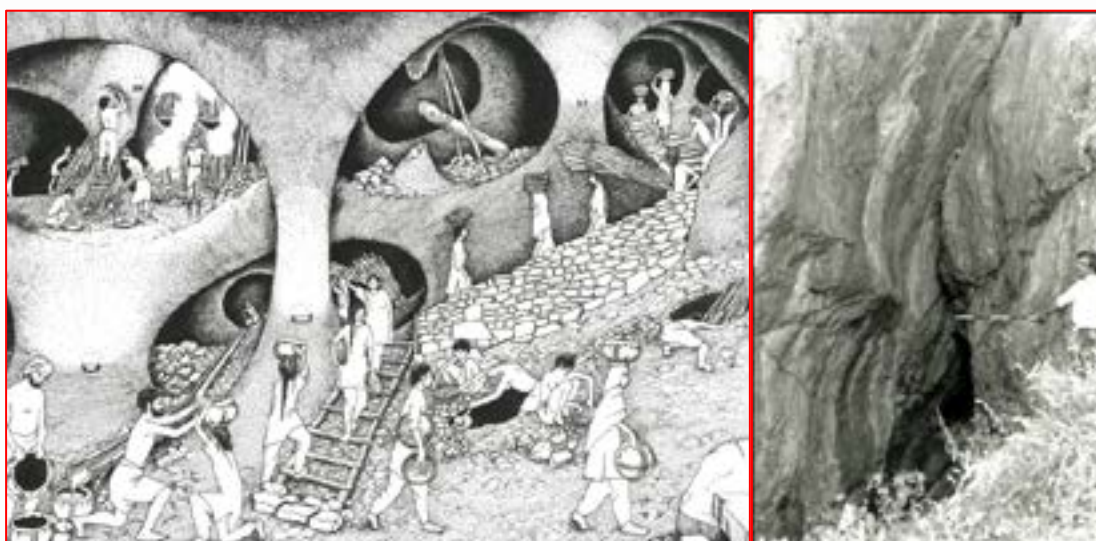


Fig. 1: A sketch (L) and a photograph (R) of old workings at Zawar, Cradock, P.T. *et al.*, 2017.

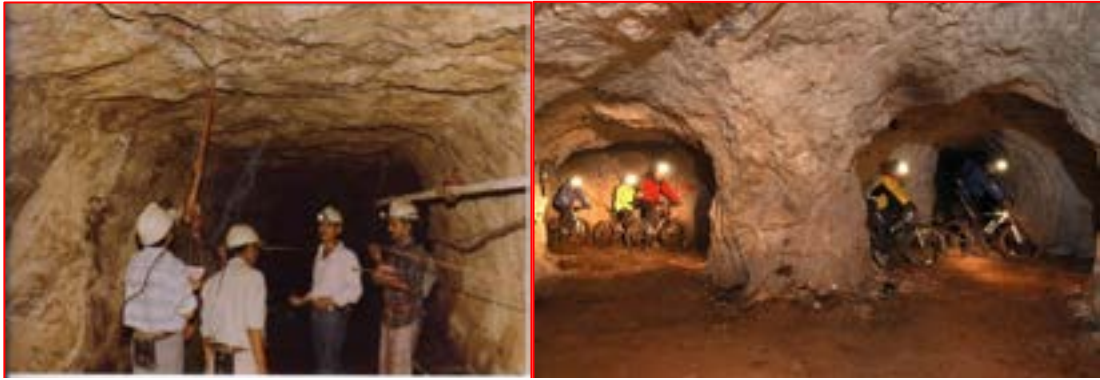


Fig. 2: L: Present-day mine openings (drives and crosscuts) are fairly large in which compressed air operated loaders and ore carrying “cars” can easily work, in still larger openings even diesel-operated machines are working, though good ventilation has to be ensured, PSR.

R: An ancient underground open stope in a European Mine that is visited by tourists on bicycles (web image); a similar development is possible at Zawar.

5 B. Slag and Clay Retort Heaps: One of the major attractions of the Zawar area is the presence of a large number of mounds made up of discarded sinter residues, clinker, broken as well as intact clay retorts and slag that are products of ancient smelting activity of the ores in the area. It is estimated that nearly half a million tonnes of discarded waste (sinter residue, slag, and retorts) is present in the area that has also given about 7000 tonnes of zinc and about 500 tonnes of lead (Straczek, J.A. and Srikantan, B., 1966). The scale of ancient mining and smelting in the area must have been much higher though.

A few ancient smelting furnaces too have been discovered, which give an idea of how the smelting was done. These are represented in sketches drawn by Mrs. Craddock.

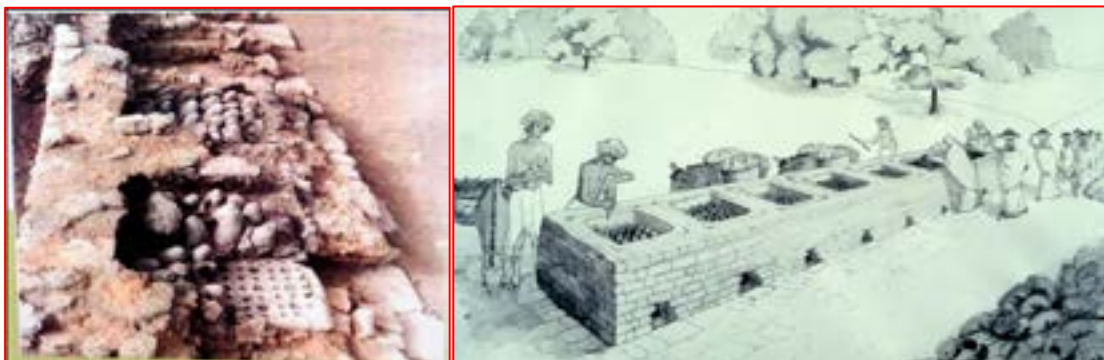


Fig. 3: A battery of furnace with heating chamber, perforated clay plates that supported inverted clay retorts for distillation of zinc metal at Zawar, actual (L) and a sketch, Craddock, P. T., *et al.*, 2017.



Heaps of slag and retorts prove a thriving metal smelting industry in the past at Zawar area. (PSR).

5 C. Some Historic Aspects: Radiocarbon dates of timbers and coals recovered from the ancient mining and smelting sites of Zawar have given dates from 430 ± 100 BCE through early Current Era-40 -115 CE- down to 1675 CE!

Widespread destructions of temples and dwellings are seen in the area, but luckily a dozen or so inscriptions on the stone slabs of the temples which must have been overlooked or considered less important for destruction by the invaders survived the damage. These rock inscriptions tell us of the thriving township and its socio-economic stature. Most of them are written in Devnagari script, the language is *Prakrit/Sanskrit*, but a few in *Brahmi* to later-day *Mahajani Lipi* are also present, indicating a long period of continuity. Zawar Township witnessed the hosting of renowned Jain monks and other activities associated with a rich industrial society. The first recorded Sisodia Era reference is at the Shantinath Temple which gives the date of completion of the temple as December 29, 1421 CE during the reign of Maharana Mokaldev (1421-1433 CE), but the temple was started during the reign of his father Maharana Lakha (1382-1421) who had deputed his elder son Prince Choonda with *Pradhana* (PM) Ramdev to welcome the distinguished Jain Acharya Shree Som Sunder Suri for its opening ceremony. It is wrongly believed, based on this inscription that the mining activity at Zawar commenced during the reign of Maharana Lakha, but the fact is that Zawar was already a well-established and thriving industrial town at that point of time and the mining and smelting activities commenced in the area much earlier, as evidenced by the Sambholi inscription of 646 CE and C^{14} dating of timber from ancient underground mines.



Fig. 4: Discarded clay retorts used for smelting were reused as a construction material for the huts in this area. Kumar (2017).



Fig. 5: The plaque of ASM at Zawar: The American Society of Metals (ASM International) recognized Zawar as an “International Historic Landmark” in 1988: “At this site are preserved the zinc retort distillation furnaces and remnants of related operation. The village artefacts together with temple ruins attest to the success of this metallurgical technology. This operation first supplied the zinc for making of the brass instrument in Europe, a forerunner of the Industrial Revolution”. (HZL).

5 D. The Ramanath (Vishnu) temple and the elegant Ramanath Kund (step-well) are important built heritage landmarks of the Zawar area. There is also a stone inscription (*shilalekh*) with 40 *sloks* (couplets), composed of “*Mahanyayvidhh*” (the great legal authority) Maheshwar Dashora. It is mentioned that Princess Rama Baisa, the daughter of Maharana Kumbha (1433-1468), who was married to Junagadh ruler Mandaleek, built this well-designed structure that was commissioned in 1497 CE (*Chaitra Shukl Saptami*, Sunday VS1554) with great fanfare. It is also mentioned in some records that Kr. “*Udan*” (flying) Prithviraj (elder brother of Rana Sanga) brought her back from her *sasural* where she was not happy, and Maharana Raimal (1473-1509), Rama Baisa’s brother arranged for her living at the then thriving metal producing township of Zawar. The Ramanath Temple and the *Kund* are in good condition, possibly restored post-18th century when this area witnessed the end of hostility. The niches in Ramanath *Kund* have sculptures of deities, but some of these are missing. These heritage sites are being looked after by the Department of Archaeology & Museums, Government of Rajasthan.



Fig. 6: Views of the elegant Ramanath Kund (step-well) and the Ramanath (Vishnu) Temple built by Rama Baisa, the daughter of Maharana Kumbha in 1497 CE (commissioned on *Chaitra Shukl Saptami*, Sunday VS 1554). (PSR).

5 E. Temples, statues, and panels: There are more Jain temples at Zawar (that show marks of heavy damage inflicted by later invaders) built by the prosperous (Jain) metal producers of this locality. Maharana Kumbha's courtier, Shah Velaak (कुंभा के दरबारी साह वेलाक (is also mentioned in the *shilalekh* and local folklore of “*Vela Vaniya ri Gatha*” (वेला वाणियां री गाथा Vela the Jain's narrative) possibly constructed the Zawar Mata Temple, which was later wrongly attributed to Shah Bhama, Maharana Pratap's trusted official (*Pradhaan*. It is highly unlikely that Bhama Shah would spend money on such activity at that difficult period of Udaipur history).

There are several Sanatan Dharm temples too of Vishnu, Shiv, Devi, Ganpati, Hanuman, Surya, and statues and relief panels of deities in the niches of buildings and wells. There are also stone symbols of cremation in the fields along the river banks. Jain temples are in ruins, which need to be restored along with putting up of attractive descriptive signage and QR-Code.



Fig. 7: L: The vandalized Jain Temples of Zawar area that witnessed wars and destructions before which it must have witnessed the presence of a thriving Jain community. (PSR).

R: A meter-high marble statue of Lord Ganesh with his consorts - *Riddhi* and *Siddhi* and their sons *Laabh* and *Shubh*. The inscription at the base gives names of all five deities, the statue was installed at Zawar in VS 1580 (1523 CE) during the reign of Maharana Sanga but it is presently preserved at the Government Museum, Udaipur. (PSR).

5 F. Stone Inscriptions: Rawal-Rana-era mining, smelting, and trading in Mewad were certainly in the hands of Jain merchants and the state provided protection and collected tax. The significance of Zawar township is also manifested by the fact that on the assassination of Maharana Kumbha by his son Udai Singh-I in 1468 CE, Kumbha's younger son Raimal was invited by Mewad nobles to replace the patricidal Udai (Hatyara=the murderer). Raimal moved from Idar in Gujarat where he was based, to Zawar, where he assembled his forces in 1473 and attacked Chittaur to dethrone his elder brother who was hated by all. Likewise, when Maharana Udai

Singh-II defeated usurper Banveer at Chittaurgarh in 1540 CE, Banveer escaped from Chittaurgarh through *Lakhota Bari* (a window in fortification) and reached Zawar from where he sent a message to Maharana Udai Singh to spare his family in exchange for his assurance that he will not contest his claim to the throne and move “south” (to Maharashtra) forever; the young Maharana sent Banveer’s family safely to Zawar, from where they all moved out of Mewad forever. An inscription of 1539 CE (a year before Pratap was born and Udai Singh captured Chittaurgarh) during the reign of Maharana Udai Singh, is present at Adinath Temple and another one at Chandraprabhu Temple which was constructed during the reign of Maharana Udai Singh-II in 1540 CE, while the inscription of Shiv Temple on the banks of Tidi River south of Zawarmata Temple has a few dates of significance - it mentions that a sacred function was held here on Monday VS 1610, Vaishakh Sudi 15. It is pertinent to note that Udaipur was founded on Vaishakh Shukl Teej VS1609; 1553 CE). Another date of significance at this temple inscription is Magh Sudi 3 VS 1648 (1591 CE) on which a religious activity associated with successful completion of pilgrimage tour was held. This corresponds with the later days of the reign of Maharana Pratap (1572-1597 CE) who founded the new capital at Chavand in 1582 CE. Subsequently, the record of revenue from this mine during the reigns of Maharana Jagat Singh (1628-1652), and Maharana Raj Singh (1653-1680) are also available. Thereafter the production must have stopped following start of hostilities with Aurangzeb. But increase in depth of mining too must have made the commercial activity uneconomical. Modern mining and smelting resumed in a big way in 1966 with the formation of public sector undertaking M/s Hindustan Zinc Ltd. (subsequent details at www.hzindia.com, temple inscription material based on site-discussion with Dr. Arvind Kumar & based on his published Ph.D. thesis, 2017).



Fig. 8: Three stone inscriptions that throw light on the history of the Zawar area. (PSR).

5 G. The Old Tidi Dam: Mining activity at Zawar must have slowed down during Maharana Pratap era due to Mughal hostilities but were continuing at a slow pace as proved by above inscriptions, which were resumed with full vitality after 1615 CE following the MewadMughal Treaty of Maharana Amar Singh and Mughal Emporer - Jahagir as evidenced by the construction (or reconstruction?) of the old Zawar Dam. A washed off section of medieval dam over the Tidi River (stream) at the former town of Zawar (N 24° 21' 01.7": E 073° 41' 24.6", 407± 7.3 m; west of Ramanath Temple is present which was constructed during the reign of Maharana Amar Singh (most difficult days of Mewad history) by his sons. The ruler or the Maharani of those days did construct public utility structures - Rani *Vaav*, *Sarai* etc. But this is a rare case of princes undertaking construction of a dam which must have been an operative industry at that point of time.



Fig. 9: The Old Zawar Dam, at left, is the washed off section of the medieval dam over the Tidi River (stream) at the former town of Zawar, west of Ramanath Temple that was constructed during the reign of Maharana Amar Singh (r: 1597-1620 CE, the most difficult days of Udaipur history) by his sons Kr. Karan Singh, Bheem Singh, Surajmal, Baagh Singh, and Arjun Singh. At the right is the dam mostly built of phyllite, instead of quartzite. (PSR).

6. CURRENT TOURISM STATUS AND FUTURE POTENTIAL OF GEOLOGICAL, ARCHAEOLOGICAL, AND CULTURAL SITES; THE SCOPE FOR ENHANCEMENT AND SUGGESTIONS FOR THE PROMOTION OF GEOTOURISM OF THE PROPOSED GEOPARK.

Every year a large number of graduate and post-graduate earth science students of various universities (up to 22, as enumerated by the University Geology Department at Udaipur that coordinates their visit) across India and occasionally from abroad to visit Zawar to study the unique geological and heritage aspects. Not just earth science students, but also those of mining, metallurgical, mechanical, engineering visit Zawar for field training. GSI has its permanent Field Training Center (FTC) here where the new officers selected by UPSC are provided field training every year. But the area is not yet on the itinerary of regular tourists, because the Tourist Reception Centre, Udaipur is yet to include Zawar in its literature and website. Hence 'tourists' still do not visit this area for having a look at our past technical heritage.

Because of its scientific, economic, historic, and archaeological importance, the Zawar area's ancient underground mines and the remains of the ancient smelting industry should be promoted through a well-created Monument or a Geopark (cf. Introduction) of International importance. It has the potential of being developed as a

part of the Global Geopark Network of UNESCO. An Interpretation Centre (a medium-sized hall for the museum) with suitable diagrams, models, photographs, samples, and description brochure should be made available with the joint efforts of district administration, State Department of Archaeology & Museums, Directorate of Mines & Geology, Government of Rajasthan, Udaipur; Geological Survey of India, Western Region, and State Department of Tourism (TRC Udaipur), Rajasthan Tourism Development Corporation, Jaipur; Hindustan Zinc Ltd., Udaipur, and INTACH, Udaipur Chapter.

Natural Heritage Division (NHD) of INTACH has drawn up a proposal for it. Briefly stated, it is as follows:

Suggestions for the Promotion of Geotourism of the proposed Geopark.

At Zawar geopark, a tour route of Interpretation Centre, Ramanath Temple and *Kund*, temple ruins, sinter residue and retort heaps (layered), retort-built huts, including an ancient underground mine for adventure tourism, Harn Magra fort, Field Training Centre of Geological Survey of India (with prior permission of GSI) should be provided. A map showing the sites of interest in this area should be developed. The Geopark will promote tourism and help in local economic development. Important site stations are as follows:

1. Interpretation Center: An indoor museum with samples, display boards, interactive displays about ancient and modern mining, metallurgy, etc., describing Zawar's geoheritage, archaeology, history, spiritual elements through printed folders, handouts, booklets etc..
2. Refreshment/Eatery, Signages, Souvenir Shop, Vehicle Parking, & Wash Rooms.
3. Visit to slag and discarded retort heaps.
4. Ruins of old Jain temples and stone inscriptions.
5. Ruins of retort-made huts.
6. Ramanath Temple and *Kund*.
7. Tidi River area with temple ruins and inscriptions and slag-heap hills with living tribal huts.
8. Ancient washed-off section of an ancient gravity dam on Tidi River, restored at the time of Kr. Karan Singh, in the early 1600s.
9. Zawar Mata Temple and carved statues in stones.
10. Optional: Visit to GSI Field Training Center (FTC), Harn Magra ancient fort ruins and ancient underground mines.

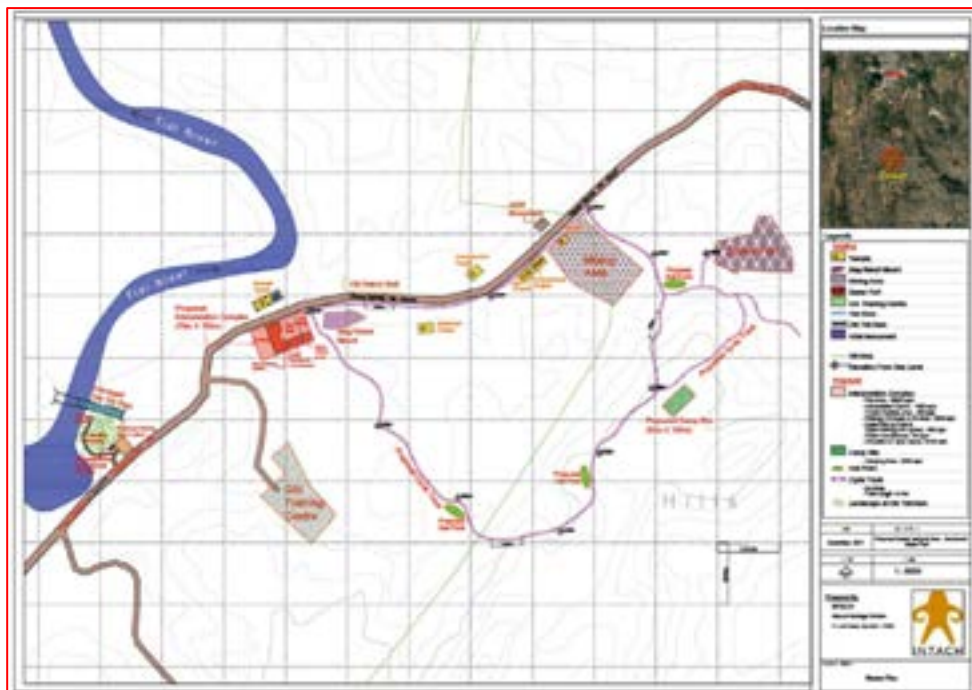
Souvenir Shop with ore and rock samples, fancy rock paper weights, replicas of terracotta ancient smelting items, retorts, *diya* (oil lamps), perforated plates, funnel, small Zn, Pb, Ag ingots with HZL logo mark, porcelain, and metal items, booklets, folders, coffee table books, pictorial postcards, rural artefacts.

Zawar Geoheritage Museum: A suitable, Ahar Museum type building, for the indoor museum of samples, display boards, reconstructed ancient furnaces, audio-visual contents describing the various elements of Zawar geoheritage including, archaeology [replicas and transcripts of (stone) inscriptions], history, spiritual elements, geomorphic elements, present-day mining, beneficiation, and smelting displays. A discarded ancient retort column or a panel will look unique on the museum building.

Eatery: Highways like Midway-type restaurant as setup on Highways with good washroom facilities.

Department of Tourism should list it in its promotional literature, including putting up promotional boards at airport, railway station, bus stand etc.

A website of this geoheritage site too will expose its salient features for the global audience.



Map 3: A plan prepared by the NHD-INTACH on 1:8000 scale showing major geoheritage, geographical, archaeological, and cultural sites at Zawar.

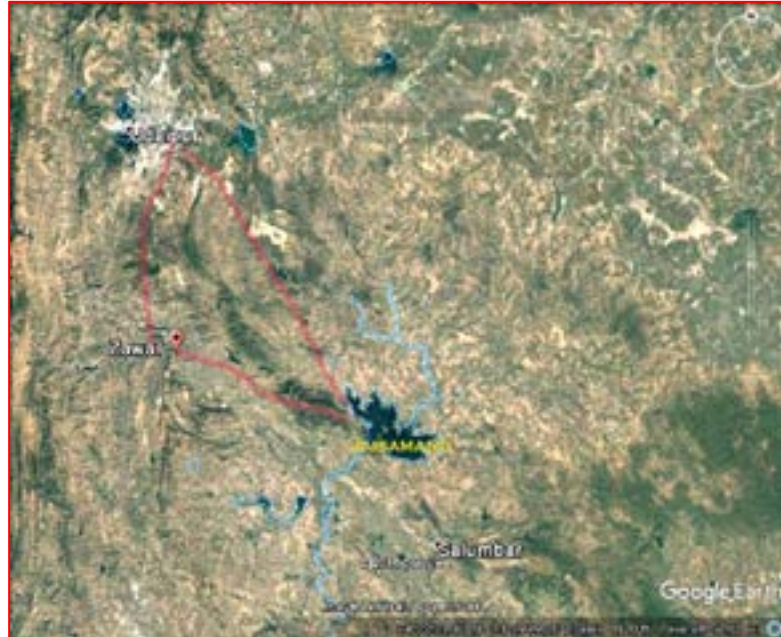


Fig. 10: A tourist could also take a trip to Udaipur-Zawar Geopark Maharana Pratap founded capital Chavand, Nathara-ki-Pal, ancient iron ore mining and smelting site, and also visit Jaisamand lake boating lunch and Udaipur Trip by road, via Jaisamand Wildlife Sanctuary.

7. COMMUNICATION, WEB SITES, AND OTHER EXISTING AND REQUIRED INFRASTRUCTURE:

As stated above, the area needs proper promotional literature and a dedicated website. The infrastructure for tourists is outlined above. The following images highlight this aspect:



Fig. 11: Manifestations of multi-heritage attributes of Zawar area. (PSR).

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RAHR BENGAL GEOHERITAGE TRAIL: A PROSPECT AND AN OVERVIEW

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INTRODUCTION

The undivided Bengal province had occupied a primal position in the history of the country over a long period for its fabulous riches. However, the early history of Bengal prior to the rise of the Gaur kingdom under Sasanka (in early 7th century) is not documented and has to be pieced together from passing references in Sanskrit or Pali texts, Buddhist and Jain writings and the works of foreign writers (Sengupta, 2011). Although the geology education had started from Kolkata (erstwhile Calcutta), – the former capital of India till 1911 and the capital of West Bengal following partition of Bengal after Independence – which still houses the Central Headquarters of the Geological Survey of India since its inception around 170 years ago, the State has failed to garner recognition for any of its geoheritage so far. One reason for this perhaps is the fact that the major part of it is covered by Gangetic (and other) alluvium. I propose here a geoheritage trail, ca. 250-km long, in parts of Rahr Bengal, from the western or southwestern part of West Bengal, between Garhbeta (in West Medinipur district) and Shantiniketan (in Birbhum district) through several interesting places in between like Bishnupur, Susunia, Raniganj and Amkhoi (near Illambazar) (Fig. 1). The trail truly represents an ensemble cast with all the different types of heritage (Abiotic, Biotic and Cultural, both tangible and intangible) present along it. Apart from its geological and geomorphological heritage, the zone bears ample evidence of continuous human history starting from Paleolithic (Acheulian) to Chalcolithic through Meso- and Neo-lithic times. Surprisingly, however, most compiled maps of such sites in India have tended to ignore or overlook these so far (Sonakia, 2003; Mathur, 2005). It has also witnessed a large number of battles and wars for supremacy over its territory during the period of recorded history resulting in a melting pot of sorts.

Historically, the Rahr region has been known by many different names and has hosted numerous settlements throughout history. One theory identifies it with the powerful Gangaridai nation of the Mahajanapada era also mentioned in the ancient Greco-Roman accounts. An inscription of Vallalasena names it as the ancestral place of the Sena dynasty.

Geologically, the Meso- to Neo-proterozoic rocks of Singbhum craton and the Eastern Ghat mobile belt forms the oldest formation which was first affected by transverse faults to give rise to tectonic valleys in which the deposition of the Gondwana sedimentary rocks took place (in the instance case along the Damodar valley) in the late Paleozoic and Mesozoic era (Fig. 2). Almost concomitantly, the Indian Plate kept moving northwards till it crossed the equator finally to collide with the Asian Plate. With the resultant episodic Himalayan tectonism and onset of monsoon, the Bengal Basin kept accumulating a thick pile of sediments brought about by the newly formed rivers originating from the rising mountains of the north also aided by those from the

Chhotanagpur plateau in the west. The delta complex of the Ganga-Brahmaputra River System kept prograding pushing the sea to recede since the Neogene time; the climate too went through periodic upheavals through the by-now-established tropical monsoon (with high temperature and rainfall) coupled with the frequent colder phases and their intervening warmer periods during Pleistocene. The resultant eustatic sea-level changes too played their part. Thus, the lower reaches gradually evolved from estuarine to deltaic (shelf part) to river alluvial terraces in different phases.

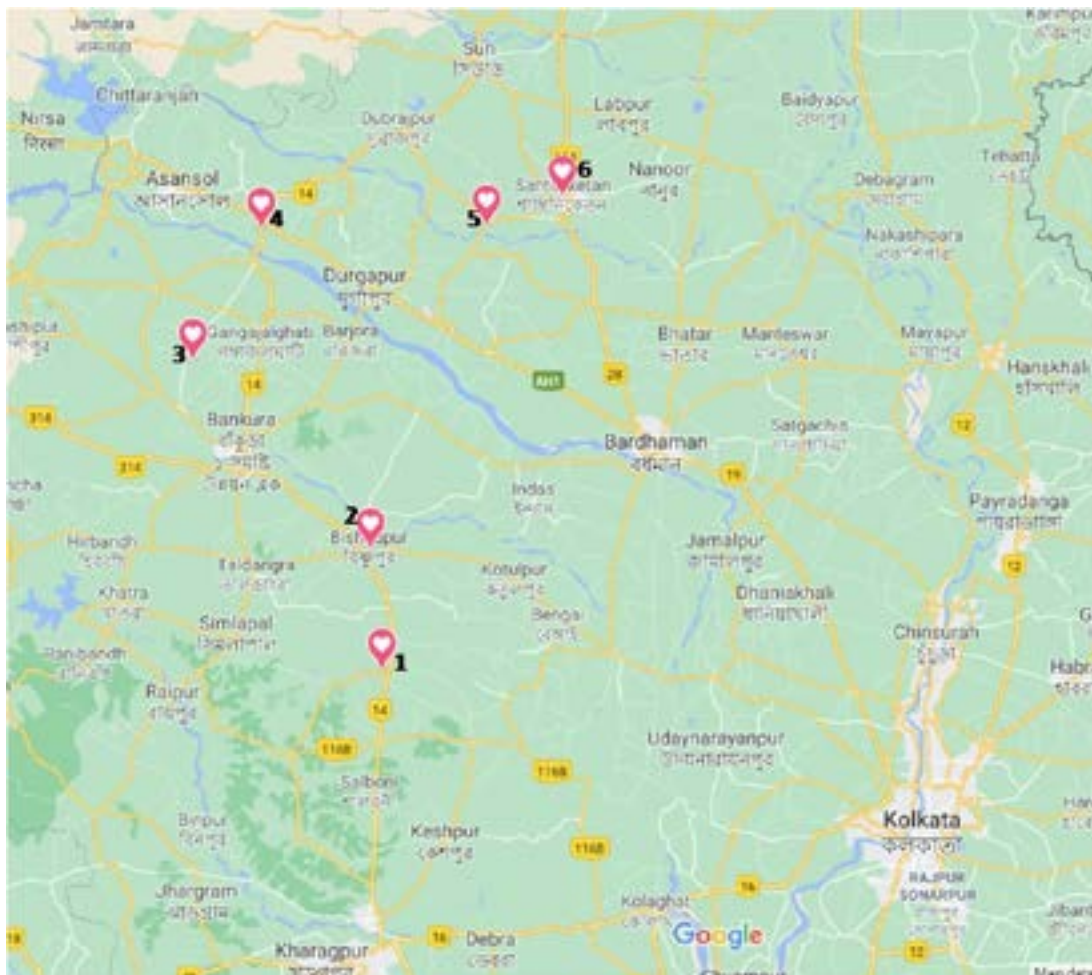


Fig. 1. Location map showing the six Places of Interest. 1. Garhbeta-Gangani; 2. Bishnupur; 3. Susunia; 4. Raniganj; 5. Amkhoy, and 6. Santiniketan.

Lateritisation process of the metamorphic/igneous rocks set in during the humid, tropical climate starting from the Lower to Middle Pleistocene epoch that on weathering and erosion gave the fringe area a characteristic red colouration. The intervening dry, semi-arid regimes also left their signature in the form of calcrete and ferricretes at places. The easy availability of food and water along with an abundance of raw materials for implement-making made it a haven and inviting place for the early humans whose imprints are ubiquitous all through the zone. The availability of copper and iron ores nearby (at Dhalbhum and Mayurbhanj-Keonjhar-Singbhum belt respectively) also contributed immensely to carry on with their habitation through the metallic ages. Expectedly, therefore, Chalcolithic sites too galore in this belt. In fact, it soon developed into a 'rich' zone for both the hunter-gatherers transitioning into permanent dwellers.

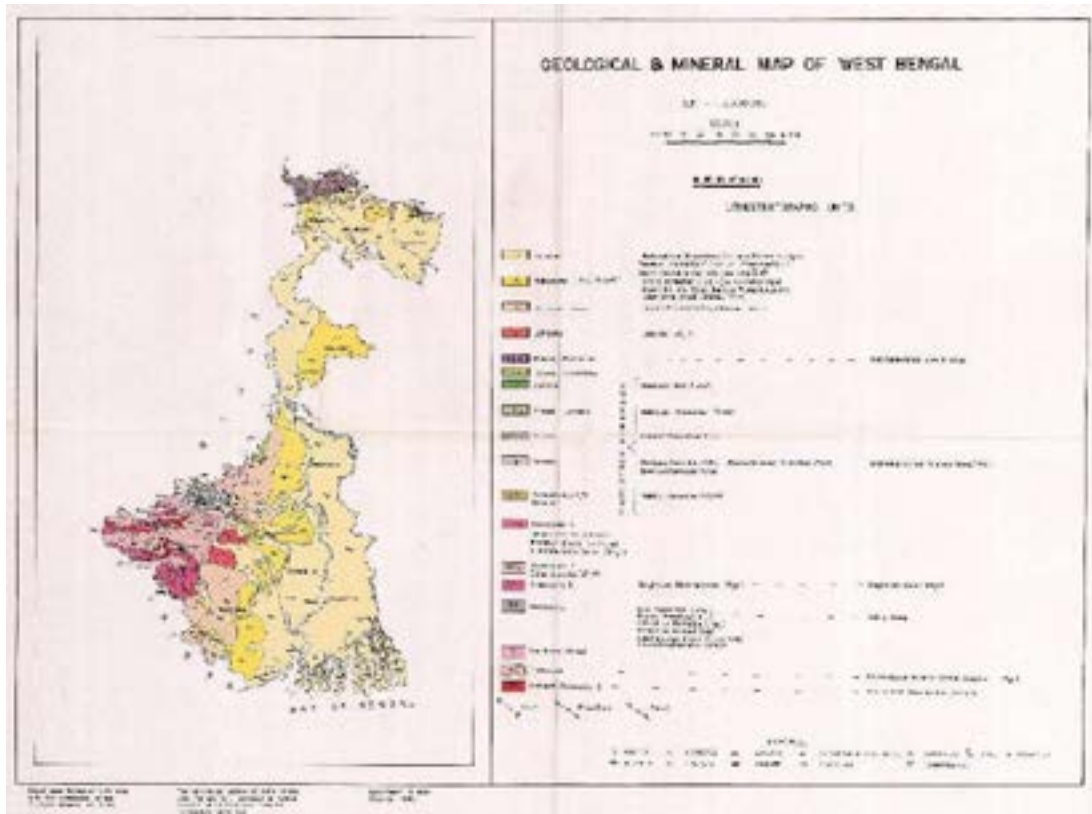


Fig. 2. Geological and Mineral map of West Bengal (after GSI).

Paleoliths have been found in Medinipur (now divided into East, West as well as Jhargram), Bankura, Bardhaman (both East and West) and Birbhum (as indeed in the Puruliya or erstwhile Manbhum) districts of West Bengal and the adjoining areas. The paleoliths all bear striking affinity of technology with the Madras specimens. These discoveries thus point to the existence of a paleolithic culture zone stretching from south India to the Gangetic valley (Sur, 1992).

Implements of the Neo-lithic Period have been recovered from Medinipur, Bankura, Bardhaman, Hooghly and other places. They have also been found in adjacent areas of Bengal to the west. Some of these places were both factories for the manufacture of neo-lithic implements and settlements of neo-lithic man.

A fossilized human jawbone was reportedly discovered at Sijua on the left bank of Kanshabati (Kasai) river a little way off from Ramgarh in the district of West Medinipur and was tentatively dated at 10,000 B.C. (Sur, op.cit).

Maritime trading too developed almost as a natural corollary using an inland port at Tamralipti (or Tamralipta, present-day Tamluk in East Medinipur district) that remained arguably the biggest port in this part for more than two millennia (from 1st Millennium B.C. to 1st Millennium A.D. and beyond) and even carried a hint of trading in copper (*Tamra* in Sanskrit) in its name. Incidentally, the Rarh area served as a melting pot of culture and religion as Jainism and Buddhism once thrived in it (till about 12th century AD) before Hindu (since 5th century AD) and Islam religions (from 13th century AD) gradually settled in transforming its religious demography though relics of the former can still be found here. It still has a sizeable tribal

population as well. A brief picture of the society is obtained from accounts given by different travellers, most notably Xiun-Tsang, the famous Buddhist pilgrim from China, among them, who visited the place in 638 AD.

Although many such sites have irretrievably been lost already and much of its history erased – apart from vagaries of nature – through ignorance, apathy, and negligence, six sites have been chosen on the trail taking into consideration all these aspects mentioned above. Care has nevertheless been taken to choose them keeping in view the easy accessibility too.

PHYSICAL AND HUMAN GEOGRAPHY

Rarh region (Bengali pronunciation: ra:ɽ) is an NNE-SSW trending zone in the southwestern part of West Bengal roughly about 40-50 km wide (Fig. 3). It is a toponym for an area in the Indian subcontinent that lies between the Chotanagpur Plateau on the West and the Ganges Delta on the East. Although the boundaries of the region have been defined differently according to various sources throughout history, it is *mainly* coextensive with the state of West Bengal. Linguistically, the region is defined with a population speaking the Rahr Bangla local dialect.

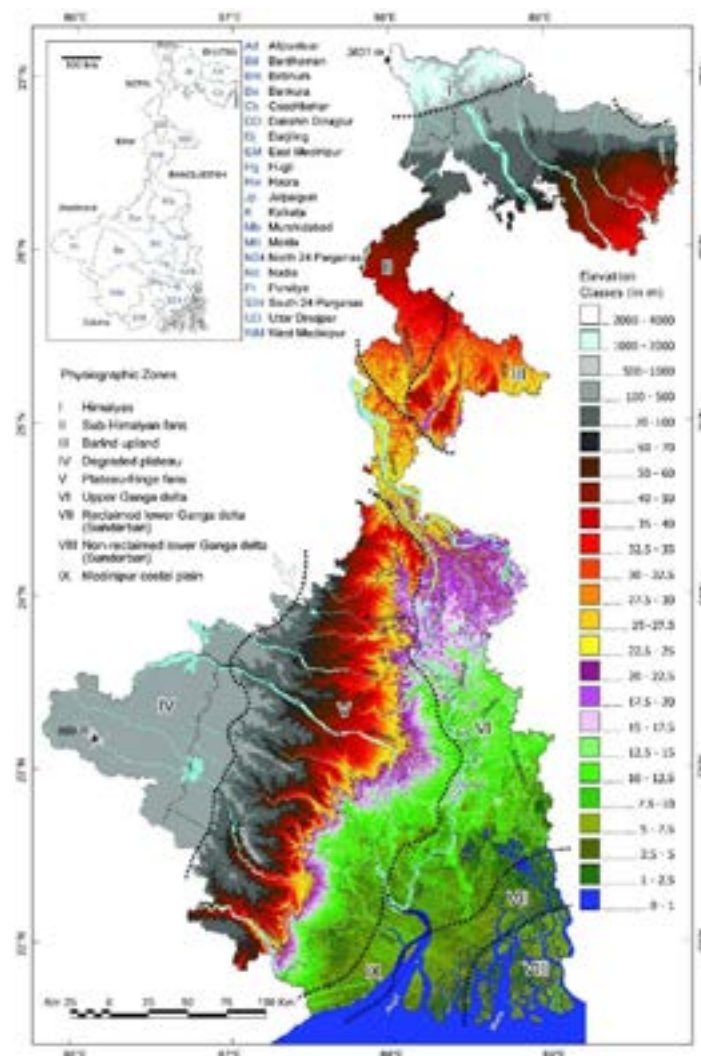


Fig. 3. Physiographic map of West Bengal. Zone V in it roughly corresponds to Rahr Bengal.

Rarh Bengal, as it is popularly known, has a unique geomorphologic and pedological identity. It is nestled between the eastern fringe of the rocky uplands of the Chhotanagpur plateau to its west spanning up to the fertile plain of the westernmost sea-bound channel of R. Ganga (called R. Bhagirathi or R. Hooghly) that traverses through the largest delta complex in the world (Ganga-Brahmaputra Delta Complex) to the east. Once covered under a thick deciduous forest for most parts, it occupies the transitional zone between the two and apparently enjoys the best of both worlds.

Rāḍha (Sanskrit) and Lāḍ[h]a (Prakrit) are the ancient names of the Rarh region. Other variations of the name that appear in the ancient Jain literature include Rarha, Lara, and Rara. The Srilankan Buddhist chronicles such as Dipavamsa and Mahavamsa state that the legendary Prince Vijaya of 6th century BC came from a region called Lāla, which is identified with Rāḍha by several scholars.

Characterised by the red colour of its soil (locally known as ‘lalmati’ or ‘rangamati’), it is drained by a number of rivers (Mayurakshi, Ajoy, Damodar, Dwarkeshwar, Shilabati, Kanshabati, etc. are the major ones) originating from the western uplands that almost always debouch into R. Hooghly or one of its tributaries with a general slope towards southeast. Though its forest cover has dwindled substantially in recent times through anthropological intervention, it still harbours a sizeable portion of it that provides a perfect foil to the variety of its ecosystem. No wonder the zone has been considered a favourite habitation with animals and humans alike right from the early times (Pleistocene epoch) transgressing the vicissitudes of its geological and climatological history. The proposed trail here traverses along a length of around 250 km from south to north and northeast that integrates the different aspects of geology, anthropology, archaeology, and protohistory to modern history in a near-continuum along with its different cultural (both tangible and intangible) heritage.

The Rahr area has been a melting pot where we get a continuum of sorts of history. The region also came under the direct influence of Jainism, Buddhism, Hinduism, and Islam at different times in the past 2500 years or so, giving rise to a syncretic culture of its own.

GENERAL DESCRIPTION OF THE PLACES OF INTEREST

1) Garhbeta-Gangani

Primary Heritage Type: Abiotic/ Cultural

Geographic Coordinates: 22.8631° N, 87.3538° E

Close to the historic town of Garhbeta and around 6 km from the Garhbeta Road railway station on the Kharagpur-Adra section of Eastern Railways in the West Medinipur district, the small village of Gangani is located (Fig. 4). It is a site of great geological and geomorphological interest that has of late gained huge popularity amongst the common tourists for its extraordinary natural beauty and aesthetic appeal.

Ravines or Badlands (called *Bihad* or *Behad* in north India) are not unique to our country and examples of these can be found from different corners of it covered by different geological setup as well as the climatological regime. Here, lying on the eastern fringe of the Precambrian shield area (Chotanagpur plateau) in the State of

West Bengal, this badland region in northern West Medinipur district of West Bengal is spread over ca. 3.4 square kilometers on the southern bank of R.Shilabati, a minor (ephemeral) easterly flowing river originating from the Chotanagpur plateau to its west and northwest (Fig. 5). Capped only on this side by *murumy* or clinkery laterite (in-situ and ex-situ) as well as ferricrete that acts as a protective cover over the primarily loose and semi-consolidated sediments, it produces a spectacular erosional architecture creating a badland morphology often exposing myriad mind-boggling forms, set in an ensemble of colours ranging from red, brown, buff, cream, grey to even white, that not only are an Earth scientist's delight but does enchant the common people as well for their extraordinary beauty and aesthetic appeal. Though *prima facie* it appears to be the handiwork of the river that cuts through a ca. 70-ft-thick sedimentary profile only on one side (the northern bank of the river is more than 50 ft lower in elevation and enjoys good agriculture) aided by rampant headward erosion through its attendant rills and gullies, the jury is still out regarding whether that's the sole reason for its origin (structural disturbance being a close aide). The lower part belongs to the Pleistocene Lalgah Formation deposited under sub-deltaic condition (shelf zone) that gradually gives way to a fluvial depositional environment of the Sijua Formation (late Pleistocene to early Holocene) time (Goswami and Chakrabarti, 1988). To begin with, the asymmetry (in altitude, landscape, and vegetation) between the two banks is remarkable on the ground and all the geomorphological marvels are confined to the right (south) higher bank of the river. Now, on the lean season, the river flows at least a good 50m away from the edge of the highland at the most commonly frequented spot (Fig. 6) while the water level rises substantially during the rainy season.

Garhbeta and Surroundings



Source : High Resolution Ikonos Image

Fig. 4. Satellite image showing the location of Garhbeta (-Gangani) and its environs.



Fig. 5. Panoramic view of Gangani area.



Fig. 6. Tourists seen here using the staircase built for convenience.

The sediment architecture often produces the appearance of multi-storied pillar-and-roof structure in profile with occasional caves formed in it. Ferricretes were evidently formed at a later stage through leaching of soluble ferric oxide and their subsequent deposition encrusting the sediments at a lower level.

Laterite in general does not support much vegetation barring a few varieties of palm and cashew nuts, etc. The top and side slopes of these uplands here are thus mostly left abandoned as wastelands. Scattered grasses and thorny shrubs dotted with isolated deciduous trees are common vegetal covers in the valley part. Rain and runoff not only remove top-soils with nutrients suitable for plant growth but water erosion in the form of rain splashes, rills and gullies also deeply dissects the bare, unvegetated slopes and fallow lands. Presently the region falls under Monsoon Sub-Humid Zone characterized by humid summer and dry winter. The soil here is yellowish red in colour, very strongly acidic sandy loam (Mrigindihi).

Locally known as “Gangani Danga” (the higher terrace part) and “Gangani Khola” (the valley part), “it is lovingly called – though not with good reason perhaps - the 'Grand Canyon of West Bengal' for bearing some similarities (though essentially cosmetic) to the famous Grand Canyon, USA [Canyons are by definition a deep, narrow valley with steep walls generally occupied by a river which is certainly not the case here].

The different exposed stratigraphic, as well as compositional bands, reveal an astounding range of landform/ structures through differential weathering and erosion that people can sometimes relate to different known forms (Figs. 7 & 8). The geological explanation put forward by a different set of workers for the development of such a feature is however ambiguous. One theory surmises a sympathetic disconformity parallel to the Singbhum Shear Zone that created the Bengal basin. However, bereft of any clear evidence of faulting on the ground (though several faults have been inferred, mostly sub-surface; cf. Das and Banerjee, 2001), the most common explanation comes in the form of partial upliftment of the cratonic part and periodic crustal subsidence of the central part of the Bengal basin possibly in response to the Himalayan orogeny towards the end of the Neogene Period (Miogeosyncline). Episodic land movement, the eustatic sea-level changes with marine transgression and regression (both concomitantly and independently of the former), the onset of monsoon and shifting of the climatic pattern from time to time, the development and evolution of the fluvial regime, etc., are all responsible for the creation of a complex sedimentary architecture that this spot as a part of the transition zone (between hard rock and soft sediments amongst others) appears to showcase. Here, apparently, the lowermost sediment layer is sub-deltaic while the successive one primarily fluvial in nature with the overall successive progression of the delta front even possibly after the rise in the sea-level since the end of the Last Glacial Maxima. Laterite (in situ and ex situ) capping, as well as the formation of ferricrete and calcretes, have indeed given it protection against the erosional agents, even if temporarily. And at the end of it all, Mother Nature assumes here the role of a master sculptor who has carved these forms over thousands of years in this sprawling open-air studio. The forms produced here include caves, pillars of different sizes and shapes, current bedding, and several other sedimentary (aggradational) and erosional (degradational) structures. The 70-ft thick profile here includes loosely consolidated sediments to somewhat hard calcrete/ferricrete-type formation that have different

colourings too below the red in-situ to ex-situ lateritic cover. It also points to a history of climate change as calcretes are products of a somewhat dry, arid to semi-arid condition. Interestingly, the area presently enjoys a substantial amount of rain that possibly helps exacerbate the effect of erosion in two different ways: a) through rills and gullies, as well as sheet erosion, and b) raising the water level of the river during the rainy season thereby causing seasonal variation in its base level. Its proximity to the coast in the geological past might have played a key role in carving the forms through wind erosion too, a possibility that also needs to be researched in detail.



Fig. 7. Different forms and structures carved in semi-consolidated sediment pile.

Wood fossils are not difficult to find from this place either that at times resemble bones. As per local folklore, it is at this place that Bhima the second Pandava killed the demon Bakasura mentioned in Mahabharat after a protracted fight turning the land into what it looks now and the fossil logs represent the bones of the latter. Geochronology of few secondary laterite profiles has been determined by the OSL dating method in three sample sites of the Rarh region, representing late Quaternary palaeogenesis of laterites and ferruginized sediments (150–35 ka), i.e. late Pleistocene (Chakraborti, 2011; Ghosh and Guchhait, 2018). Apart from the interest being shown by the researchers and students, the spot has of late assumed huge popularity amongst general tourists and picnickers for its beauty arising out of its aesthetic appeal (the unusual and colourful landform). As already mentioned, the rate of erosion is pretty high (accentuated further by anthropogenic activities) producing even a gully fan that gets exposed during the lean season. In fact, considering the high vulnerability of the landform, some restrictive measures need to be taken immediately to protect it from further degradation.

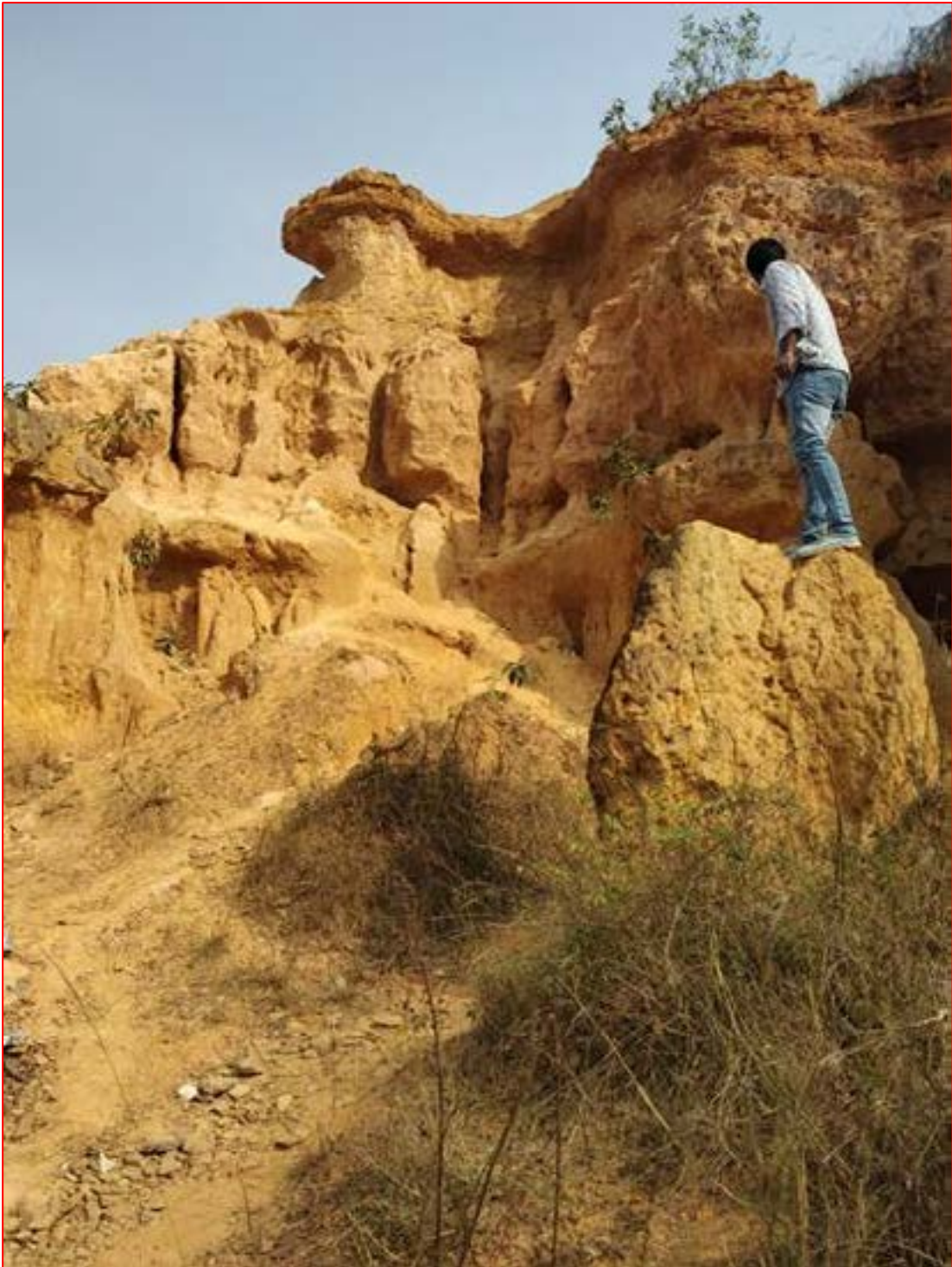


Fig. 8. Different forms and structures carved in semi-consolidated sediment pile.

The Gangani badlands have now made it to the extended revised list of Geosites prepared on the eve of the forthcoming International Geological Congress (IGC) that was originally slated to be hosted by New Delhi during March 2020, but has since been postponed twice due to the COVID-19 pandemic raging worldwide.

Apart from being blessed with unmatched geological or geomorphological stuff, the area around Garhbeta is blessed with some beautiful ancient temples and other historical remnants. This includes the ruins of a fort (Raikota Fort of the Bagri

kingdom that once ruled over the area) and several temples (Sarvamangala, Krishnarai Jieu, Kameshwar, and Radhamadhab temples), etc.

There are a few other archaeological sites too in the vicinity of the area. For example, in 1976, there was found at Aguibani within the Garhbeta P.S., 40 feet below the present surface of land, the whole of a copper celt, the broken head of another celt, another copper celt of smaller size, eleven pieces of copper bangles and several pieces of copper-made wicker baskets which are believed by some experts to be either contemporaneous with the Harappan civilization or of an even earlier age (Sur, 1992). Plans are afoot at different levels to develop the site at Garhbeta-Gangani further to harness its huge geoheritage potential (Fig. 9).

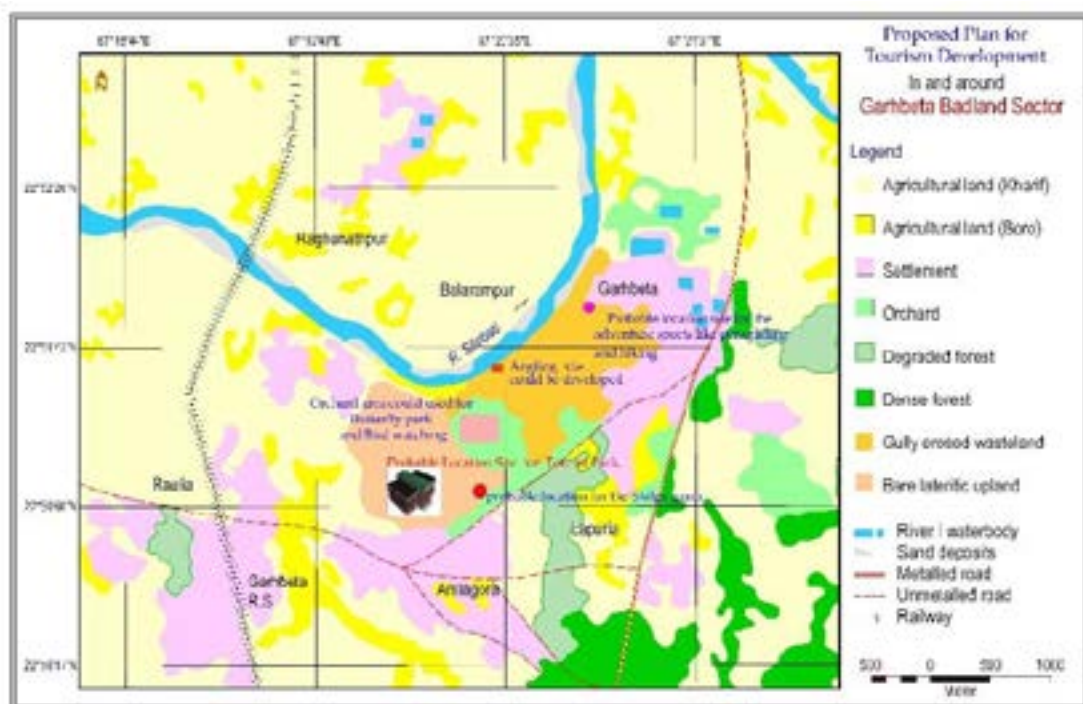


Fig. 9. Proposed plan for tourism development in and around Garhbeta badland sector.

2) Bishnupur

Primary Heritage Type: Cultural (Tangible/ Intangible)

Geographic Coordinates: 23.0672° N, 87.3215° E

Bishnupur, a Sub-Divisional Headquarters of Bankura district in West Bengal, is celebrated worldwide for its beautiful temples which are still preserved in reasonably fine condition. While some of these (four in number) temples, constructed between the early 17th and mid-18th century, are made up of terracotta (Latin 'terra' – earth or clay; 'cotta' – dry coating or baked), there are others that are carved out of lateritic rocks found locally and also of bricks. That way impoverished with stones that are useful or ideally suited for building edifices (like massive granite, marble, chloritic schist, sandstone, etc.), these ingredients are Rarh Bengal's answer to the most remaining part of the country. Though several exquisite terracotta temples are present in different other parts of the Rarh region, none possibly comes close to this place (Bishnupur) wherein so many exquisite terracotta temples can be seen localised at a single place. This temple town of Bishnupur was the capital of a large territory called

Mallabhum (or the land of the *Mallas*, the name of the dynasty) which comprised besides the entire district of Bankura, extensive parts of the adjacent districts as well.

The Malla dynasty started in the late 7th century (their private calendar, called the *Mallabda*, started from 695 CE) by one Raghunatha, also called the Adi Malla, a scion of an old Kayastha family and lasted till the last century when the last representative of the dynasty died without any successor. While these kings were initially worshippers of Shakti and Shiva with their capital at Pradyumnapur a little distance away, Jagat Malla, the 19th king of the dynasty, shifted his capital to this place towards the end of the 10th century. Later on, Maharaja Vir Hambir, the 49th king of the dynasty, converted into Vaishnavism under the influence of Guru Sreenivas Acharyya, a direct disciple of Sree Chaitanyadev, in the second half of the 16th century and named it after Lord Vishnu, its presiding deity. Some of the more famous temples and monuments of Bishnupur include *Rasamancha* (1600 CE) (Fig. 10), *Mallesvara* temple (1622 CE), *Shyamaraya* or *Paanchchura* temple (1643 CE), *Jorbangla* or *Keshta-Raya* temple (1655 CE), *Kalachand* temple (1656 CE), *Radhalal Jiew* temple (1658 CE), *Madanmohan* temple (1694 CE), *Pathar Darja* (or the Stone Gate) (1700 CE), *Jor Mandir* (1726 CE), *Radhagovinda* temple (1729 CE), *Radhamadhav* temple (1737 CE), etc. and many more (Biswas, 2003).

The temples represent nearly all varieties of structural forms (*deul*, *chala* or *ratna* style) of medieval temple architecture of Bengal (McCutchion, 1972) (Fig. 11). These monuments and temples are often pretty unique as in the case of *Rasamancha* that infused Egyptian (as in the upper pyramidal part), Bengali Hindu (as in the middle part), and Islamic architecture (as in the arches in the lower part) into one (Fig. 10). The ca. 6-foot-high foundation of it is made up of laterite rock while the upper portion is built of bricks. The terracotta temples in particular exhibit some of the finest and most delicate art forms depicting stories from the Epics (like the Ramayana and Mahabharata) and Puranas besides contemporary lives as well. Even the lateritic temples often exhibit exquisite craftsmanship on the exterior walls and may remind one some of the world-famous temples of Angkor Wat in Cambodia. *Rasa-mandala* depicting scenes from *Krishna-lila* and the original Foundation Stones of the temples can be seen in some of these terracotta temples too. Though many of these temples were once in an advanced state of decay, the Archaeological Survey of India is now actively engaged in their restoration and preservation.

Several large water bodies (called ‘Baandh’) were also dug up by the kings only two of which still survive. A huge 18th-century cannon called Dalmadol (a corrupt form of ‘*Dalmaridon*’ or the slayer of the enemy) still finds a pride of place in its history and myth. Weighing about 112 quintals, it is around 3.8m long with a diameter of 30 cm. As per myth, the resident deity of the town scared off the Maratha (Bargi) invaders in 1742 with its blast. The then British administration had placed it on a concrete pedestal in 1919 for tourist attraction. Apart from its celebrated terracotta art forms that transgress from the temple architecture to even household items and toys, the region still retains a huge reputation for a wide array of handicraft and folk art in the forms of metal, silk, cotton-weaving, woodcraft, conch shell art, Dasavtar card making, etc. This is the only center where the famous Baluchari silk sarees in Bengal presently come from. The only Gharana of Indian classical music from the State (and the whole of eastern India) is also named after this place (*Bishnupur Gharana*). All of

these were once initiated and patronized by the successive kings of the Malla dynasty that ruled the region for several centuries.



Fig. 10. Some cultural heritage items from the temple town of Bishnupur, *Rasa-mancha*.



Fig. 11. Different characteristic styles and forms (e.g. *Ekchala*, *Dochala*, *Ekratna*, *Pancharatna*, *Jorbangla*, etc.) of medieval temple architecture of Bengal.

There is a small but beautiful museum (Acharyya Jogesh Chandra Archaeological Museum) in this town that depicts the cultural history of the whole district and its heritage (both tangible and intangible).

Bishnupur features in the Tentative List of World Heritage Sites in India for its temples and Baluchari saree weaving since 1998. There is a proposal for declaring Bishnupur as the first heritage town of the State too.

Besides the regular curio shops, a weekly fair cum rural market, called the *Poramatir Haat* (i.e. terracotta market), held on every Saturday afternoon at the outskirts of the town caters to the visitors wherein they can purchase terracotta mementos and enjoy some cultural extravaganza as well. Visitors may also venture into some of the nearby villages for watching Baluchari saree weaving, etc. A 3-day-long annual cultural festival called the Bishnupur festival is also arranged every year after the Durga Puja.

3) Susunia Hills and its environs

Primary Heritage Type: Abiotic/Biotic/Cultural

Geographic Coordinates: 23.3951° N, 86.9874° E

Susunia Hill, within an otherwise near-peneplain country, is a very interesting site located within the Bankura district around 60 km northwest of Bishnupur town. It perhaps is one of the easternmost remnant hills of the Precambrian shield in this part. Apart from its scenic beauty (Fig. 12), it is famous for its holy spring, its rich flora, medicinal plants, and its rock faces that are used for rock climbing training, etc.



Fig. 12. Panoramic view of Susunia hill.

The area around Susunia Hill, the second-highest hill (448 m) in the Bankura district, is very interesting from the point of view of geology (petrology and vertebrate paleontology), archaeology and anthropology as well. High-grade metamorphic (upper amphibolite to granulite facies) rocks occur both in the hill as well as its surrounding areas nearby. The typical assemblage comprising granitic gneiss, hornblende gneiss, quartzite, etc. is often found intruded by veins of pegmatite (dumortierite-bearing at times) and quartz (containing tungsten-bearing minerals like

scheelite and wolframite as in Chhendapathar), or even an anorthosite massif is found near Saltora. Alluvium beds surrounding the hill (particularly those of R. Gandheshwari, Dwarkeshwar, Kansai, etc.) are often found to contain a large number of vertebrate fossils from Pleistocene time. Some notable fossils among them are Elephant (*Paleoloxodon namadicus*), Water Buffalo (*Bubalus palaeindicus*), Lion (*Panthera leo*), Gaur (*Bos* sp.), Antelope (*Gazella* sp.), Wild Boar (*Sus* sp.), Giraffe (*Giraffa* sp.), Spotted Hyena (*Crocuta* sp.), Porcupine (*Hystrix* sp.), Indian Wild Ass (*Onager* sp.), Gharial (*Gavialis* sp.), Turtle (*Trionyx* sp.), etc. (Sastry, 1966; Das Sharma and Biswas, 1978, 1982). While the last two are reptiles the rest are mammals. Almost all of the above species have either gone extinct (like the *Paleoloxodon namadicus*, arguably one of the biggest land mammals ever to have roamed the earth) now or have migrated to other regions or continents (like the *Panthera* sp. having moved to Gujarat and *Crocuta* sp. to Africa, etc.).

As in the whole of the Rarh region, stone-age artifacts are ubiquitous in these alluvium beds, often in close association with these vertebrate fossils. There are at least thirty such stone-age sites close to Susunia Hill alone. Late P.C. Dasgupta, former Director of the Dept. of Archaeology of the Govt. of West Bengal reported some 2000 artifacts ranging from Acheulian to Neo-lithic (Dasgupta, 1967). Besides, the area is found to be highly implementiferous too. Manibrata Chattopadhyay of the Department of Anthropology had also collected a huge number of stone tools from the area. Avick Biswas had done some critical archaeological study of the area in recent years under the supervision and guidance of Prof. S. N. Rajguru of the Deccan College, Pune (Biswas, 2014). The preponderance of stone-age tools in the area surrounding Susunia Hills are evidently indicative of the availability of raw material as well as food and water in the vicinity during Upper Pleistocene through Holocene times. Evidence like simultaneous occurrence of a large number of bones and other body parts of black bucks found scattered on paleosols, darkened through use of fire, mixed with lime in an area around Payrasol in Bankura district not very far from Susunia led Das Sahrma and Biswas to surmise it as a kitchen hearth (Das Sharma and Biswas, 1982). It gives a fair idea about the climate and paleogeography of that time as well.

Halfway to the top of another adjacent subsidiary hill, an original stone inscription of King Chandravarman of Pushkarana kingdom (from 4th century CE) contemporary to the late Gupta period is still preserved. Incidentally, Chandravarman, whose name is found in Allahabad inscriptions of the Guptas and is thus believed to be an important king of that time, was defeated by Samudragupta and the area became a part of the Gupta Empire. It however remains undeciphered so far.

Other Nearby Places of Interest: There are several temples with distinctive architectural styles in the district some of which like the ones at Bahulara (*Siddheswar* temple) and Sonatapal (Sun temple), both on the banks of Dwarkeswar river and close to the trail (between Bishnupur and Susunia), that date back to 11th and 12th centuries respectively. Interestingly, the former has statues of Jain tirthankars in the inner sanctum besides several slightly elevated round platforms believed to be either *samadhis* or *chaityas* in the open courtyard while the latter has Buddha statues found on its exterior wall. The architectural splendor of the Bahulara temple was regarded very highly by J.D. Beglar, the famous archaeologist and assistant to the ‘Father of Indian Archaeology’ Sir Alexander Cunningham in the 19th century. Close to the

banks of the same river, there are two other Shiva temples - *Shaandeshwar* and *Shaileshwar* - that date back to the 10th to 11 century. These temples rank among the oldest examples of the *Rekh Deul* style of architecture in West Bengal.

4) Raniganj Coal Field

Primary Heritage Type: Cultural (Tangible)

Geographic Coordinates: 23.6234° N, 87.1143° E

The name Raniganj is perhaps not unknown or unfamiliar to most, particularly to the students of geology and mining in India. Raniganj in the West Bardhaman district of West Bengal has a huge bearing on the socio-political as well as commercial evolution in the country. Situated on the left bank of R. Damodar, it is credited with the following: a) the oldest official (Gondwana) coal mine in India; b) the first coal mine (Raniganj Coal Mine) owned by an Indian (jointly with a European), viz. Prince Dwarkanath Tagore (grandfather of Rabindranath Tagore) under a joint venture (Carr Tagore & Co.); c) the first published geological map from the Geological Survey of India on 1 inch: 1 mile scale was of the Raniganj Coal Field area, prepared by W. T. Blanford and published in 1863 (Mem. GSI, Vol. III, Pt. 1) where he recognised three groups (called Series that time) viz. Talcher, Damuda and Panchet (Blanford, 1865). Prior to him, it was also investigated upon by D. H. Williams, the first qualified geological surveyor in the country, during 1845-47, and d) the first Railway in the eastern sector was inaugurated to run between Howrah and Hooghly in 1854. The very next year, i.e. in 1855, it was extended up to Raniganj for fetching the coal to Calcutta that shows its importance to the Company officials. Before that, the only mode of transport for coal was by the river (Damodar) route which would not be navigable for nearly half of the year.

At a time when the face of navigation and transport was about to be changed dramatically in this huge country, Raniganj provided the answer. It not only helped in transferring to this country the fruits of the industrial revolution to facilitate harnessing its resources for the East India Company mandarins, it completely changed the geopolitical scenario starting from the late 18th century. Coal was virtually the only source of energy available at that time to run machines like, say, the steam engines and Raniganj was to be the cradle for coal mining in India.

The coal-mining industry of India is a relatively recent development as compared with that of many European countries. The first published reference to the mining of coal in India dates back to the year 1774, during the time of Warren Hastings when permission to work coal mines in Bengal was accorded to John Sumner and Suetonius Grant Heatly (their first attempt in 1770 was turned down). As a result, mines doubtless as open cast or incline workings, were reported to have been developed in the Raniganj field; at Aitura (Ethora) possibly in the Dishergarh seam, at Chinakuri near the Damodar river, most certainly in one of the middle Raniganj seams, and at Damulia, also near the Damodar river, apparently in the Nega-Raniganj seam. Miners were initially brought from the UK but they didn't last long. So, local labourers (mostly from the Bihar and Jharkhand region of today) had to be deployed. But after a few years, these coals were found on testing to be not half as good as those brought from outside thus bringing an end to the adventure.

After a quiescence of around 35 years, the demand for coal picked up in Kolkata in 1814 when the economics of mining Indian coal made sense again. The East India Company sponsored William Jones for mining coal in Bardhaman (then Burdwan). He took land on lease from the Rani of Bardhaman and named it Raniganj in her honour. Jones mined coal but incurred persistent losses. In 1821, Alexander & Company, which had secured the loans taken by Jones, took over and started mining. They performed better, raised production, and even earned profits for some time, but the company failed in 1832. With his strong business acumen, Dwarkanath saw the potential, formed Carr, Tagore, and Company, the first-ever joint-venture holding company in 1834 and bought up, after some haggling, the Raniganj Coal Mine, the oldest and richest source of fuel in Bengal at that time, in January 1836 from M/s Alexander & Co. for Rs. 70,000 only (later that year, the Coal Committee was formed by the East India Company that eventually led to the formation of Geological Survey of India in 1851).

The first rail engine in eastern India chugged on the line from Calcutta (Howrah) up to Hooghly in 1854 and in another few months was extended to Raniganj to transport coal of the Bengal Coal Company to Calcutta. The first official publication (Annual Report) of the Geological Survey of India, formally established in the meanwhile in 1851, was brought out that contained a geological map of this belt, viz. Map of the Damuda (Raniganj) Coalfield, again the first of its kind, by W.T. Blanford under the overall supervision of Thomas Oldham in its third edition (Mem. GSI, V.III, Pt.1, 1863).

Globally there are several examples in countries like S. Africa and Australia where such old mines with heritage value have subsequently been converted into tourism sites. Some of the old mines here are still in operation (though the original mines doubtless were open or incline workings) that can be given a makeover to suit it to the requirements of a Geoheritage site. Of late, an attempt has been made through the efforts by some local groups to declare the ruins of the bungalow built by Dwarkanath at Narankuri on the bank of Nuniya river in Raniganj as a heritage property by the State Heritage Commission.

5) Amkhoi Wood Fossil Park

Primary Heritage Type: Biotic

Geographic Co-ordinates: 23.6279° N, 87.5421° E

Amkhoi Wood Fossil Park is located in the tribal village of Amkhoi near Illambazar in the Birbhum District of West Bengal. It contains fossilized wood of angiospermous flora of 15 to 20 million years of age (Lower Miocene epoch). These fossil logs (petrified wood) were excavated during the digging of a pond at this site and have since been developed into this park and officially recognized by the State Forest Department of West Bengal only very recently (in 2017) (Figs. 13 & 14). Though fossil logs have also been reported earlier from Bardhaman, Bankura and Medinipur districts, Amkhoi Wood Fossil Park in Birbhum district is the only fossil park of West Bengal state and has an area of 10 hectares. Apart from helping the researchers, the park was created as an attempt to raise awareness among the students and people interested in it and also to prevent vandalism by thieves and fossil hunters. This also happens to be a geosite proposed in the Revised List of Geoheritage by GSI from the State other than Gangani. The families and genera identified by scientists from the

place are Dipterocarpaceae, Anacardiaceae, Combretaceae, and Leguminosae, etc. While some of the families continue to inhabit this area, some have fallen extinct. However, they occur in the present-day forests of the Western Ghats, Myanmar and Malaysia. This forest thrived in the uplands of Rajmahal Hills and Chotanagpur Plateau at the northwest of Birbhum. It is presumed that the trees were carried by occasional floods of the river system flowing from northwest of the river basin towards the southeast in Birbhum, Bardhaman, Bankura and Medinipur districts and deposited rapidly under sand and clay gradually to transform into wood fossils though the degree of transport is yet to be ascertained.



Fig. 13. Amkhoi Wood Fossil Park and a few wood fossil specimens displayed in it.



Fig. 14. Amkhoi Wood Fossil Park and a few wood fossil specimens displayed in it.

6) Shantiniketan

Primary Heritage Type: Cultural (Tangible/Intangible)

Geographic Co-ordinates: 23.6776° N, 87.6852° E

Shantiniketan (literally meaning ‘Abode of Peace’) is located in the neighbourhood of Bolpur city in Bolpur subdivision of Birbhum district in West Bengal, approximately 152 km north of Kolkata. Though the land was procured by Maharshi Debendranath Tagore in the 1880s being enamored by its charm, his youngest son Rabindranath chose to make a humble beginning here with opening of a school (Brahma-Vidyalyaya) on 22nd December 1901. It was later expanded by Rabindranath whose vision to become what it is now, a university town, with the creation of Visva Bharati since 23rd November 1921. It was a dream project for the latter who introduced open-air learning with an emphasis on free-thinking, fine arts (art & craft, music, dance, drama), agriculture and rural welfare, etc. under the tutelage of teachers handpicked by him from across the globe. He also made it his home for the last few decades of his life and resided in several buildings here at different times till his death in 1941.



Fig. 15. Kalo Bari.

There are a large number of buildings and monuments within its campus that are worth visiting, like the Shantiniketan, Natun Bari, Deholi, Uttarayan Complex, Patha Bhavan, Sangit Kala Bhavan, Kalo Bari (Fig. 15), Hindi Bhavan, Cheena Bhavan, Chhatimtala, Mandir or Upasana Griha, etc. (Chattopadhyaya, 1979). A decade after Tagore's death, the Govt. of India took over Visva Bharati in 1951. Apart from Rabindranath, the place has direct link with another Indian Nobel laureate, viz. Amartya Sen. Many eminent personalities and world leaders have visited the town at different times (Fig. 16). Today, this university-town is a popular tourist destination frequented by thousands of national and international tourists every year and, like Bishnupur, it also features in the Tentative List of UNESCO World Heritage Sites in India. There are other tourist spots too outside of the sprawling Visva Bharati campus where one can have a feel of the place including its geomorphology, rural scene, cultural life (Fig. 17), produce of the self-help group typical of the place to be collected as mementos, etc.

SUMMARY AND CONCLUSIONS

It may be appreciated from the above narrative that the zone of Rarh Bengal has a huge Geoheritage potential that can and should be harnessed and preserved for posterity. The Gangani site is extremely fragile and needs immediate protection. Other sites such as Susunia and Raniganj too have huge heritage value and needs to be protected and developed from the geotourism point of view. Being economically backward, the region as a whole is also ideally suited for tapping its human potential.



Fig. 16. Tagore in conversation with Gandhi at Santiniketan.



Fig. 17. Baul (a folk form) singers performing at Sonajhuri.

All the places of interest along the trail are well connected by railway and/or excellent highways with each other and also with the city of Kolkata, the nearest metropolis with an international airport. Good accommodation facilities are available in almost all places. The area enjoys a tropical monsoon climate and though the best season to travel to these places is from October to March, the trail can be covered any time of the year.

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AJMER, RAJASTHAN - A POTENTIAL NATIONAL GEOPARK OF INDIA

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INTRODUCTION

The proposed Ajmer Geopark covering an area of 91sq. km in Ajmer, Pushkar, and Kishangarh cities of Rajasthan is located in the northwestern part of India. Geopark area occupy the valley areas between the *Madar*, *Taragarh*, *Ajaisar*, *Kharekari*, and *Nag* hills, belonging to the world's oldest South Delhi Fold Belt (SDFB). These ranges protect the Geopark area to prevent the expansion of the Thar Desert. The importance of Ajmer Geopark immensely increases as it is endowed with the world's largest building stone market, national geological monument of nepheline syenite, *Kayad* silver-rich Pb-Zn mine with many natural geoheritage elements. Besides all these specialties, the Geopark area is a culturally and historically rich legacy of India. Pushkar has great antiquity because of its great religious importance. In *Budha Pushkar*, one of the earliest human habitations has been found which is of great archeological importance. For centuries, Pushkar has enjoyed the reputation of being one of the most important sacred places of Hinduism, where the only temple of Lord *Brahma* is located. The world's famous *Ajmer Shareef* mosque is also a sacred place not only for Muslims but also for people of all religions. Owing to the significant aspects, Ajmer has recently been selected as one of the heritage cities for the HRIDAY (Heritage City Development and Augmentation Yojana), which is already a SMART City under the Government of India Smart City scheme. Endowed with such a remarkable geological, hydrogeological, archeological, religious, cultural, and administrative scenario, twenty-one geosites have been identified in Ajmer, representing five types of geoheritage (Ruban, 2010), which has regional, national, and international significance. These are i. Geological, ii. Geomorphological iii. Hydrogeological, iv. Geohistorical and Cultural v. Archaeological types. The combination of all these geoheritage types in one complex type geosite with existing tourism facilities puts the proposed area in a favourable position to develop a dynamic and successful potential national Ajmer Geopark in India.

LOCATION AND EXTENT OF GEOPARK AREA

Culturally and religiously vibrant habitations, Ajmer (26.4499° N and 74.6399° E), Pushkar (26.4886° N, 74.5509° E), and Kishangarh (26.5866° N and 74.8542° E) are situated in the central part of Rajasthan, which lies in the north-western part of India. The proposed Geopark area covers about 91sq. km area within the rocky and desert terrain forming a spectacular landscape. Ajmer is well connected by road, rail, and air to major Indian cities. Kishangarh is about 26 km in the NE direction and has an airport, and Pushkar is located about 12 km in the NW direction from Ajmer. Ajmer and Kishangarh are connected through NH 8 while Ajmer and Pushkar by NH 89. All identified geosites are connected with tar roads having good accessibility (Fig. 1).



Fig. 1. Location map of the Geopark area with its hilly terrain, valley and plain areas.

PHYSICAL AND HUMAN GEOGRAPHIC CHARACTERISTICS

Among the three towns of the Geopark, historically Pushkar and Kishangarh were ruled by the kings of Ajmer till the close of the 12th century. Ajmer city, which is surrounded by hills and ridges of SDFB and developed in valleys on the lower slopes of the *Taragarh* hill, derives its name from *Ajaymeru* (the invincible hill). The city was founded in the 7th century by Raja Ajaipal *Chauhan*. *Chauhans* dominated Ajmer for many centuries and it was only at the end of the 12th century when the great ruler of Chauhan dynasty Prithviraj was killed by Muhammad Gauri in 1192 AD and Ajmer came into the way of the Turks. After his death, though the Chauhan dynasty ceased to exist in Ajmer but the descendants of this clan established the Chauhan dynasty of Ranthambore. From the beginning of the 13th century, Ajmer saw many upheavals and remained feudatory to Delhi until the later part of the 14th century when it was captured by the ruler of Mewar. In 1509 AD, Ajmer became a bone of contention between the Maharajas of Mewar and Marwar and was ultimately conquered by the Marwar ruler in 1535 AD. In 1559 Ajmer was conquered by the Mughal emperor Akbar and was accorded the status of a full-fledged province. It continued to be in the hands of the Mughals, with occasional revolts, until the later part of the 18th century, when it was ceded to the Marathas. From that time up to 1818, Ajmer faced struggle, being seized at different times by the Mewar and the Marwar from whom it was often retaken by the Marathas. In 1818 the Marathas sold Ajmer to the East India Company. Since then Ajmer has enjoyed stable governance with the Governor-General overseeing *Rajputana* (Chisholom, 2011).

After independence in 1947, Ajmer retained its position as a centrally administered territory. It was eventually merged into Rajasthan State on 1st November 1956 and is now the fifth-largest city of Rajasthan. Due to the political, geographical, and strategic position of Ajmer, vital and important government offices of the state were

opened here, like Rajasthan Public Service Commission (one of the authors Dr.S.S.Rathore is a member of the commission), Board of Revenue, Directorate of Ayurveda, Board of Secondary Education; along with several institutes of Government of India, like Headquarters of the Railway Recruitment Board, Central Board of Secondary Education, Regional Institute of Education, *Rastriya* Military School; and Central University of Rajasthan (HRIDAY website, 2018).

The Population of Ajmer, Pushkar, and Kishangarh was 5,42,321, 21,626 and 1,54,886 respectively, in 2011 (http://censusindia.gov.in/towns/raj_towns.pdf). The climate of the Geopark area can be divided into four seasons; 'Pre-Monsoon', which extends from April to June, is the hottest season, with temperatures ranging from 32° to 48° C; 'Monsoon', which extends from July to September receiving an average rainfall of 551mm; the 'Post monsoon', from October to December with a maximum temperature range between 18° to 20° C; 'Winters' from January to March is the coolest season with temperatures dropping as low as to 4° C.

Geopark area is a prime producer of quartz and a leading producer of feldspar. The other mineral mines are of limestone, marble, granite, asbestos (amphibole variety), wollastonite, garnet, emerald, soapstone, mica, and building stones with a well mechanized *Kayad* silver-rich Pb-Zn mine (Fig. 1; DMG report, 2018; Fareeduddin *et. al.*, 1995 and Mukhopadhyay *et al.*, 2010).

GEOLOGICAL ATTRIBUTES

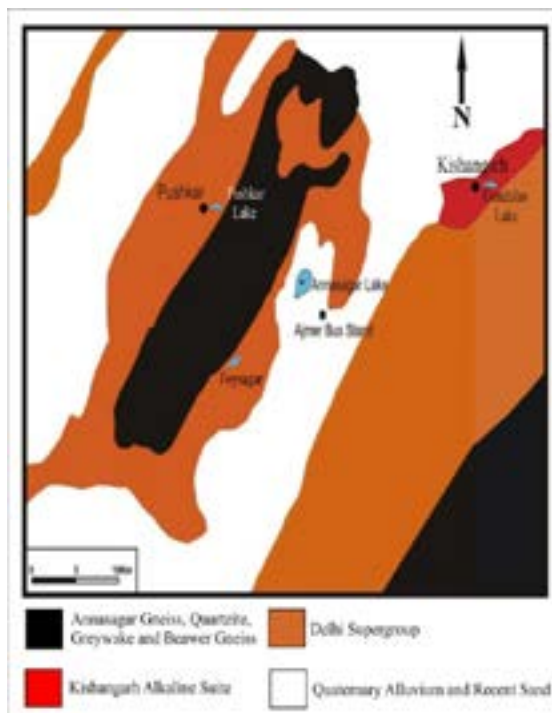
The Geopark area is endowed with spectacular hills, ridges, ranges, and valleys, which are locally named as *Mahabir* hill, *Madar* hill, and *Banri* valley in the north; *Bajaranggarh*, *Taragarh*, *Suliya*, *Bhutiya*, Ajmer valley, and *Taragarh* valley in the east; *Ajaisar*, *Gorikund* and main Ajmer valley in the south; *Kharekari*, *Nag Pahar*, *Parwata Dungari* hills in the western fringes with respect to Ajmer of SDFB. The Kishangarh hills and other hills of the alkaline complex occur in the NE direction from Ajmer (Fig. 2).

Geopark area is represented by the hilly terrain of NE-SW trending South Delhi Fold Belt (SDFB). These hills and ridges mainly belong to Bhilwara Supergroup (>2500 Ma), Delhi Supergroup (2000 Ma to 700 Ma), and *Ana Sagar* migmatites along with concordant and discordant intrusive and extrusive phases of igneous rock. Little outcrops of Bhilwara Supergroup comprise metasedimentary sequences with associated magmatic complex and intrusive igneous rocks forming the basement rocks in the northern part of the Geopark. These are overlaid by *Ana Sagar* migmatites in the Ajmer valley area. Delhi Supergroup is represented by rocks of Alwar and Ajabgarh Groups. Alwar Group in Ajmer is represented by phyllite, calc-gneiss, quartzite, and marble of Srinagar and Naulakha Formations. Ajabgarh Group comprises *Taragarh* quartzite and *Kalyanipura* pilitic rocks designated as Ajmer Formations (Mishra *et al.* 2013). The intrusive and extrusive phases of the Kishangarh alkaline suite mainly intrude in all the above rocks and crops out mainly in the Kishangarh area. These rocks are occasionally intruded by Erinpura granite in the base of *Ana Sagar* (Fig. 2 and 3). Ajmer-Pushkar valley is situated in the northwest direction in the Geopark area. Geologically, it is classified into *Ana Sagar* gneiss and the overlying Ajmer Formation (Fig. 2 and 3). Structurally, Ajmer gneisses and migmatites formed *Ana Sagar* gneiss dome (AGD). It occurs as an elongate rectangular

body enveloped by quartzite. Four phases of folding, three metamorphic zones, and two shearing movements characterize the rocks of AGD. AGD is intruded by granite (1600 Ma) and post-orogenic ultramafic and alkaline rocks (Roy and Jakhar, 2002).



Fig. 2. Geomorphological attribute of the Ajmer Geopark area showing various hill valley, drainage and water bodies.



CHRONOSTRATIGRAPHY		LITHOSTRATIGRAPHY	
EON	SUPER GROUP	GROUP	FORMATIONS AND LITHOLOGY
MESOPROTEROZOIC	Erinpur Sarda Granite (Anasagar Granite)		Anasagar Granite and Pushkar Granite
	Delhi Supergroup	Ajphar Group	Ajmer Formation, Taragarh Quartzite, Kishangarh (Blue Schist and Gneiss)
		Alwar Group	(Sengra and Nohkila Formations), (Quartzite, Pyroxene, Calcite Gneiss and Marble)
	Kishangarh Alkaline Suite		Basalt, Nepheline Syenite
PALEOPROTEROZOIC	Anasagar Migmatite		Anasagar Migmatite Gneiss
	Bhaiswari Supergroup		Mafic Sediments and Intrusive Igneous Rocks
Not to Scale			

Fig. 3. Geological Map of Geopark area. **Fig. 4.** Lithostratigraphy of Geopark area (Modified after Mukhoupdya *et al.* 2010).

A large-scale *Kayad* underground mine of Pb-Zn is situated in the northern part of the Geopark, which is operated by the Vedanta Group. Mining of masonry stone (quartzite), Clay with small marble and granite mines are also there in the Geopark area. The main industries in the area are textile, food products, leather products, wood products, feldspar and quartz grinding, marble processing, and asbestos, cement, plastic, chemicals, and fertilizers. Tourism is also one of the main industry in this area.

GEOHERITAGE OF THE GEOPARK AREA

The local geology discussed above and our fieldwork reveals that twenty-one geoheritage sites can be recognised in Ajmer Geopark (Fig. 5). Based on Ruban, (2010), these geosites can be categorised into five geoheritage types in the proposed Geopark area: geological (eight geosites), geomorphological (one geosite), hydrogeological (five geosites), geo-historical-cultural (five geosites), and archaeological (two geosite). Ajmer Geopark with its variety of geosites of national and regional significance will certainly provide an opportunity to create a more balanced development between geoheritage conservation, public education, and socio-economic development in the region through geotourism.

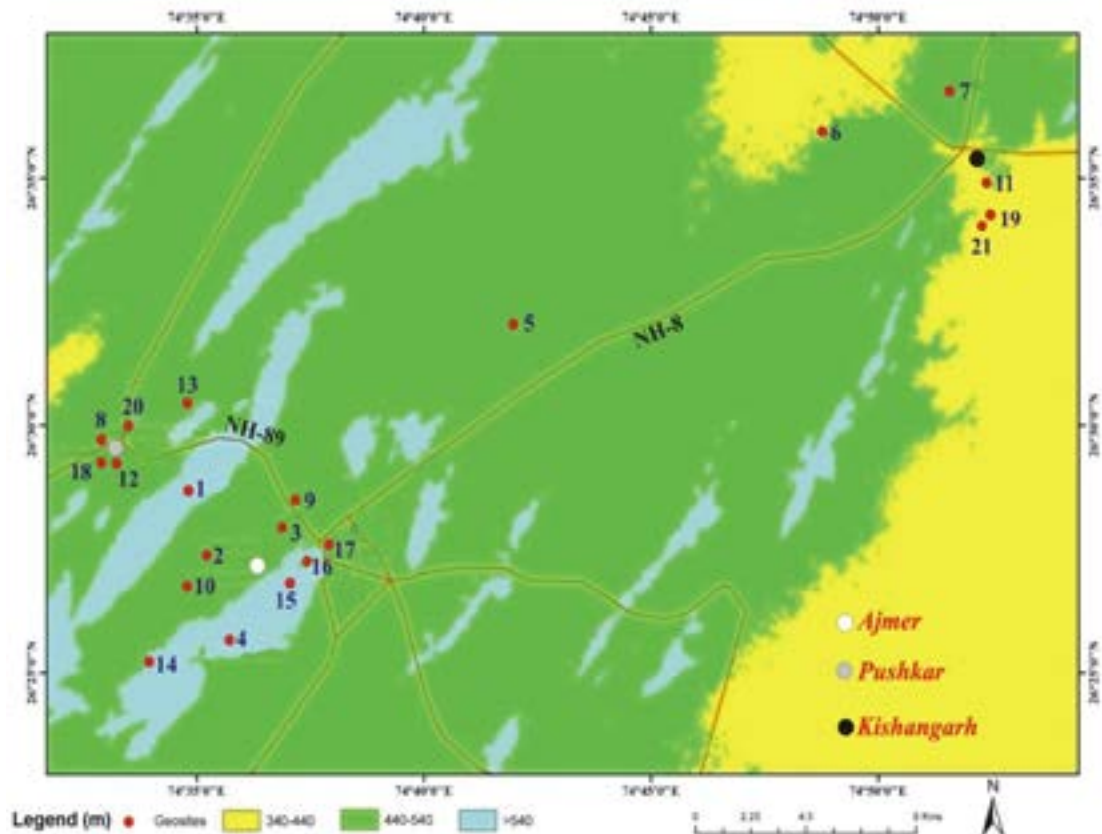


Fig. 5. DEM of the Geopark area showing various geosites (numbering as per text).

A: GEOLOGICAL TYPES

1. Nag Mountain Range or Snake mountain (*Nag Pahar*, Fig. 6)

Nag Mountain is located between Pushkar Lake and Ajmer and is believed that Agastya Muni lived here. Geomorphologically, in the Geopark area, Nag hill is in the east and southwest, the *Parvata* hill in the south, the *Savitri* hill in the southwest,

and *Dungri* hill in the north, forming the Pushkar valley in between them (Fig. 2). The rocks of *Nag* hill mainly constitute the AGD in which the lower plains are occupied by gneisses and quartzite at the top represented by Alwar and Ajabgarh Group of Delhi Super Group, respectively. Many sites in the *Nag* Mountain are showcasing beautiful metamorphic textures and structures. The AGD occupies the lower plains of Ajmer and the eastern part of Pushkar Valley. Geologically, *Nag* hill and *Taragarh* hill are mainly composed of rocks of Ajabgarh and Alwar Group of rocks in which quartzite is dominantly present in both. It is believed that the *Nag Kund* on the *Nag* hill was home to Vatu, Lord Brahma's son who was confined to the hill after he was punished by *Chyavan Rishi* for being a mischief-maker. The attraction, thus, has religious significance and is also famous for trekking and natural walks. Sand hills and dunes occupy the west and north part of the Pushkar valley. Among many small streams and *nalas*, the Saraswati river (local ephemeral river) originates from *Nag Pahar* and Sagarmati river originates from *Pal Bisala* and joins at Govindgarh to form the main Luni River which thus originates from *Nag pahar*.

2. Ajmer valley (Fig. 7)

The valley, in which the city of Ajmer is situated, is a syncline, the core of which is occupied by the Ajabgarh schists. The Taragarh quartzite to the southwest of Ajmer forms the western limb of the syncline. A similar limb of quartzites appears on the eastern side of the valley. Structurally, these form an anticlinal arch over the Ana Sagar Gneiss. The Ana Sagar granite gneiss occupies a wide, low-lying valley and is surrounded by escarpments of the quartzite of Alwar Group dipping away from the granite gneiss, which has been described by Heron as “either a laccolith or a great sill folded into an anticline. Due to erosion, the top of the anticline has been removed leaving behind bold escarpments of quartzite overlooking the valley on all sides except in the northeast (Fig. 2).



Fig. 6. Nag Mountain in background of Ana Sagar.

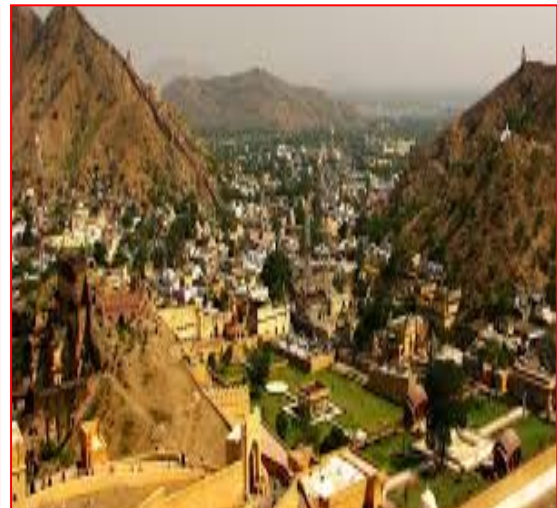


Fig. 7. Ajmer Valley and its settlement.

3. Ana Sagar Gneiss Dome (AGD, Fig. 8 & 9)

The AGD occurs as an elongate rectangular body, enveloped by quartzite of *Nag pahar* and *Taragarh* hills occupying low-lying hills dominantly occur in Ajmer valley (Heron, 1953). Good outcrops near Ana Sagar form a large and spectacular landscape. The hillocks and ridges of AGD are made up of Ana Sagar gneiss and the intervening valleys and are occupied by amphibolites and mica schist. Granite gneisses which occupy the flat land between the eastern and western ridge systems display four

phases of folding. It is similar to the world-fame mantled dome gneiss (Escola, 1949). It is a core of the metamorphic complex and is a thrust related dome. Because of these unique characteristics, AGD is a good educational site for geology students. Ana Sagar gneiss suggests a crystallization age of 1849 ± 8 Ma. (Lopez *et al.* 1996).



Fig. 8. Outcrops of Ana Sagar Gneissic Dome.



Fig. 9. Outcrops of Ana Sagar Gneissic Dome.

4. Taragarh Range (Taragarh Hills, Fig. 10 & 11)

The *Taragarh* range represents the western limb of Ajmer syncline, which is mainly composed of *Taragarh* quartzite. *Taragarh* quartzite forms the high scarps and hillocks and the lower part of *Taragarh* hills are occupied by mica schist and greywacke of Ajabgarh Group. The foothills and plains are occupied by AGD. The *Taragarh* quartzite displays a beautiful variety of ripple marks on the way to *Taragarh* fort. These unique outcrops are spotted on the road going to *Taragarh* fort from Ajmer city and mark significant educational sites in the Geopark.



Fig. 10. Taragarh Hill and rampart of Taragarh Fort.

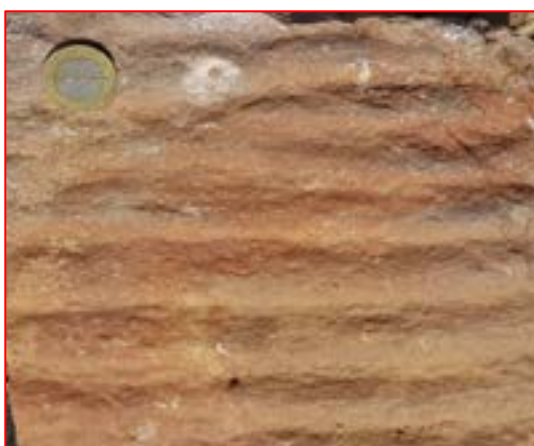


Fig. 11. Ripple Marks in Quartzite at Taragarh Hill.

5. Mining activities in Geopark: Kayad (Fig. 12 & 13)

i. Pb-Zn and associated Ag and Cu deposits are mined out at *Kayad* village situated at about 9 km NNE of Ajmer. The mine was earlier operated by India's largest Pb-Zn mining company i.e. Hindustan Zinc Limited and now by the Vedanta Group. The

deposit is hosted by quartz mica schist and calc silicates of Ajmer Formation of Ajabgarh Group of Delhi Supergroup. These rocks host three main lenses of 250-900 M length and 5-35 M width covering a 480-hectare area with mineralization of Pb (1.17%), Zn (7.23%) with the minor occurrence of chalcopyrite, pyrrhotite, and pyrite. It is a mechanised underground mine and an important centre for the training and education of geology and mining engineering students. Mining is carried out by the decline-stopping method. It has a total reserve of about 9.7 million tonnes of ore contributing to the socio-economy of the area (Zinc News, 2019).

ii. Marble deposits belonging to Ajmer Group are extensively found in the Ajmer and surrounding areas and are quarried at several places. These marble occurrences can be grouped as the eastern belt and western belt. The eastern belt of the area belongs to the Sawar Group of Bhilwara Supergroup and the western marble belt belongs to Ajabgarh Group of Delhi Supergroup. Both are good quality building and decorative stones extensively utilized in the state.

iii. Kishangarh is the largest producer and resource holder of marble in India. Marble City, Kishangarh is one of the largest producers in the world with hundreds of cutting and polishing plants of dimensional stones. The production of dimensional stone accounts for almost 30% of the world's stone and 90% of Indian production indicating huge business and economic activity in the Geopark area.



Fig. 12. Entry of *Kayad* underground Pb-Zn mine.



Fig. 13. Granite Mining in Geopark Area.

6. Nepheline Syenite

Kishangarh National Geological Monument (NGM, Fig. 14)

Kishangarh is situated on NH-8, about 26 km northeast of Ajmer. It is well connected by railway and airways to major cities of India (Fig. 1). Due to the rarity of alkaline rocks in SDFB, the nepheline syenite of Kishangarh was declared as NGM (GSI, 2001; INTACH, 2009). It is a large pluton emplaced along with the core of an antiform of metamorphites of SDFB. NGM outcrops marked by GSI are situated about 500 m after the bypass bifurcation of Kishangarh towards Jaipur on NH-8. This significant outcrops has been destructed to large extent during construction of NH-8 and need urgent conservation. However, its outcrops can be seen upto Gondulao Lake at Kishangarh. The occurrence of nepheline syenite is unique for the reason that there is no such other known occurrence in Rajasthan. Kishangarh syenite has been dated

1590 million years to 1910 million years of age. Its unique outcrops also occur at Harmara along with *Buharu*, *Rampura*, *Chhota-Narena*, and *Tonkra* hills. Nepheline syenite is intrusive in to older rocks (Fig. 4) and occurs in three geological settings: (a) as isolated conformable bodies within the basement of Bhilwara Supergroup at Harmara-Buharu area, (b) as conformable bodies, co-folded with a sequence of metasedimentary and metavolcanic rocks of Aravalli Supergroup at Kishangarh-Mandawaria–Gundalav Lake, and (c) at the base of Delhi quartzite at Tonkra. In Geopark area a massive variety of nepheline syenite is present near Harmara-Buharu area. Petrographically, medium to coarse-grained nepheline syenite of greyish white to bluish in colour composed of K-feldspar, amphibole, biotite, nepheline, garnet, fluorite, and sodalite. Nepheline syenite also traversed by numerous pegmatites and thin feldspathic veins at Kishangarh (Roy and Jakhar, 2002; Abhishek. 2016) are the significant outcrops available for education to students.

7. Marble Dumping Yard (Fig. 15)

It is a huge dumping yard of marble slurry (calcium carbonate). During marble cutting and polishing 70% of the stone is gathered as waste (slurry) and only 30% of marble is recovered. As a result, a huge slurry of marble is produced and dumped near the industrial area of Kishangarh. This dumping resembles the white snow of Kashmir and Switzerland and gives a scenic view to the geosite. The site excellently resembles a vast snow-clad ground. That is why it is a popular location for shooting of films of Bollywood and also pre-wedding shoots. Hence, it has now become a hot tourist destination in Kishangarh. However, huge dumping of marble wastes contaminates the soil which has an adverse effect on the flora and fauna of the region. It has been found that the presence of ultra-fine CaCO_3 can be reused after utilizing some industrial application as discussed by Vaishnav and Sharma (2018). This waste can be used as ultra-fine CaCO_3 in Personal Health and Food Production, Paper, Plastics, Paints, Coatings stained glass and ceramic industries.



Fig. 14. Outcrops of Nephiline Syenite. **Fig. 15.** Marble dump station at Kishangarh.

8. Budha Pushkar Sand Dunes (Fig. 16)

Sand dunes at Budha Pushkar are located about 4.5 km NE of Pushkar. The wind-blown sand invades the plains of Budha Pushkar because of the prevailing winds from SW windows in the Aravalli-Delhi fold belt of the western Thar Desert. A variety of sand dunes include sand sheet, fossils sand dunes, linear dunes, stabilized sand dunes

and are tourist attractions mainly for camel safari similar to the world-famed Sam sand dunes in Jaisalmer (Mathur et al. 2020c).



Fig. 16. *Budha Pushkar Sand Dunes.*

B. HYDROGEOLOGICAL TYPE

9. Ana Sagar Lake (Fig. 17 & 18)

It is a man-made lake built by *Arnoraja*, the grand father of Prithviraj Chauhan, during 1135-1150 CE. It is formed by throwing up an embankment between two hillocks named *Bajranggarh and Khobra-Bhehru* hills (Fig. 2). The lake covers an area of 5.25sq. km with the imposing Mahabir hills in its background. Erinpura granite forms its floor and a number of *nalas* from all directions flow into it. The *Banri* River flowing from the southwest is the longest. The southern side is fringed by steps (*ghats*) and gardens. On the hill, near its weir, stands the circuit house (Residency of AGG during the colonial period). Ana Sagar supplied drinking water to the city of Ajmer before the construction of Foy Sagar (Fig. 2). A Beautiful building of marble with carving is situated on the northern side of the lake known as Daulat Bagh. The beauty of the lake reaches its zenith during winters when migratory birds come to the lake. Recently, under the Smart City project, Marine Drive and Jogger Park were constructed surrounding the lake. Additionally, beautiful palm trees, walkways, and heritage lights here make the place an attractive site for visitors and tourists.



Fig. 17. Walking track and palm trees at *Ana Sagar*.



Fig. 18. *Ana Sagar* with buildings of *Daulat Bagh*.

10. *Foy Sagar* (Fig. 19)

It is situated about eight km SW of *Ana Sagar* in *Banri* valley between the *Nag pahar* and the *Taragarh* ranges. *Banri* river has a dam constructed in the middle of its course to give rise to a lake which is called *Foy Sagar*. It is named after Mr. Foy, a British engineer who designed it and the lake was constructed under his supervision, during the period 1891- 92 by the Municipal Committee of Ajmer as a famine work. It was primarily aimed to supply drinking water to Ajmer city. The over flow of this lake goes to *Ana Sagar* (Fig. 2).

11. *Gundolav Lake* (Fig. 20)

It is situated in the centre of *Kishangarh* town. It was used for drinking water as well as for recreational activities in the olden days. Boating and fish feeding in this Lake are the main attractions for visitors. On the bank of the Lake, beautiful palaces were built which have been converted into hotels and another part is the residence of the royal family. The Physico-chemical and planktonic composition of the Lake reveals that it is tending- fast towards 'eutrophism'. The quality of water is deteriorating day by day due to the inflow of domestic sewage, municipal waste, agricultural runoffs, and effluents of organic waste of animal and human origin into the Lake. Hence, it is in a pathetic condition and requires conservation and protection.



Fig. 19. *Foy Sagar*.



Fig. 20. *Gundolav Lake*, *Kishangarh*.

12. *Pushkar Lake (Fig. 21)*

Pushkar Lake is an important pilgrimage centre in Rajasthan. It is surrounded by the *Dungri* hills in the north, the *Gurumba* hills in the northwest, the *Nag* ranges in the east and southeast, the *Parvata* hills in the south, and the *Savitri* hills in the southwest direction. There are sand hills and dunes in the west and north (Fig. 2). It also receives a few streams of which the biggest one is the *Gori* river flowing from the south. It has great religious importance for *Hindu* pilgrimage.

13. *Budha Pushkar Lake (Fig. 22)*

It is the richest cultural node of Rajasthan. The snake hill (*Nag Hill*) separates it from Ajmer city. *Budha Pushkar* lake occupies the vast valley which is formed between the parallel and high ranges of *Gurumba – Sungiri* and *Naghills* (elevation range of 650-856m) running in southwest and northwest direction respectively. It is considered as one of the most religious places for the holy bath for Hindus.



Fig. 21. *Pushkar Lake and Temples at its bank.*



Fig. 22. *Budha Pushkar Lake.*

Rivers

There are two prominent rivers in the area viz., *Sagarmati* and *Saraswati* Rivers. The *Saraswati* River originates from the southwest part of the *Savitri* hills, while the *Sagarmati* River originates from *Pal Bisala*. Both these rivers in the south-west direction of the Geopark area join at *govindgarh* to form the main Luni River course, the largest River of western Rajasthan (Fig. 2).

C. GEOMORPHOLOGICAL TYPES

At several places, including *Ajaisar* hills and *Sreenagar* hills, the granite is intruded into the gneisses of AGD. The intrusion is structurally controlled, occurring in the hinge of Anticline gives hook-shaped profile. Beautiful various types of folding, faulting, schistosity, cleavages, lineaments, mullions, and boudinage features can be observed which are the main structural elements at this geosite of great educational value.

14. Elephant Shape Sculpture (Fig. 23)

At *Ajaisar* hills near *Ajaipal* and lord *Shiva* temple, there are spectacular landscapes and sculpture shapes in granite like the mouth of *Ganesha* or elephant and many spheroidal and onion shell weathering structures along with pot holes formed due to weathering and erosional processes. Landscape of such shapes has given it religious importance. This place which is developed as the location of the famous *Ganesha* Temple, is also a recreational place of Ajmer city and is also famous for tracking and nature walk for nature-loving groups. The granite outcrops of Geopark areas shows many wind and water erosional structures like pot holes, spheroidal and exfoliation weathering features.

D. GEOHISTORICAL- CULTURAL TYPES

15. Taragarh Fort (Fig. 24)

Taragarh Fort stands on *Taragarh* quartzite ridge at a height of about 395 m on the tar road that goes via Chandra Vardai nagar and Prithvi Raj Chauhan Smarak from Ajmer city. On the way, well-preserved ripple marks can also be observed at several places. *Taragarh* fort was built in 1113 CE by *Ajaipal* of the *Chouhan* dynasty. The fort has immense archaeological and historical importance. It is considered as the oldest hill fort of India. Its outer walls effortlessly merge with quartzite hill ranges and make it extremely difficult to get in. It has a rampart with prominent six gates named-*Laxmi Pol*, *Phuta Darwaza*, *Bada Darwaza*, *Bhawani Pol*, *Mathi Pol*, and *Arcot Darwaza* (gate). It is interesting to note that in the fort area, a number of ponds are situated in which water drained from natural small perennial streams from *Taragarh* hills is accumulated. The fort is accessible through an adventurous ride through a tar road amidst the Happy Valley. A mosque is situated at the top of ridge in the fort. The whole area is now converting into ruins hence, needs cleaning and conservation.



Fig. 23. *Ajaisar*, Elephant sculpture shape.



Fig. 24. Taragarh Fort.

16. *Adhai Din Ka Jhopra* (Fig. 25, 26, 27 & 28)

Adhai Din Ka Jhopra is one of the most noticeable buildings in Ajmer in the context of historical importance. *Adhai Din Ka Jhopra*, was built by *Visaldev* in 1193 CE, is now the finest and the largest example of an ancient Muslim mosque showcasing Indo-Islamic architecture. Earlier, it was a Sanskrit learning college. In 1153 CE, *Pir Panjab Shah* from Punjab stayed here for two and a half days and thus it was named *Adhai Din Ka Jhopra*. Besides *Adhai Din Ka Jhopra*, there are several other very important tourist places like *Soniji ki Nasiya*, *Prithviraj Smarak*, *Pratap Smarak etc.* for the tourists visiting Ajmer.



Fig. 25. *Adhai Din Ka Jhopra*.



Fig. 26. *Soniji Ki Nasiyan* at Ajmer.



Fig. 27. *Prithvi Raj Smarak*, Ajmer.



Fig. 28. *Maharana Pratap Smarak*.

17. *Ajmer Sharif* (Fig. 29)

It is a shrine, considered of importance next only to *Macca/ Madina* in the world. The sacred shrine was built in the early 13th century. It is the final resting place of *sufi saint Khwaja Moinuddin Chisti*, better known as '*Garib Nawaj*'. It attracts millions of visitors and tourists from all over the world. The shrine is situated at the foot of the *Taragarh* hill and separated from the hill only by a water tank, known as *Jhalra* tank.

18. *Brahma and Varaha Temple (Fig. 30, 31 & 32)*

Brahma Temple is a very ancient and important pilgrim center of India situated at Pushkar (Fig. 5). It is the only temple in India which is dedicated to the Creator of the Universe, *Jagatpita Brahma*, built in the 14th century. In 1866 CE, it was re-built using marble and decorated with silver coins. There is also a silver turtle (*Vahan*, the mount of Brahma) on the floor of the temple. The *Shikhar* (top) of the Brahma temple shows many smaller *Shikharas* which enhances the beauty of the temple. Another important temple near Brahma temple is known as *Varaha* Temple having a height of ~45 m. *Varaha* is a rare avatara (incarnation) of Lord *Vishnu*. It was constructed by king *Arnoraja* in the Year-1123-1150 CE. It is built superbly with remarkable architecture consisting of a dome, walls and golden pillars, and hanging eaves of ancient times.



Fig. 29. Ajmer Sharif.



Fig. 30. *Brahma* Temple, Pushkar.



Fig. 31. Carvings and sculptures at *Varaha* Temple.



Fig. 32. Statue of cow at *Varaha* Temple.

19. Kishangarh Fort (Fig. 33 & 34)

Kishangarh Fort, also known as *Roopangarh* Fort, was built in 1649 by *Maharaja Roop Singh*, and is an epitome of the Rajput and Mughal styles of architecture, situated in Kishangarh. The nine turreted fortifications of the fort encompass within it several battlements, jails, granaries, armories, and foundries. Entry to this fort is restricted and is open only for the tourists and guests residing in the adjacent hotel *Phool Mahal* Palace, which is owned by the former ruling family.



Fig. 33. Kishangarh Fort.



Fig. 34. Kishangarh Fort on the Bank of *Gundolav*.

E. ARCHAEOLOGICAL TYPE

20. Sand dunes (Fig. 16)

Budha Pushkar Sand Dunes occur within the inter-hill valleys in the SDFB near *Budha Pushkar* about 10 km northwest of Ajmer. Stratigraphically, yellowish-brown sand dune horizon is aeolian in nature, followed by 1 to 3 m thick calcareous pale brown fine sand having numerous carbonate nodules. The oldest unit is a palaeosol consisting of yellowish-brown fine sand. Budha Pushkar is also known for lenses of detritus that include rolled lower and upper Palaeolithic artefacts and tools which occur in the lower sandsheet of wash debris deposits. These include many objects like cores, burin, and keeled scraper, end scraper, flake, blades, and flakes of Mousterian tradition (Allchin and Goudie, 1978). Based on microliths found within the aeolian units and other archaeological evidence, Agrawal *et al.* (1980) gave 2000 to 4000 years of age, while Singhvi *et al.* (1994), based on the obtained TL dates, have concluded that the dune activity in this part has been confined to two epochs around ca. 25 and ca. 15 ky.

21. Kishangarh Ancient Art Palace (*Bani-Thani* Paintings)

The most famous Kishangarh painting is called Bani-Thani. The Indian government has displayed it on one of its postal stamps. According to folklores, *Bani-Thani* was a beautiful singer who was the love (interest) of *Nagridas*, a famous Artist of the court. Painting's main subject is the lady with anaesthetic use of bright red and blue colours. The natural scenery is also well portrayed in this style of painting where ducks, flamingos, a beautiful pond, and birds are emphatically drawn. The story of the discovery of Kishangarh paintings is quite thrilling. When Eric Dickinson, professor of English literature visited Mayo College, Ajmer in 1943, he was taken to Kishangarh palace to see the collection of paintings. He greatly admired them and some of the paintings he later exhibited at the National Museum, New Delhi. After that, it became famous worldwide and an altogether independent style of painting was recognised as Kishangarh school.



Fig. 35. *Bani Thani* paintings, Kishangarh.

CURRENT STATUS IN TERMS OF PROTECTION AND MANAGEMENT

Most of the historical and cultural geoheritage sites of Geopark are managed by individuals, trusts, and societies. Several hydrological geosites are under Government or religious trusts and are well managed, except for *Foy Sagar* and *Gondulav Lake*. Hence, most of the geosites of Ajmer Geopark are well protected and conserved. Geosites of NGM and hills of nepheline syenite are situated on Government and partially on private land. Due to illegal mining for masonry stone and road construction; these sites are threatened by these anthropological activities. Hence, rare and most significant NGM outcrops of nepheline syenite should be conserved on priority by state and/or central Govt. as it is of great scientific values. These geological sites with NGM after conservation will certainly become popular educational and geotourism sites, specially shape sculpture and Buddha Pushkar dune sites. Most importantly, *Kayad* Pb-Zn underground mine is a remarkable geosite of Ajmer Geopark because it is a centre of training for UG, PG, and research students of Earth Science, and Mining Engineering. Many Universities and institutes conduct their educational tour and training programmes every year and owners provide supporting facilities of boarding and lodging to them. Hence, it has come up as a big educational and training centre in India. Besides this, the majority of tourists visit hilltop temples and the fort have the opportunity for nature sightseeing, adventure and nature walk, hence these geosites have unique geotourism potential to attract tourists. Pushkar is a hub for tourists from abroad and many stay for longer periods and some are even permanently settled here for peace. Creating some necessary infrastructural facilities such as a visitor centre, ticket counter, money exchange counter, a hall, audio commentary facilities, restaurant, souvenir shop, brochures and sign boards (details of NGM, various rocks their features, flora, and fauna) and guides *etc.* will help in the promotion of geotourism in the region. Importantly, all geosites can be easily accessible through tar roads on suggested route maps and this is a positive aspect of the proposed Ajmer Geopark (Fig. 5). However, few geosites which are unclaimed or not under Government management need conservation. In the quartzite terrain, the anthropological activities and rapid urbanization are severely threatening these sites especially outcrops of sedimentary structures in quartzites.

For promotional activities, many videos of tourist and religious geosites of Ajmer, Pushkar, and Kishangarh are available on YouTube, websites of temples of Pushkar with details. Besides this, the unique and representative geosites of Ajmer Geopark satisfies the requirements of UNESCO with its five types of geoheritage of educational, aesthetic, historical, cultural, and geotourism values of national and international significance. Since a majority of historical-cultural geosites are well managed, a legal body should be established to achieve the goal of Geopark. This body may ensure partnerships and involvement of researchers, academic bodies, state Government, and local communities with a firm conservation plan. After fulfilling these criteria along with other aspects, a national body should evaluate it to provide a national Geopark tag to potential sites to be qualified for the UNESCO global Geopark for socio-economic development through geotourism in the region *viz a viz* in India.

CURRENT OR POTENTIAL THREATS AND REMEDIAL MEASURES FOR GEOCONSERVATION OF GEOSITE

Geological and some hydrological geosites outside the management of religious, historical trusts and agencies are poorly managed and are under serious anthropological threats due to local mining activities, rapid urbanisation, and various geological processes. To save these geosites, protected status to these areas can help in mitigation of negative anthropogenic influence on them (Mathur et al. 2020a and b). On the whole, all the twenty-two identified geosites combined into a unified area under the Geopark management system can be a better option for their conservation in the future to promote geotourism for the sustainable development of the region.

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POTENTIAL GEOHERITAGE TOURISM SITES AROUND DEHRADUN

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Nature has gifted its treasure to mankind that was created in many millions to billions of years ago by amazing numbers of activities operating in isolation or group. These treasure - items cannot be recreated by man or existing technologies owing to obvious limitations, such as, time, energy, unbelievable physical, chemical, and biological conditions. Nature's marvel is particularly amazing, if the region has a tectonic turmoil history. Due to expansion in population and economic activities nature's creation are ruthlessly destroyed. Of late, voices are being raised world over about conservation of these natural creations through government and public involvements. To boost their effectiveness several new concepts are contoured related to human-nature interactions viz., social geology, societal geology, rural geology, urban geology, geopark, geotourism, geoarchaeology, geoethics, geoheritage, environmental geosciences, etc. These emerging fields are concerned with protecting nature from ruthless destructions and educating society about long term impact of human actions. Irreversible destructions are easily spotted where natural resources can be readily exploited and Dehradun is one such region where landscape modification is taking place with frantic pace. Dehradun – an intermontane tectonic valley has abundant geological landscapes of international to regional importance. These features may arise public curiosity if maintained properly and their significance highlighted adequately. Some of the significant sites with archaeological, historical, or other significances are discussed in this write-up along with a brief note on the geological setup of the area.

LOCATION OF DEHRADUN

Dehradun (Fig. 1) is interim capital of Uttarakhand state and the city is situated in the center of the lush green picturesque valley, popularly called Doon Valley, on the south of the Himalaya mountain. The valley is located on the southwest corner of the state and is linked by air and surface (both road and rail) with metro and other cities. It is 250 km NNE of the national capital New Delhi. The important towns and cities around Dehradun with approximate distance are Mussoorie (30 km), Rishikesh (44km), Haridwar (55 km), Dakpathar (48 km), Roorkee (70 km), and Saharanpur (70 km).

The arcuate tectonic Himalaya mountain is divided both geologically and geographically. The Outer, Lesser, Higher, and Tethyan Himalaya are geological divisions (Fig. 2) and Assam, Nepal, Kumaun and Punjab Himalaya are geographical terms.

GEOMORPHOLOGICAL SETUP OF THE DOON VALLEY

The rough parallelogram or bow-shaped, longitudinal valley is nearly 70 km long and maximum 25 km wide. To the north of the valley, high rising Lesser Himalayan hills are present while in the south exist dwarf Siwalik hills. The maximum height of these is 3100 and 800 m, respectively. The east and west borders of the valley are drawn by

two mighty, holy, perennial, and turbulent rivers, namely, the Ganga that enters near Rishikesh (340 m) and leaves at Haridwar (300 m) mean sea level (msl), and the Yamuna that enters near Dakpathar and leaves at Paonta Sahib (389 m msl) in Himachal Pradesh. Doon valley is drained by the Suswa/Song and Asan rivers which debouch in the Ganga and Yamuna rivers. The two principal streams have numerous tributaries. The river Rispana, Bandal, Baldi, Kaligad, Bindal are tributaries of the Song river and Nun, Tons, Nimi of the Asan river (Nossin, 1971).



Fig. 1. District map of Dehradun.

GEOLOGICAL SETUP

Geologically heterogeneous rocks form the body fabric of the valley. It is mainly located in the Outer Himalaya and the northern portion of the valley or Mussoorie Ranges is constituted by Lesser Himalaya (Fig. 3). The Late Pleistocene valley floor is made up of Doon Gravels having wedged geometry.

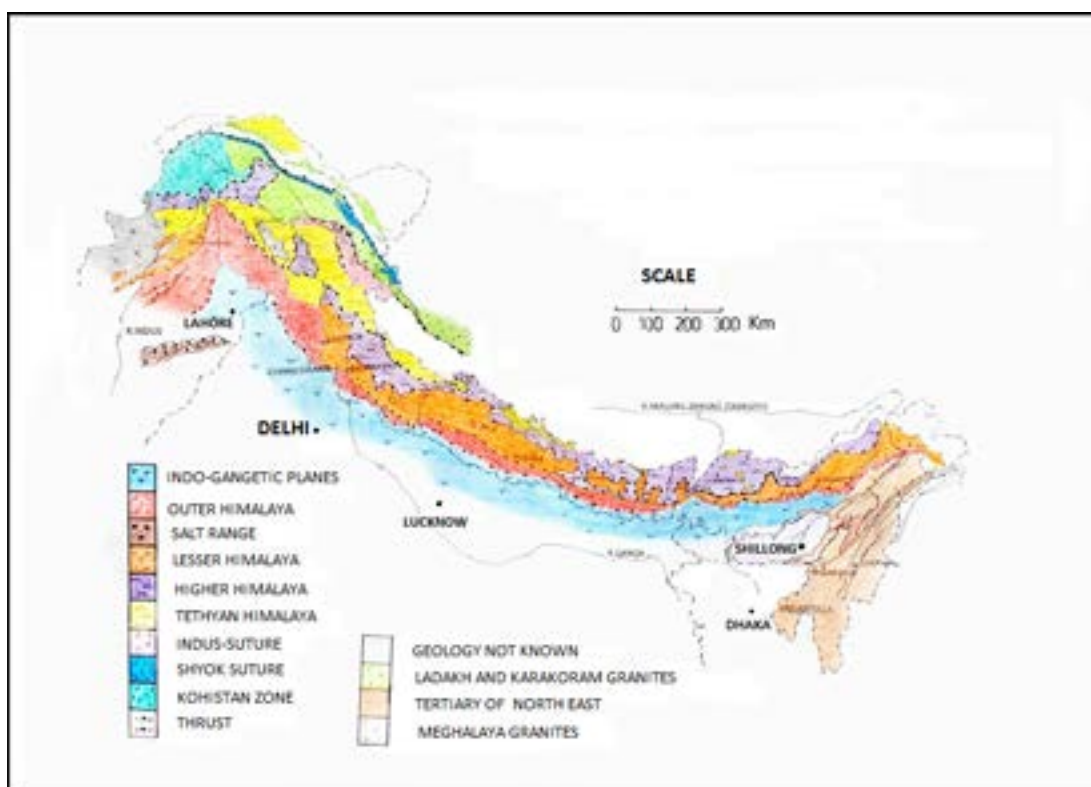


Fig. 2. Tectonic map of Himalaya (drawn by Biyani, Jindal, Dutta and Kaur, 2004).

The broad stratigraphy of the Dehradun district is :

	Recent alluvium	Holocene
	Doon Gravel	Late Pleistocene
Outer Himalaya	Undifferentiated Siwaliks	Neogene
	MBF	
Lesser Himalaya	Amri Nappe	Proterozoic
	Amri Thrust	
Lesser Himalaya	Subathu Fm	Eocene -
	Kakara/Neelkanth Fm	Paleocene
	Unconformity	
	Tal Fm	
	Krol Fm	
	Infra Krol Fm	
	Blaini Fm	
	Nagthat Fm	
Lesser Himalaya	Chandpur Fm	Proterozoic
	Deoban Fm	
	Mandhali Fm	
	Rautgarha Fm	
	Chakrata Fm	

All these formations occur in Dehradun district (Fig. 1). The geological and tectonic map of Doon Valley is shown in Fig. 3. The central part of the valley is occupied almost horizontally bedded Doon Gravels which are fully stratified to loose sediment.

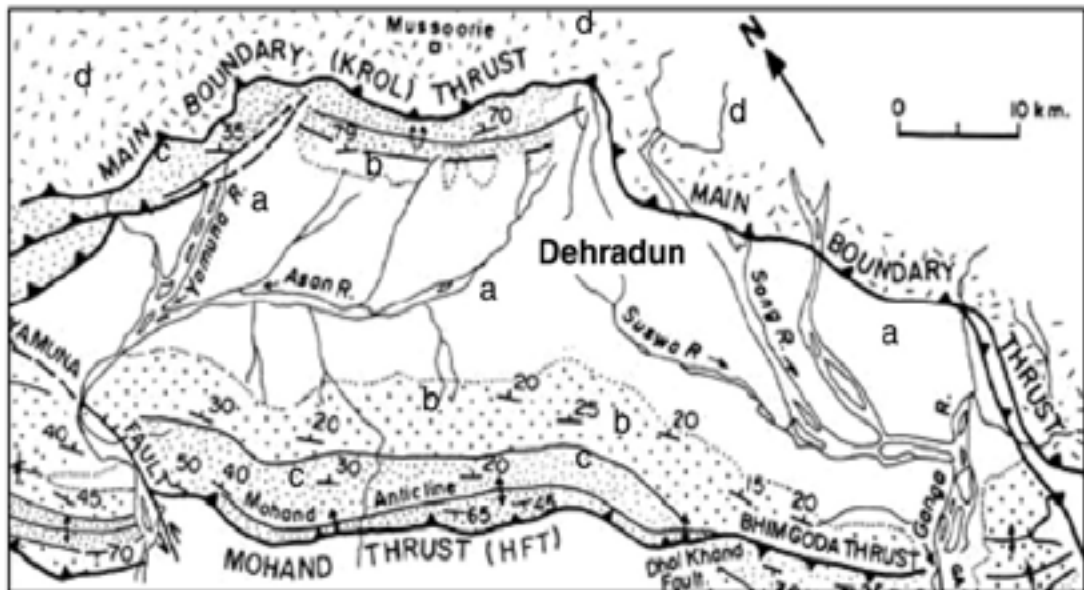


Fig. 3. Geological map of Doon Valley (after Thakur et al. 2007).

Structure and Tectonics of Doon Valley – The Doon Valley is mainly developed in the Outer Himalaya which is the youngest tectonic division of the Himalaya. The Doon Valley and adjoining area are delineated by two longitudinal and two transverse faults (Fig. 3). The southern boundary of the Outer Himalaya with the Indo-Gangetic Plain is drawn by the Main Frontal Thrust (MFT) that runs from Rehna (Badshahibagh) in the west to Mohand to Jwalapur (Haridwar) in the east. The emergent Siwalik against plain is faintly sinuous in the south while in the north, i.e., in Doon Valley sinuosity is moderately pronounced. At the foot of the towering Lesser Himalayan hills, the Main Boundary Fault/Thrust passes in a sinuous way and at places it is dislocated by the younger faults. The eastern boundary of the valley is demarcated by tectonically right-handed Ganga Tear and the western boundary is marked partly by the Yamuna river and left-handed or sinistral Yamuna Tear. The emergence of the Yamuna river in the plain's region is characterised by a re-entrant, i.e., folded Siwalik that takes a concave shape towards foreland or Indo-Gangetic Plain. To the north of the Main Boundary Fault, the Krol and Tal formation form a nearly 35 km long and 15-20 km wide Mussoorie Syncline, while across the Ganga river in the east huge Garhwal Syncline is present which is highly deformed. The Lesser Himalayan sequence is moderately folded. Siwaliks show broad open folds having regional Mohand anticline which is breached by MFT.

GEOHERITAGE IMPORTANCE OF THE AREA AROUND DEHRADUN

The geological, geomorphological, and tectonic setup of the area around Dehradun is highly fascinating owing to the diversity in its geological characters. There are very young Holocene features to billions of years old framework, abundant water, and mineral resources, and breath-taking sculpturing by nature. In a range of 60-70 km, most of the geological features can be studied. However, with increasing population, pressure and upward change in economic conditions, pressure on land is acceleratingly

increasing in this region due to easy approachability and congenial climate and center of State's activities. These factors have caused massive destruction of geological features created by nature over a long period of time. And what is destroyed cannot be reconstructed or recreated. Whatever is best and is of utilities should have been protected. The important Geoheritage sites with Geotourism potential in Dehradun district and near by areas are:

- Sahastradhara
- Robbers cave
- Tapkeshwar temples
- Main Boundary Fault
- Himalayan Frontal Fault
- Precambrian-Cambrian/Krol-Tal boundary, Phosphorite mines,
- Tal valley
- Yamuna Valley
- Chakrata Formation
- Bidhalana window

A brief description of these proposed heritage sites are as follows:

Sahastradhara - This famous tourist spot is situated 17 km from Dehradun on river Baldi, a good place for hill climbing to Mussoorie. The scenic waterfalls, limestone caves, stalactite and stalagmite, sulfur springs, minor rapids are popular attractions for visitors. Geologically, one can study, MBF, brittle fault zone, phyllites, quartzite, black chert/shale, fault zone gypsum mineralization, folds, dolerite dyke, and the core of Mussoorie Syncline.



Fig. 4. Shahastradhara limestone cave having stalactites and stalagmites.



Fig. 5. Sulphur spring in Shahastradhara. Sulphur rich water is coming out from pipes.

Robbers Cave - This very popular picnic spot is located 7 km from Dehradun. It is a 50 ft deep very narrow gorge of 600 m length carved by the perennial Nalota Nala in

consolidated Doon Gravels. The gorge floor has a chain of lukewarm hot water springs which is felt by barefooted walk. In the center of the gorge, a modest cascade of two waterfalls with a plunge pool and stalactite stalagmites and strong conglomerate are present. Geologically it is of regional importance where one can watch Quaternary epiorogenic upliftment.

Tapkeshwar Temple - This famous palace of worship is an extension of Nalota Nala. A stalagmite is worshipped as Shivlinga in the main uplifted caves, where Guru Dronacharya performed tapas or penance. On the way to Tapkeshwar temple, War Memorial Museum, Doon School, and ONGC museums can be visited. Doon Gravels, for about 7 km from Dehradun city continue in Nalota Nala. Stalactites and stalagmites in Doon Gravel or calcareously cemented conglomerate, several epiorogenic upliftments can be counted in the slit-like a vertical gorge.

Main Boundary Fault - This shallow brittle thrust of nearly ten-million-year-old is perceived as intracrustal thrust fault that joins the Outer Himalaya with the Lesser Himalaya and is of international significance owing to its pivotal role in Himalayan upliftment growth and evolution. It is a 2500 km long active fault. It is a brittle fault that makes a 200-300 m wide zone. It can be seen at Shahanshahi Ashram, Judnala, Sahastradhara, Rajpur-Mussoorie road, in Rishikesh, Doonga, near Dakpathar in Yamuna valley. At some places, it is was concealed under road construction.

Himalayan Frontal Fault - This active thrust makes the emergence of Himalayan hills in contact with plain having immense tectonic significance and is well displayed at village Mohand about 29 km from Dehradun, marking the contact between plain and hills comprised of occasionally fossiliferous Middle and Upper Siwalik supergroup (Nakata, 1992, Singh and Jain, 2009 and Thakur, et al. 2007). Here one can observe various fault identification criteria and moving 4 km towards Dehradun, a 15-20 cm thick bituminous coal seam can be seen on the left bank of Mohandrao river. At the southern entrance of the Doon Valley, one can visit Buddhist monasteries in Clement Town.



Fig. 6. Folded and faulted rocks 1 km upstream of Shahastradhara.



Fig. 7. Lakhwar dams site on 800 m thick dolerite sill in Yamuna valley.

Krol-Tal Boundary at Maldeota - The village Maldeota is situated about 14 km from Dehradun in a very wide, faulted origin Song river valley. The Krol-Tal contact is a stratigraphical feature of international significance because it is Precambrian-Cambrian contact. A team of International Stratigraphic midsession came here to assess this place but declined to give type area status. This contact, 2-3 m thick phosphorite bed, had preserved conodonts fossil of phosphatic affinity and have appeared first time in Cambrian. One can see now an abandoned portal of Phosphorite Mines in Bandal river, a tributary of River Song. This was the only underground working mine in Himalayan domain. Another phosphorite mine is located at Durmala village on the way to Mussoorie – Tehri road. On this road trilobite fossils have been reported in black shales and also brachiopods at another place.



Fig. 8. Crushed phyllite/schist in MBT at Shahanshahi Ashram, now concealed under a retaining wall.

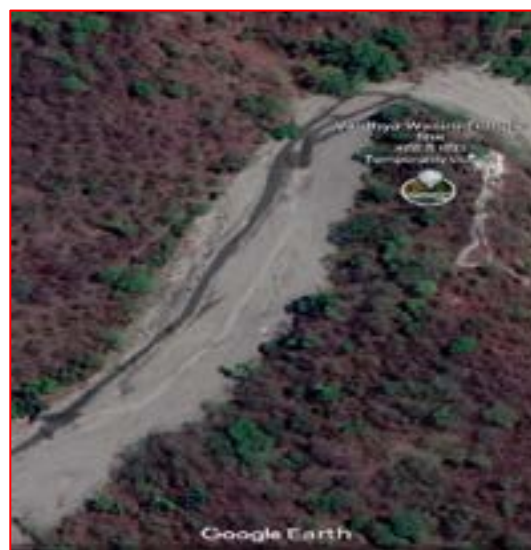


Fig. 9. A Google view of Tal river near Binjvasini temple, Haridwar-Rishikesh.

Tal Valley - This valley is carved by river Tal and is the type locality of famous uppermost Lesser Himalayan Tal Formation of Cambrian age. Tal Valley is situated on the left side across the Ganga Canal between Rishikesh- Haridwar and is at a distance of 70 km from Dehradun and 15 km from Rishikesh. This valley is located in thickly forested Rajaji National Park, an abode of elephants. It is an ideal location for showing students and trainees many geomorphic, structural and tectonic, palaeontological marvels of nature. One can enter the valley from Bhogpur village located on the left bank of the Ganga canal. In this valley, one can see MBF crushed, burnt, and brittle fault zone having small transparent selenite (gypsum, $\text{CaSO}_4 \cdot 2\text{H}_2\text{O}$) crystals, fossiliferous Kakara Formation's bluish grey very hard and compact crystalline limestone, across limestone rain prints, angular unconformity, folded/faulted Tal formation, 50 ft high vertical scarp, fossiliferous marine transgression, Subathu Fm and Amri thrust sheet of micaceous phyllite and hour glass shaped big landslide zone. This valley has a Binjvasini temple on the top of the cliff which attracts devotees round the year. One can take 3 hours uphill walk to famous Neelkanth shrine (Shivlinga formed by stalagmite) from Binjvasini temple site; from there Rishikesh is 25 km by road and 8 km by mule track.

Yamuna Valley- The river Yamuna enters Doon Valley at Dakpathar, where a barrage is constructed across the river in Siwaliks to divert the water in the Yamuna canal. By travelling nearly 10 km along the canal one can visit the historical Paonta Sahib Gurudwara in Himachal Pradesh. Few kilometers from Dakpathar and across Yamuna river, one can see King Ashok's stone edict in Kalsi. Geologically, one can see juxtaposed Krol Thrust and MBF on the right bank of the river, a few kilometers in the upstream direction. Moving 15 km further in the upstream direction one can come to the Lakhwar dam site. Here a massive 800 m wide dolerite dyke is exposed on which foundation of the dam is planned. This is an ideal dam foundation site. Moving nearly 5 km further in the upstream direction, opposite Aglar river valley, a gossan zone is present in crushed quartzite. The brittle Aglar fault is exposed in road cuttings. After crossing the river Yamuna one can reach the famous hill station Mussoorie by travelling 28 km.



Fig. 11. Gossan in brittle fault zone near Yamuna Bridge.



Fig. 10. Folded phyllite in Chandpur FM near Yamuna Bridge, Aglar Valley.



Fig. 12. Polished faulted surface, slickensides, in quartzite near gossan.



Fig. 13. Burnt zone in Lesser Himalaya in MBT zone in Shahanshahi Ashram, Rajpur Road, Dehradun.

Chakrata Formation - This formation is named after a small Chakrata town present 96 km from Dehradun across the Yamuna valley. Here the oldest Lesser Himalayan autochthonous Chakrata Formation is probably of early/middle Precambrian age comprising of impure sandstone and siltstone and shale of flysch origin. It is an ideal place to study deep water sedimentary structures (Valdiya, 1980) and has the potential to become a type area for flysch (Biyani, 2006). One can club Yamuna valley and Chakrata Fm visit in one tour. Guru Shikhar is the highest point (~10000 ft) in this region (10 km from Chakrata) and one can watch from Guru Shikhar the breath taking view of distant snow-clad peaks in a wide spectrum.



Fig. 14. MBT in Tal valley, area is famous for selenite variety of gypsum.



Fig. 15. A view of Aglar Fault Dehradun.

Bidhalana Window - This geological window shows underlying autochthonous Nagthat quartzite in older and tectonically transported Shimla Slate/ Chandpur phyllite. It is named after the Bidhalana river, a tributary of the river Ganga. It is 20 km from Dehradun. This feature is of academic interest only but the place is easily approachable.

FEW SUGGESTIONS

Preservation of geological sites requires urgent attention from the authorities with a legal mandate and people's cooperation. However, it is a fringe priority concern for governmental organizations in the wake of a non-existing sensitization scenario. NGO like Geoheritage should take a formal shape by getting registered and exert itself. Geoheritage may consider the following suggestions:

- ✓ Strive to work for treating the geological heritage as the property of mankind and positive contribution for this is the bounden duty of everyone.
- ✓ Make all geology-related departments of the Central and State governments, colleges and universities, research labs and NGOs to act as voluntary custodians of geological heritage after due identification process.
- ✓ Work for making degrading/destroying of heritage sites punishable offense.
- ✓ Work for the preservation of Geoheritage sites should be part of the curriculum.
- ✓ Digital and print media should regularly educate viewers/readers on Geoheritage issues and the geological community should be vocal and interactive about it. Though awareness generated by the Geoheritage is in the formative stage, sustained campaign would definitely bear fruits.

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JAIPUR, RAJASTHAN - A POTENTIAL GEOPARK OF INDIA

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INTRODUCTION

Proposed Jaipur Geopark covers an area of 33 sq. km and is situated mainly in the old walled city of Jaipur which is popularly known as the Pink City and the City of Victory. Historical and culturally vibrant Jaipur city is the capital city of the Rajasthan state located in northwestern part of India. It was found by *Maharaja Sawai Jai Singh II* in the year 1727 and is known to be one of the oldest well-planned cities of India. Proposed Jaipur Geopark is significantly endowed with the brand of UNESCO'S world heritage city, glorious *Amer Fort* as world Heritage hill Fort along with world's largest *Jantar Mantar*, stone astronomical observatory. Geologically, the hilly terrain of Geopark area represents the oldest fold mountain range of India (part of North Delhi fold belt) with spectacular ground water bodies (Baories) among which the unique Chand Baori is the largest Baori of India. Remarkable palaces, cenotaphs, temples, and museums are constructed by heritage stones showcasing the rich history and culture of Jaipur and representing about 300 year old patronage of our ancestors. All this uniqueness with natural scenic sites and panoramic beauty of Jaipur attracts tourists from all corners of the world. The hilly terrain of rocks of Delhi Supergroup of Alwar sub-basin (except to the south) encircles the Jaipur city in the horse-shoes shaped outcrops. The importance of Jaipur Geopark immensely increases as old Jaipur city has also been selected as one of the heritage cities for Smart City Mission by Govt. of India. Under such a remarkable geological, historical, and cultural scenario with UNESCO brandings, twenty six geosites have been identified representing four geoheritage types of regional, national and international significance (Ruban, 2010 and Brilha, 2016). Accordingly, these are i. Geological, ii. Geomorphological, iii. Hydrogeological, iv. Archaeological type geoheritage. Combination of all these geoheritage types of educational and geotouristic values in one complex type geosite with existing tourism facilities puts the proposed area in a strong position to develop a dynamic and successful potential Jaipur Geopark in India.

LOCATION AND EXTENT OF GEOPARK AREA

Jaipur, the capital of Rajasthan state is located at about 260 km south-west of New Delhi in the north-western part of India. Jaipur Geopark covering an area of 33 sq. km. represents hilly terrain and plains situated to the west of the Great Thar Desert. Jaipur is well connected by rail and air to major Indian cities. Jaipur has an international airport connecting many important cities of the world through New Delhi. Jaipur is also well connected through NH 8 (now part of the express highway) to Delhi - Mumbai and by National Highway 248 (Fig. 1) to major cities of India through Haryana. All the identified geosites are connected with tar roads and are easy to access.



Fig. 1. Google image showing hilly terrain and settlements in the Jaipur Geopark area.

PHYSICAL AND HUMAN GEOGRAPHIC CHARACTERISTICS

Jaipur displays a mosaic of land features: rocky highlands, pediment zone, rocky peneplains, alluvial plains, and Aeolian plains. Rocky High lands feature continuous to discontinuous ridges and hillocks of rocks of Delhi Supergroup representing part of the north Delhi fold belt (NDFB; Fig. 2a and b). Many hillocks are more than 500m in height with *Jaigarh* hillock as the highest peak (648m). The area is also characterized by narrow to wide valleys, numerous small streams, and rivulets. Pediment zone is restricted to a narrow belt that runs along the hill trends comprising of colluvial as

well as dune sands. Alluvial Plains are characterised by a rich assemblage of recent to sub-recent alluvial materials mainly around the *Dravyavati* River. Some Aeolian sand and windblown sands occur around the northern part of the Geopark. In the plain areas, soils are mostly lateritic (red) and arid. All these features constitute the quaternary stratigraphy of the Geopark area.

Till the sixteenth century, the capital of the Jaipur state was *Amer*, which lies at a distance of 11 km from present Jaipur city. The construction of Jaipur city began in 1727 by *Maharaja Jai Singh* and took four years to complete the major roads, offices, and palaces. It is one of the oldest planned cities of India, wonderfully developed adapting the grid method of construction and following the rules of *Vastu Shastra*. The city was divided into nine blocks, out of which two consist of state buildings and palaces, whereas the remaining seven blocks were allotted to the public (Chisholm, 1911; <https://en.wikipedia.org/wiki/Jaipur>). In order to ensure the security of the city, huge fortification walls were built along with seven strong gates. Later, *Maharaja Ram Singh* of Jaipur painted the whole city pink to welcome the Prince of Wales and Queen Victoria in 1876. Subsequently, Lord Albert exclaimed Jaipur to be the 'Pink City', and hence the name. Later on, the city was ruled by several *Rajput* rulers. *Pratap Singh* (1764 - 1803), *Ram Singh II* (1835 - 1880), *Madho Singh II* (1861 - 1922), and *Man Singh II* (1911 - 1949) were among the main rulers who kept the heritage of the city alive. The city was attacked many times by *Marathas*. However Jaipur stayed under the rule of *Rajputs*. Significantly, it was one of the few parts of the country which never came under the rule of the British.

Geopark area of Jaipur has a semi-arid climate. There are three distinct seasons in a year. The winter season lasts from November to February with an average temperature of about 15-18° C with low humidity. December and January are coldest with 5-10°C temperature. Summers (March to June) record an average daily temperature of around 35 to 45°C in which May and June are the hottest. Rest of the months experience rainfall. The city has several industries including cloth, textile, electronics, computers, chemicals, plastics, wood, paper, leather, food, metals, and marble. Jaipur is a hub for gems and metal jewelry, various handicraft items, and camel leather *juttis* (foot wares). Jaipur is 10th among the most populated cities of India with a population of 66, 26,178, as per the 2011 census (<https://en.wikipedia.org/wiki/Jaipur>).

GEOLOGICAL ATTRIBUTES

Hilly terrain around Jaipur represents the southern part of Alwar sub-basin of the NDFB. The BGC, rocks of Aravalli Supergroup and Delhi Supergroup mainly constitute the regional geology of the area (Fig. 2a; Patel, 2018 and Mishra et al., 2020). The rocks of Alwar sub-basin had undergone polyphase deformation and resulted in complex outcrop patterns. The rocks are folded upright to isoclinal shallow to moderate plunging antiforms and complementary synforms trending NNE–SSW. These were subsequently refolded on NW–SE and ENE–WSW axial planes, resulting in axial culminations and depressions. Hilly terrain of the Geopark area is an expression of tectonic activities of the basin represented by four large and bold ridges with two other small hillocks encircling the Jaipur city. Among the four ridges, the first eastern one is *Jhalana* ridge (about 125 km long and 50 km max. width) trending roughly NE-SW; the smaller middle north-eastern one is *Amer* ridge (about 25 km

long and 15km max. width) trending N-S; the third one is largest *Nahargarh* ridge (about 175 km long and 75 km max width) trending roughly NNE-SSW and forth one is *Harmada* ridge (about 112 km long and 11 km max width). Among hillocks, *Bhomia Ji* hillocks in the west and *Moti Dungri* hill in the south-western part together with four ridges are formed horseshoe shaped in which southern part is open plains. The *Jhalana* and *Amer* ridges are separated by a large *Maota* Lake. The *Kanak Vrindawan* and *Amer* valleys are situated between *Jhalana*, *Amer*, and *Nahargarh* ridges (Fig. 2b).

The ridges, valleys, and pediment areas of the Geopark area are geologically belonging to the rocks of Delhi Supergroup. The depositional age of these rocks ranges approximately from 1.7 to 1.5 Ga. The Delhi Supergroup in and around the Geopark area can be classified chronologically into three groups (Sinha Roy et al., 1995):

The Ajabgarh Group (Upper) – Dominated by mica schist, quartzite and phyllite.

The Alwar Group (Middle) – Consisting dominantly of quartzite rocks.

The Raialo Group (Lower) - Consists predominantly of carbonate rocks (marble).

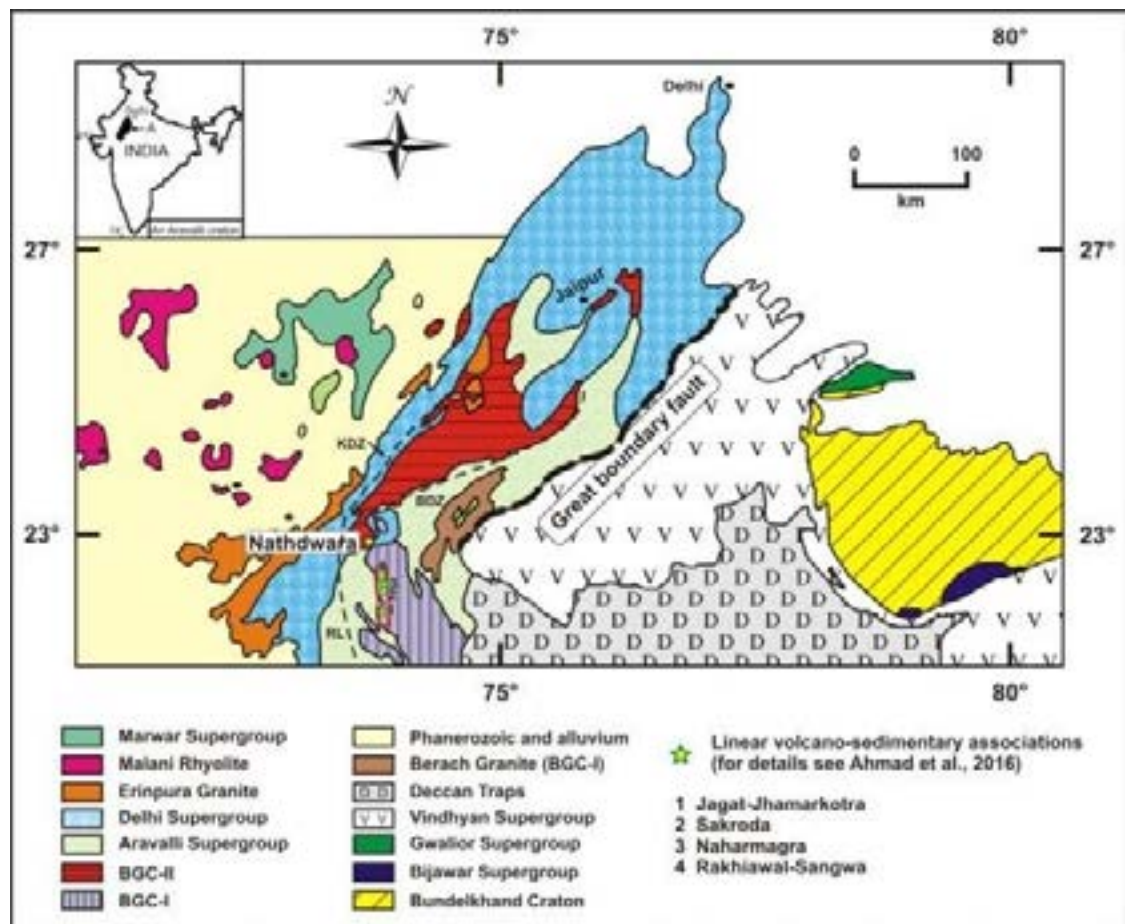


Fig. 2a. Regional geological map of Delhi fold belt (modified from Kaur et al., 2017 and Mishra et al., 2020).

The rocks of these ridges of Geopark area dominantly belonging to Alwar Group with minor occurrences of Raialo Group around Andhi area and outer peripheral areas by Ajabgarh Group at foot hills of *Jhalana* ridge. All the ridges and hillocks are dominantly composed of quartzite with minor occurrences of dolomitic marble, mica

schist and minor conglomerate. Amer and Jaigarh ridges of the Geopark area are dominantly composed of quartzite and their variants. At *Nahargarh* ridge, quartzite at places is interbedded with mica-schist with dips towards east and west. Along the road that goes to *Jaigarh* and *Nahargarh* fort, there is profuse development of ripple marks and some unusual trace fossil like structures may be of biogenic nature in quartzite. Quartzite of all ridges is the metamorphosed products of sedimentary origin and is composed of medium to fine-grained quartz, with minor feldspar and muscovite. It shows the colour variation of white to light pink with reddish to dark brown stains of iron oxides. Thin bands of sheared schistose rocks ranging from a few centimetres to more than 1m in thickness can be seen within the easternmost quartzite hill near the Delhi Bypass road and SE of *Jaigarh* Fort. It is interpreted that these schistose bands represent mylonitic bands produced as a result of slippage along bedding faults during the deformation accompanying folding trends of the NDFB.

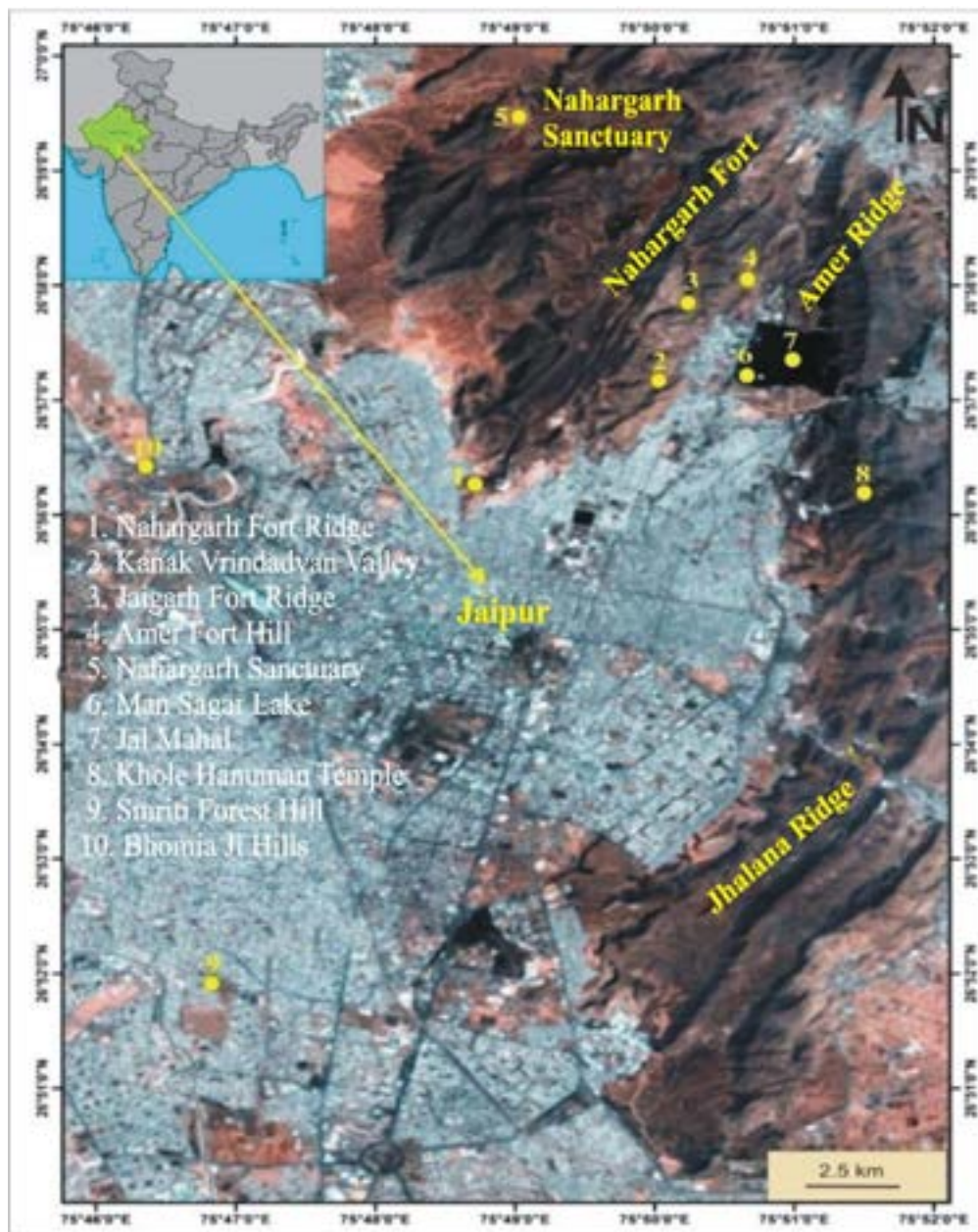


Fig. 2b. Google image showing hilly terrain and geomorphosites of Jaipur Geopark.

Structure

The geological disposition and deformation in ridges of the Geopark area define the major fold where the S0/S1 have a strike of NNE-SSW to NNW-SSE and dip both easterly and westerly, forming a major synformal structure in conformity with the tectonics of the Alwar sub-basin. The beds of quartzite to the east of *Amer* and towards north and east of Jal Mahal show steep westerly dips while beds to the west of *Amer* and *Jal Mahal* show a shallow easterly dip. Thus, the ranges to the east and west of Jal Mahal form the two limbs of an asymmetrical synform. The current bedding in the quartzite on either side of Jal Mahal indicates a normal sequence and hence the major fold can be considered as a syncline. The fold plunges moderately towards SSW. Minor faults are seen in the area within the quartzite of localised nature with minor displacement. A major NE-SW trending fault is inferred west of *Amer* near Man Sagar Lake where a distinct change in the strike of the quartzite band is noticed on either side of the Lake (Sinha Roy et al., 1995). The quartzite is extensively quarried along the dip slopes of the ridges particularly to the east of *Amer* and west of *Sarwa* village. These materials are being used extensively in Jaipur for construction of buildings and roads and destructed many geoheritage elements in them.

GEOHERITAGE OF THE GEOPARK AREA

The above discussed local geology and our field work reveal that thirty-two geoheritage sites can be recognised in Jaipur Geopark (Fig. 3). Based on Ruban, (2010) and Brilha, (2016), these geomorphosites / geosites can be categorised into four geoheritage types: geological (five geosites), geomorphological (two geosite), hydrogeological (thirteen geosites) and archaeological (i.e. geo-historical, nine and geo-cultural type, three). These four types of geoheritage of Jaipur Geopark are of international, national and regional significance. All together, these will provide an opportunity to create a more balanced development between geoheritage conservation, public education and socio-economic development. Present efforts will certainly help in promoting tourism through geotourism in the region. Among these geoheritage sites, twelve other sites (temples, small ponds, palaces, gardens and museum), which are situated in and around the present geosites, additionally increase the aesthetic values of the Geopark.

A. GEOLOGICAL TYPE GEOHERITAGE

1. *Moti Dungri* (Fig. 4)

Moti Dungri Hillock is situated in the heart of the Jaipur city about eight km from Jaipur railway station and ranges in height from 410 to 450m (Fig. 3). This small hillock is composed of grey to brownish colour quartzite of Alwar Group of Delhi Supergroup. It is a popular tourist attraction because of its rocks, natural beauty, fort, palace and famous *Ganesha* temple. The *Ganesha* Temple was built in the year 1761 under the supervision of *Seth Jai Ram Paliwal* at the top of the hillock. The layout and structure of *Moti Dungri* palace conform to the *Nagara* style and is based on the model of Scottish Castle using limestone, quartzite and marble rocks. At the foothill of *Moti Dungri*, a famous *Lakshmi Narayan* temple is constructed by heritage stone marble named and is famously known as *Birla* Temple. All these together impart additional historical and cultural values to this geosite.

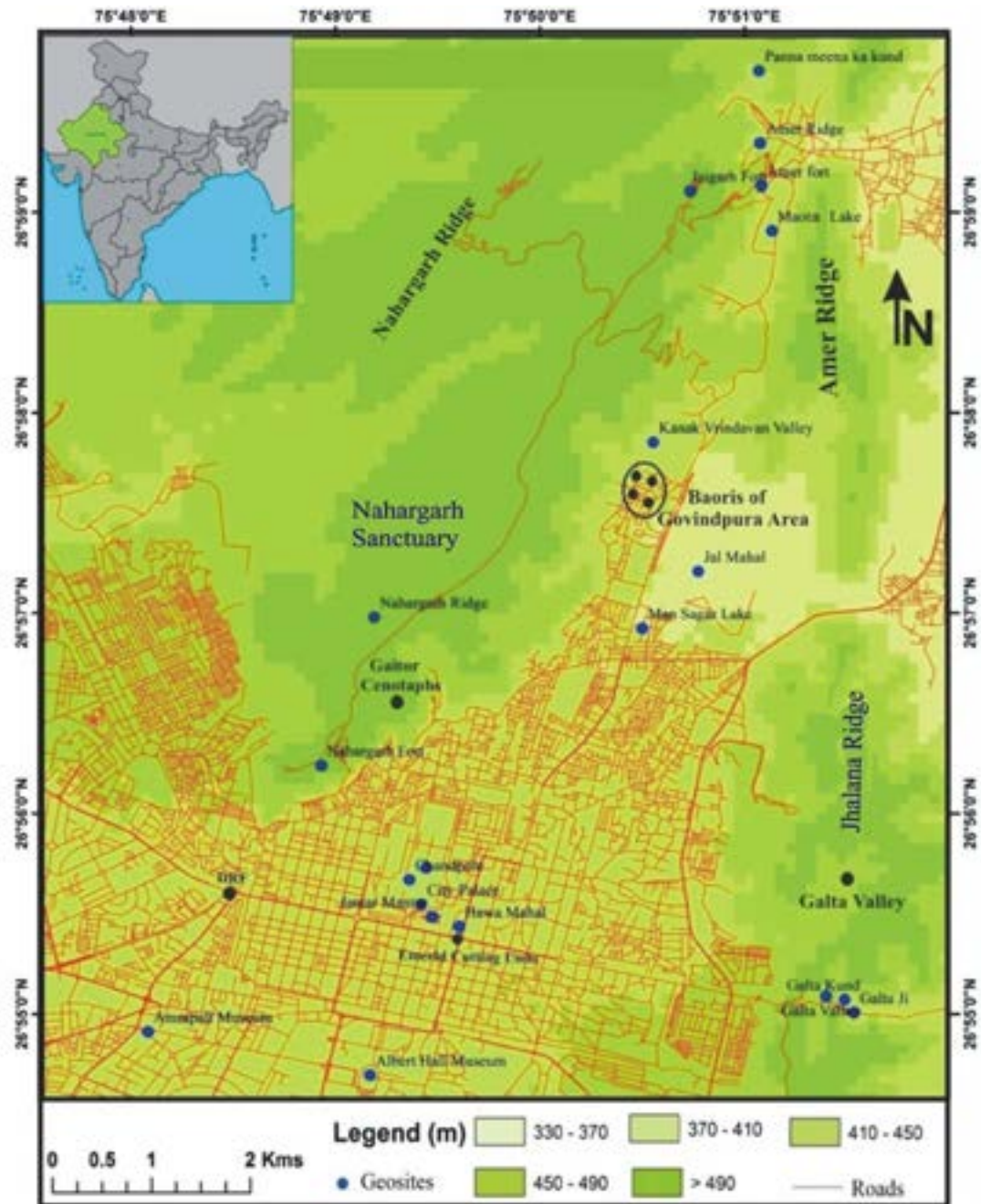


Fig. 3. DEM of the Jaipur Geopark showing various Geosites and Geomorphosites.

2. Nahargarh Ridge (Fig. 5)

Hilly terrain with higher elevations (Jaigarh, 648m) in the northern part of Jaipur is represented by many low to high flat-topped hills constituting the largest *Nahargarh* ridge in the Geopark area. The rocks exposed on this ridge have undergone polyphase deformation and represent the western limb of the main synclinal structure. The ridge is dominantly composed of quartzite of fine to medium-grained nature showing granoblastic texture. Northern part of Nahargarh ridge (7.2 sq. km) is a dense dry deciduous and tropical rain forest area known as *Nahargarh* Sanctuary. One can spot leopards and tigers with many other animals here. A small *Nahargarh* Biological Park houses many animals and other wildlife. Due to erosional processes, the southernmost

tip of *Nahargarh* ridge has acquired the shape of an eagle on which *Nahargarh* fort is situated (Fig. 2b and 3).



Fig. 4. Moti Dungri – Its fort and temple. **Fig. 5.** Nahargarh Ridge and Jaipur city.

3. *Amer* Ridge (Fig. 6)

Amer ridge is located about 11 km from Jaipur on the Jaipur - Delhi National Highway. It is represented by many forested hills and hillocks with 370 to 450m height promontory that juts into *Maota* Lake. *Amer* ridge is dominantly composed of quartzite of Alwar Group. Quartzite rocks on the ridge represent the eastern limb of the main synclinal structure of Jaipur. A thick unit of mica schist is exposed interbedded with quartzite in the eastern most hillocks near the Delhi Bypass road showing the development of foliation, schistose and lineation structures. Quartzite exposed in the area is being extensively quarried near *Amer* and west of *Sarwa* village.

4. *Andhi* Marble Mine (Fig. 7)

Andhi marble mine area is located at *Andhi - Jamwa - Ramgarh* areas about 27 km from Jaipur city on Jaipur Alwar road covering about 254 hectares with reserves more than adequate to last next 100 years. *Andhi* marble is dolomitic in nature and belongs to Railo Group. The outcrops of marble mainly occur along the north-eastern periphery of *Jhalana* ridge. Beautiful white colour marble is crystalline and granular in nature and is mainly composed of calcite and dolomite. The area is also known for good processing facilities which make it the “Integrated Marble House of India”.

5. Stone industries (The Trading Powerhouse of the Geopark area) (Fig. 8)

Besides processing industries of world heritage marble stone, the proposed Geopark area is also famous for gemstone and jewellery industries. Existence of the stone industries dates back to the early 1700’s when the Jaipur city was founded by *Jai Singh II* of *Amer*. During this period, great importance was placed on bringing in top craftsmen, including jewellers, to create fine products of precious stones for the royal family and to make the city a leading centre for producing fine-quality luxury stony products. As a result, Jaipur now combines traditional colour gemstone cutting and jewellery manufacturing hub and artisans with the most modern techniques. Jaipur is India’s second gem and jewellery exporting centre and tops in sales to foreign tourists. Around 90% of the world-wide emeralds are cut and processed and around 95% of small diamonds are processed in Jaipur for global consumption with precious and semi-precious gems make the Geopark area the main centre of economy in the world.

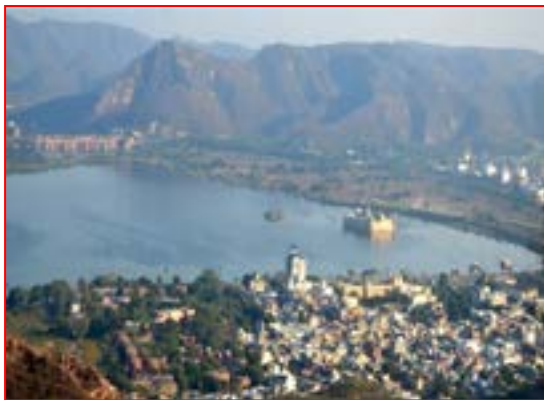


Fig. 6. Amer Ridge and Man Sagar Lake.



Fig. 7. Andhi Marble.



Fig. 8. The stone industry of Jaipur.



Fig. 9. Galta valley, palaces and Galta pond.

B. GEOMORPHOLOGICAL TYPE GEOHERITAGE

1. Galta valley (Fig. 9)

Galta valley is surrounded by 370 to 490m high series of hills in a ring outline of rocks of NDFB. Dominantly, these hillocks are composed of quartzite of *Jhalana* ridge (Fig. 2b). *Galta* valley, with its enormous natural beauty, is endowed with a small Lake, dense forest, famous Sun Temple, and *Chour* Palace which provide additional cultural and historical values to the valley. A natural spring emerges high on the hill (about 500m), and flows downward filling two ancient Baories and a series of sacred seven ponds (groundwater bodies) making this valley a combination of very important geological, cultural and religious place in Jaipur. *Galta* pond is the holiest which never goes dry because through *gaumukh* (paleo- conduit) water flows continuously even in summers showcasing the knowledge of our ancestors. Monkeys are seen everywhere in this valley. Therefore it is also known as monkey valley.

2. Kanak Vrindavan Valley (Fig. 10)

It is located between Nahargarh and Amer ridge, half a km from Govindpura on the way to Amer Fort. *Kanak Vrindavan* valley complex is dominantly surrounded by quartzite hills endowed with the lush green forest and temples constructed by red sandstone. The temples were built around 275 years ago by Maharaja Jai Singh. The hilly terrain of this valley is locally known as *Lakshman Dungri* having another *Govind Devji* temple and famous *Khole Ke Hanuman Ji* Temple located in the south-western direction on *Jhalana* ridge (Fig. 2b). Valley's layout has been given a blend of *Mughal* and *Rajput* architecture and is divided into eight sections with a series of fountains of marble, intricate '*chhatris*' (cenotaphs), exquisite buildings

with 'jali' (stone network carving) providing additional cultural values to the *Kanak Vrindavan* valley geosite (Fig. 2b).

C. HYDROGEOLOGICAL TYPE GEOHERITAGE

1. *Ramgarh Lake* (Fig. 11)

It is a naturally turned artificial Lake, situated near *Jamwa Ramgarh* village located about 25 km north-east of Jaipur. It covers 15.5 sq. km. area with nearly 4 km in length and 2 km in width. The Lake is surrounded dominantly by low to high ridges and hillocks of quartzite of Alwar Group. Opposite to the gate of the Lake, at the foot hill of quartzite section, there is excellent preservation of many types of sedimentary structures among which ripple marks are dominant and well preserved. Earlier, the Lake was the main source of water supply to Jaipur city and was a popular picnic spot, particularly after the rowing events held here in 1982 during the Asian Games. At the same time, the dense forest surrounding the Lake and the nearby area was declared as a wildlife sanctuary by the Government of India. Subsequently, during the next three decades, the water body has degraded due to negligence, pollution and encroachments. Rajasthan High Court in 2011 had ordered the district administration to clean and remove encroachments. This order helped in renovating and reviving the Lake to some extent. There are ruins of an old fort and temple of *Jamwa Mata* which reveal the glorious history of Lake and surroundings.



Fig. 10. *Kanak Vrindavan* valley and temple. **Fig. 11.** *Ramgarh Lake*.

2. *Dravyavati River Front* (Fig. 12)

Earlier, known as *Amanishah Nala*, it originates from the western slope of Amer Ridge near *Jaisalya* village is now an important hydrogeological site of Jaipur. It flows through the Jaipur city over a length of 42 km collecting storm and waste water from *Naharika*, *Ambabari*, *Ganda Nala* to finally join the *Dhund* River. Looking to its degraded conditions, Govt. of Rajasthan in 2015 started renovation work with the construction of 85 check dams and 122 fall structures to name it as Dravyavati River Front (DRF). Under this work, three mega parks with thousands of species of plants, exhibition centers and audio-video rooms were built near *Shipra Path*, *Bambala Bridge* and *Pani Pech* along with 40 washrooms. With these efforts and development works, the glory of the River returned and now it is an art and cultural hub with several shops, open amphitheatres, cycling track with a walkway for jogging, smart polls with Wi-Fi, LED lights, CCTVs and environmental monitoring systems (Report of Ministry of Environment, 2015). This project proved to be a big river rejuvenation project which converts it into a riverine geomorphosites of modern time.

3. Man Sagar Lake (Fig. 13)

It is a natural cum artificial Lake named after *Maharaja Man Singh* who constructed it by damming the River *Dravyavati* almost at the junction of hilly areas of *Nahargarh*, *Amer* and *Jhalana* ridges (Fig. 2b). Initially, the dam was constructed using local quartzite across the eastern hilly terrain of Amer hills. Jal Mahal is situated in the middle of the blue water Lake. It has a water spread area of 300 acres and is surrounded by the rocks of NDFB on the north, west and eastern sides. On the southern side, 300m long and 30m wide dam has been constructed with an outlet for irrigation system. The catchment area of the Lake is 24 sq. km contributed by surrounding hilly terrain (Report on Man Sagar Lake, 2015). Two large streams drained water from *Nahargarh* and *Amer* ridge and brought in untreated sewage and sediment run-offs which polluted the Lake. Reserve forest area of the Lake catchment has several wildlife species such as deer, jungle cat, striped hyena, Indian fox, wild boar and leopards. Beautiful *Jal Mahal* in middle of the Lake, dam embankment, a curved road with greenery, impart spectacular look to make this site as an important tourist attraction of Jaipur.



Fig. 12. Dravyavati River Front.



Fig. 13. Man Sagar Lake and Jal Mahal.

4. Maota Lake (Fig. 14)

Below the superb *Amer* fort, lies the *Maota* Lake (*Mahavata* Lake) which swathes the pink city in its allure in the monsoons giving the residents and tourists a chance to capture this absolute visual delight. *Maota* Lake is located about 11km from Jaipur. The Lake collects rainwater flowing down from the nearby hills and *Amer* fort ridge. It was the main source of water for the *Amer* Fort and the common people of old *Amer* town. The Lake contains an island in the center known as *Kesar Kyari Bagh* or saffron garden. Another garden, the *Dil-Aaram Bagh* is situated on the northern end of the lake. These together make this site a most spectacular tourist place of Jaipur.

5. Chand Baori (Fig. 15)

Chand Baori situated in *Abhaneri* (*Abha nagri*), near Jaipur was built during the 9th century by the *Chauhan* ruler named *Raja Chanda of Nikumbha* dynasty. Visually spectacular, it is considered as the oldest, deepest and biggest step well in the world. This remarkable structure is square in shape having 13 stories and is 19.5m deep with a temple on one side, and the main gate is located in north. The northern side consist of a multi-storeyed corridor supported on pillars and two projecting balconies enshrining beautiful images of goddess *Mahishasurmardini* and Lord *Ganesha*. It has 3500 steps which are criss-crossed with double flights on three sides while the fourth side boasts of a pavilion with beautifully carved *jharokhas* (windows) and galleries supported by pillars and two projecting balconies. These civil engineering structures, with beautiful sculptures of the magnificent architecture of old patronage of the city,

not only make it a famous tourist place but also an important cultural and religious place of Jaipur. Presently, it is a famous film shooting location for the world (Singh et al., 2019).



Fig. 14. *Maota Lake and Amer Fort.*



Fig. 15. *Chand Baori.*

6. Panna Meena Ki Baori (Fig. 16)

The amazing ancient yellow colored step well complex of *Panna Meena Ki Baori* is situated on the Jaipur - Amer road towards the north foot hills of *Amer* ridge. It was constructed by Jai Singh in 16th century and is named after *Panna Miah*. It is an eight storied octagonal-shaped magnificent step well. The symmetrical arrangement of criss-cross manner stairs in all four sides with a room on its northern wall imparts a spectacular look to this step well. The recessed doorways and the octagonal gazebos represent the engineering and architectural marvel of old patronage of the city (Singh et al., 2019).

7. Baories of Govindpura area

a. Parshu Ram Baori (Fig. 17)

It is located in Govindpura area on the Jaipur - Amer road on the opposite side of *Jal Mahal*. The *Baori* is situated in the large historical complex housing a famous *Parshu Ram* temple. This temple is very famous in Jaipur having great religious values. *Parshu Ram* Baori is a small rectangular ground water body with beautiful symmetrically arranged steps with terrace on all the four sides. The *Baori* is constructed by sandstone having lush green trees all around, imparting a beautiful look to this geosite - like swimming pool of modern days.



Fig. 16. *Panna Meena ki Baori.*



Fig. 17. *Parshu Ram Baori.*

b. Kale Hanuman Baori (Fig. 18)

It is located near *Parshuram Baori* just opposite *Jal Mahal* near the famous *Kale Hanuman* temple. At the entrance of this *Baori*, a beautiful, three arch-shaped gateway with many small carved arches impart a beautiful look to this *Baori*. From the gate, steps are on one side while other three sides have several arched verandas; the top floor has balcony - like terrace bounded by carved *jalties* of sandstone. All these features impart a heritage look to this groundwater body.

c. Cheela Baori (Fig. 19)

Cheela Baori is located inside Govindpura area near the road that goes to *Amer*. It is an open linear structure with about 10m in length and 5m in width. It is situated at the foot hills of *Amer* ridge surrounded by several houses. It has almost dried up and is degrading very fast as the locals use it as a dustbin. It has two beautiful levels with three gateways, each of which has arched pillars and many steps of sandstone which impart a beautiful look to it.

**Fig. 18.** Kale Hanuman Baori.**Fig. 19.** Cheela Baori.**d. Naku Baori (Fig. 20)**

It is located near *Cheela Baori* inside Govindpura area near the road which goes to *Amer*. It is also an open structure having three levels. Each level has arched pillars and few steps of sandstone. This *Baori* has almost dried, its steps are broken and the whole structure is degrading very fast. Renovation work has been taken up to revive it because it is an important place for rituals for local people.

e. Mahadev Baori (Fig. 21)

It is located inside Govindpura area near *Naku Baori* on the road that goes to *Amer*. This beautiful *Baori* has three floors, each floor has three arches having steps on one side which are broken at many places. The northern side consists of multi-storeyed pavilions supported on arches, pillars and two projecting balconies, imparting a spectacular view to the *Baori*. On the top floor, a balcony is constructed with beautifully carved sandstone to have a Panoramic view of *Amer* hills. Presently, it is in a pathetic condition and needs urgent renovation.

f. Rukmani Baori (Fig. 22)

It is located in Govindpura area on the Jaipur - *Amer* road. This *Baori* is in good condition having a single floor with an arched gate constructed by carved sandstone. It is a compact structure and well protected by walls from all sides. The top steps take you down to the terrace from a small gate. All step-wells (groundwater bodies) of

Govindpura area showcasing water conservation and water harvesting systems are undoubtedly the heritage structures of old times that have fallen into disuse with the time. However, to preserve their heritage look and values, and also to revive these ancient water conservation systems, the Govt. of Rajasthan renovated all *Baoris* in the year 2016 under *Jal Swavlamban* scheme (Singh et al., 2019).



Fig. 20. *Naku Baori.*



Fig. 21. *Mahadev Baori.*

D. ARCHAEOLOGICAL GEOHERITAGE

The historical and cultural sites which are constructed by rocks are considered as geo-monumental geosite of archaeological geoheritage types. These geosites played a subordinate role in the promotion of geotourism in the Geopark area by imparting additional cultural and historical values (Brilha, 2016). Jaipur Geopark has many such sites that can be classified into two categories: a. Geo-historical and b. Geo-cultural. The monumental type sites are similar to geo-monumental geosites of *Sanriku* shrine of *Sanriku* Geopark, Japan.

a. Geo-historical Type Monuments:

1. Amer Fort (Fig. 23)

Amer Fort is situated on *Amer* ridge about eleven km from Jaipur railway station on National Highway that goes to Delhi. It was originally built by the *Meena* ruler in the ninth century. Later on, it was built over the remnants of the earlier structure during the reign of Man Singh in the sixteenth century and expanded by his descendant, Jai Singh I in the eighteenth century. Palaces and buildings of the fort are constructed by red sandstone and marble, influenced by *Mughal* architecture. Large ramparts, series of large gates, four courtyards, attractive opulent palaces with four levels, and large *Jalebi Chowk* (ground) make it a massive and magnificent old civil engineering structure. A lush green garden with a hexagonal design was built on high platforms in the third courtyard. Looking to its glorious history, architecture, and planned civil engineering work, it was declared as UNESCO'S World Heritage fort in 2013 during the 37th session of the World Heritage Committee held at Phnom Penh, Cambodia.

2. Nahargarh Fort (Fig. 24)

Nahargarh Fort stands on the southern edge of *Cheel ka Teela* (Hill of Eagles) of Nahargarh ridge (abode of tigers). Situated about 18 km from Jaipur it is a monumental edifice of Jaipur built in the year 1734 by *Maharaja Madho Singh*. It consists of a huge gate, two temples, beautiful palaces, *Diwan-I-Aam*, *Madhavendra* palace, *Sheesh Mahal* (Glass Palace) and an open-air enclosure displaying

remarkable European, *Mughal*, and *Rajput* architecture. Another palace is utilized to house a wax museum having a life-like replica of many national heroes. There is an extended wall which connects it to *Jaigarh* Fort. Surrounding hills of the fort also significantly endorse a rare combination of three ecosystems - Aravalli Ecosystem, Desert Ecosystem, and Wetland Ecosystem named as *Nahargarh* Sanctuary and biological Park. The biological park houses Asian lions, Bengal Tiger, Leopard, Indian Wolf, Striped Hyena, Jackals, Wild Boar, Indian Gharial, Himalayan Black Bear, and Sloth Bear and is also famous for safari and adventure tours.



Fig. 22. *Rukmani Baori.*



Fig. 23. *Amer Fort.*

3. Jaigarh Fort (Fig. 25)

Jaigarh Fort (Victory Fort) is located 10 km from Jaipur at *Jaigarh* hill. It is a grand structure perched on the top of one of the highest hillocks of *Nahargarh* ridge. It was built by *Jai Singh II* in 1726 to protect the Amer Fort. The beautiful palaces were designed by Mr. Vidyadhar, a famous architect of the old time. The fort premises have a length of three km along the north-south direction and a width of one kilometre. It was constructed 400 m above the Amer Fort. The fort is highly fortified with thick walls of red sandstone. In this massive civil structure, there are two beautiful palaces, two temples and a central watch tower which impart a royal look to the fort. It is a famous tourist place of Jaipur and also a favourite place for nature walk groups.



Fig. 24. *Nahargarh hill and Fort.*



Fig. 25. *Jaigarh hill and Fort.*

4. City Palace complex (Fig. 26)

The city palace complex was constructed with the establishment of Jaipur by *Jai Singh II* in 1727. Initially, the city palace was the ceremonial and administrative place of the Maharaja of Jaipur. This heritage monument boasts a blend of *Mughal*, European and *Rajput* architecture which resulted in a magnificent building. The complex is also the location of religious and cultural buildings as well as a patron of arts, commerce and industries. It now partly houses a museum named as *Man Singh* museum and the other part continues to be the home of the royal family. Other palaces in the complex include the *Chandra Mahal* and *Mubarak Mahal* along with various other buildings like Lile museum, the famous *Govind Dev* temple of great religious significance and a library. On display at the City Palace Museum are rare manuscripts, *Mughal* and *Rajasthani* miniature arts, weapons and antique items used by the royal family earlier.

5. Royal Gaitor Cenotaphs (Fig. 27)

Royal Gaitor (means resting place of the departed souls) is a magnificent walled funerary complex of the royal family situated in a beautiful small valley surrounded by quartzite hills of Nahargarh ridge. It is constructed of white marble with a majestic appearance reflecting typical *Rajput* and *Mughal* style of architecture. There are three sets of different marble cenotaphs with well carved tombs. Gleaming domed pavilions make them a real hidden gem of architectural beauty and craftsmanship. Ample greenery, small valley and hilly terrain make the environment of this place a calm, cool and peaceful site of Jaipur.



Fig. 26. City Palace.



Fig. 27. Gaitor Cenotaphs.

6. Jal Mahal, or Water Palace (Fig. 13 and 28)

The splendid *Jal Mahal* is situated in the centre of the *Man Sagar Lake*. It is an architectural beauty of the *Rajput* style with a five storied palace of red sandstone. The top floor is exposed having rectangular four cenotaphs (*Chhatris*) on each corner erected over cremation platforms of some of the *Kachhwaha* rulers of Jaipur. Because of water logging, the palace had suffered subsidence in the past and also partial seepage which has been repaired under a restoration project of the Government of Rajasthan in 2003. Under this project, a convention centre, art gallery, multiplex, entertainment centre, arts and craft village, hotels, restaurants, food courts, and

gardens at bank of the Lake were developed and it is now the most attractive tourist place of Jaipur.

7. *Chand Pole* or Moon Gate (Fig. 29)

Almost three centuries old *Chandpole* offers spectacular views of the world famous old pink market and glimpses of the Rajasthani culture in the walled city of Jaipur. Besides the plethora of palaces, forts, lakes and Baories, the Geopark area is also the ultimate shopping paradise of India. The *Chandpole* market is most famous because of its alluring Rajasthani quintessential products including textiles, handicrafts, brass works and precious stones. The market is architecturally and symmetrically developed having shops with a *verandahs* on both sides stretched up to *Choti Chopar*. *Johari Bazaar* (jewellery Market) inside *Chand pole* is one of the oldest markets known for its vibrant ambiance, premium quality gemstones, jewellery of gold, silver, diamonds, emeralds and rubies. Adjoining *Bapu Bazaar* is mainly famous for leather items and *Mojari* (footwear of camel leather) with Rajasthani *sarees* and *lehengas*, perfumes, metal, sandstone and marble handicrafts items.



Fig. 28. *Jal Mahal*.



Fig. 29. *Chand Pole*.

8. *Hawa Mahal* (Fig. 30)

Pink coloured *Hawa Mahal* (Palace of Winds) is situated near the city palace inside the walled Jaipur city. It was built by *Maharaja Pratap Singh* in 1799. The purpose of this intricately carved five-storied pyramidal shaped monument of sandstone with 953 small windows was to allow women from royal families to observe the processions (especially world fame *Gangaur* festival) passing through the road below. Among the five floors, the top three floors have the width of a single room while the first and second floors have patios in front of them. The front elevation is like a honeycomb with small portholes. Each porthole has miniature windows and carved sandstone grills, finials and domes with decorated *Jharokhas*. Intricate lattice work make it a beautiful historical and culturally magnificent edifice.

9. *Jantar Mantar* (Fig. 31)

Jantar Mantar, the largest stone astronomical observatory in the world is situated just near the city palace in Jaipur. It was built by *Sawai Jai Singh* in the year 1734. Covering about 18,700 sq. m area, *Jantar Mantar* is an old patronage of Jaipur with the brand of UNESCO World Heritage site. It is still in operational condition and built remarkably by sandstone and marble. Bronze tablets, bricks and mortar were employed to make its instruments. The monumental instruments are operating in three main classical celestial coordinate systems: the horizon-zenith local system, the equatorial system, and the ecliptic system. Each instrument carries an astronomical scale, marked on the inner marble lining. The observatory consists of nineteen instruments for measuring time, predicting eclipses, tracking the location of major stars, ascertaining the declinations of planets and determining the celestial altitudes and related ephemerides. Because of these significances, it is a popular educational site and tourist attraction in the world as it showcases India's scientific prowess at a time when even in the US this type of outdoor laboratory did not exist (Sharma, 2016).



Fig. 30. *Hawa Mahal*.



Fig. 31. *Jantar Mantar*.

E. UNIQUE CULTURAL TYPE GEOHERITAGE

1. *Albert Hall* (Fig. 32)

Albert Hall Museum (named after King Edward VII) is one of the oldest museums in India. It was opened publically in 1887 and later on designated as the state museum of Rajasthan. It has a rich collection of various kinds of antique items such as paintings, carpets; ivory, stone, metal sculptures and colourful crystal works representing old time art, culture and traditions. It is surrounded by a lush green *Ram Nivas* Garden stuffed with appealing fountains and dazzling serene pools. Besides this park, the Geopark area has many other lush green gardens which add beauty and tranquillity to Jaipur. These include *Sisodia* Garden, *Vidyadhar* Garden, Central Park garden, Science park, *Shaheed Bhagat Singh* park, *Jhalana* park, *Jai Niwas* garden and *Zawahar* circle garden. *Zawahar* circle garden is considered as the largest circular park and circle in Asia having a beautiful Rajasthan *Patrika* (news paper) gate. It is a magnificent civil structure

with park and *chata Chauk* (food corners) for local people and is a famous tourist place of Jaipur.

2. Amrapali Museum (Fig. 33)

The recently opened *Amrapali* Museum is a unique museum of this type in the world. It is situated about 2 km from Albert hall museum. It exhibits a great collection of jewellery in different forms and designs in precious metals (gold, silver, platinum and pearl). It is considered to be a treasure of jewellery of old to modern designs. Nearly 4,000 artefacts, painstakingly collected from across the Indian subcontinent are showcased here.



Fig. 32. Albert Hall Museum.



Fig. 33. Amrapali Museum.

3. Govind Dev Temple (Fig. 34)

Govind Dev Temple is located in the city palace campus in heart of Jaipur. The largest temple in the world of that time was constructed by red sandstone by *Man Singh* in 1590. The temple is 117 feet in length with a width of 105 feet. Additionally, 135 acres of land is reserved for cowshed (*Gaushala*) for cows to live and feed. The Temple has become religiously famous because when Emperor *Aurangzeb* tried to destroy the shrine at *Vrindavan*, it is said that the idol was picked up from there and relocated to this temple to save the unique idol of Krishna. Locals believe that the statue of the deity here looks exactly like that of Krishna when he descended on Earth.



Fig. 34. Govind Dev Temple.

CURRENT STATUS IN TERMS OF PROTECTION AND MANAGEMENT

Most of the geoheritage sites of Jaipur Geopark except a few hydro-geological types are well-conserved and have educational values that can be utilized as geotourism sites as an additional element for the promotion of tourism in the region. Additionally, the scenic landform, historical and cultural values of these geosites, these are popular nationally and internationally as some of these are with UNESCO branding. Usually, UG, PG and research students of many Universities conduct their educational tour every year to these sites. Necessary infrastructural facilities are available at almost all geosites/ geomorphosites and can be utilized for geotourism by training new entrepreneurs and guides or those already working there. Importantly, all these geosites are easily accessible through tar roads situated on the suggested route map (Fig. 3). However, few geosites of hydrogeological geoheritage types need conservation as suggested by Mathur et al., (2020) for Indian geosites. For promotional activities, many videos of tourist places of Jaipur are already available but these need some modification to include geotourism values of sites. Because of these specialities and aspects, potential Jaipur Geopark satisfies the requirements of UNESCO (GGN, 2004). Jaipur significantly having four types of geoheritage undoubtedly of national and international values, are the strength of the proposed Geopark. Most of the geosites are unique and representative of educational, aesthetic, historical, cultural and geotourism values. Majority of geosites are well managed by local Govt., private stakeholders, trusts and individuals and are in good condition. Additionally, a legal body with the inclusion of local Govt., administration, stakeholders, academicians and experts on geoheritage should be setup to achieve the goal of Jaipur Geopark in future.

CURRENT OR POTENTIAL THREATS AND REMEDIAL MEASURES FOR GEOCONSERVATION

Few geosites especially geological features at various hills and Baories of *Govindpura* area of Jaipur Geopark, are poorly managed and are under serious natural and anthropological threat. To save these geosites, protected status can help in mitigating negative natural (erosion, weathering, and siltation) and anthropogenic (mining of rocks, unplanned urbanization and infrastructural development activities) influence damages, as suggested by Mathur et al., (2020). Among hydrogeological sites (few *Baories*) which are not covered under *Jal Swavlamban* Scheme of the state government, require urgent maintenance and conservation. As a whole, the geosites under the Geopark management system can be a better option for their conservation and utilization in the future for the socio-economic development of the region.

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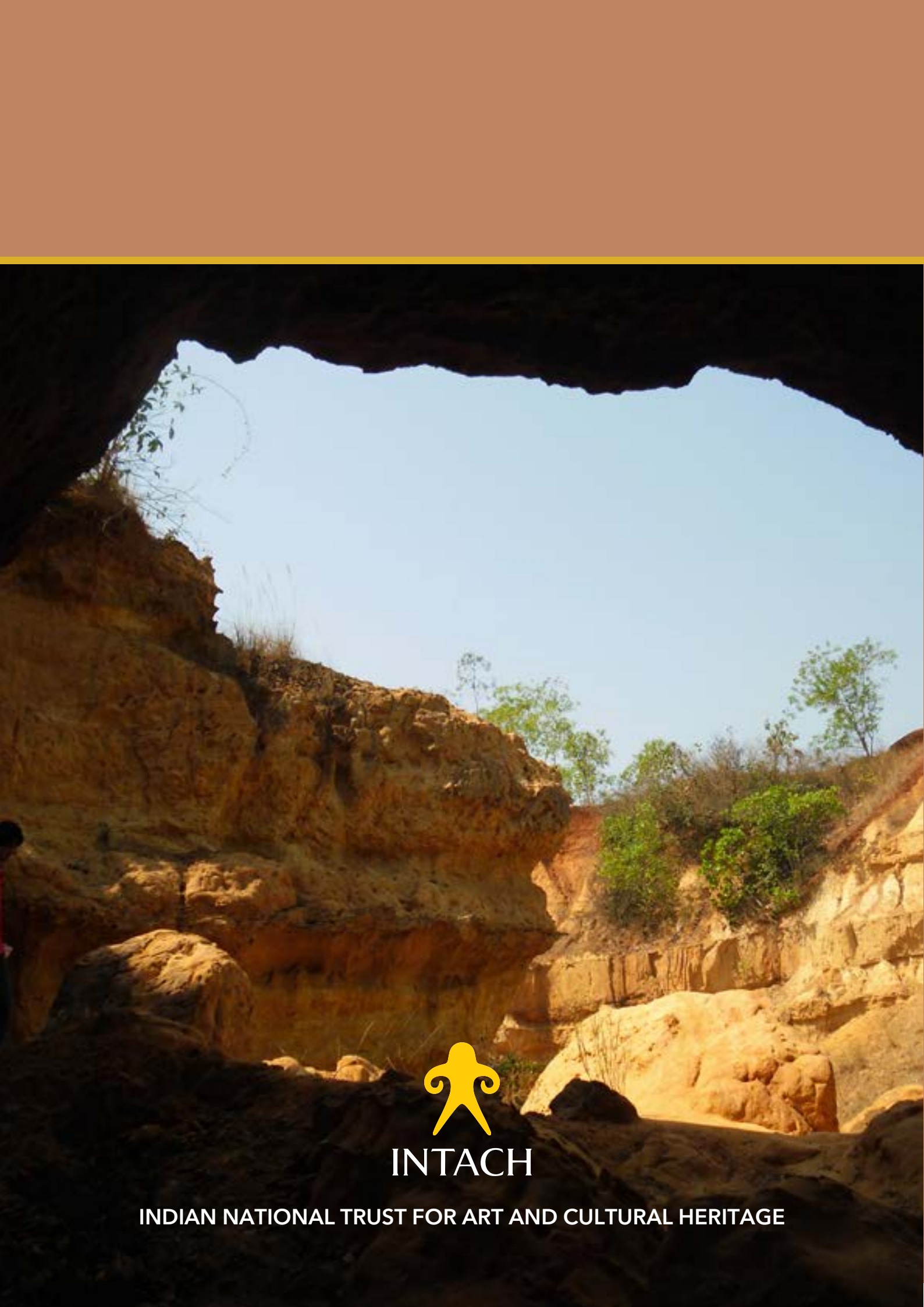
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