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 (26^0 14’20.04’’N, 73^0.01’27.48’’ 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 4^{th} to 5^{th} century and then from 6^{th} to 13^{th} century by the *Pratiharas, the Chahamanas* and the Muslim Sultans of Delhi, from whom it was wrested by the Rajputs in the 14^{th} 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

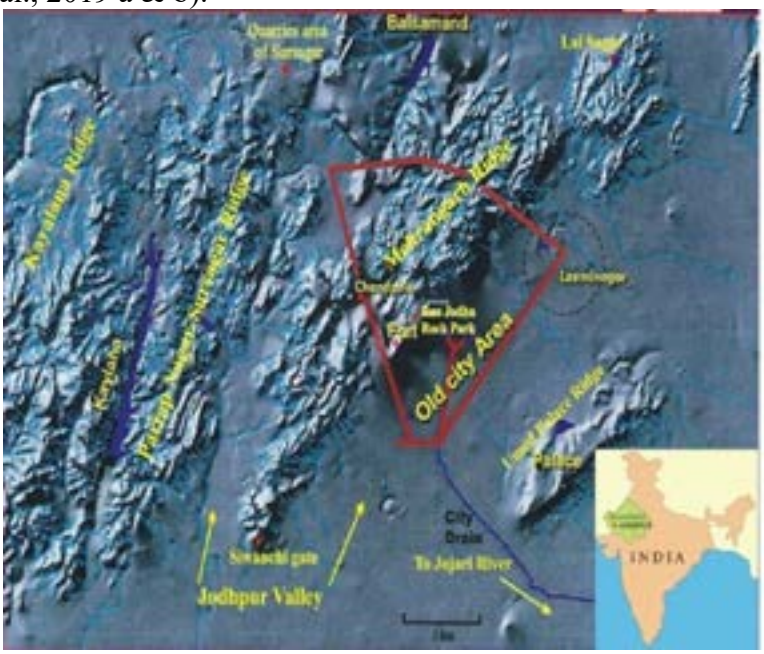
The geology of Jodhpur has been studied in great detail with its various aspects – Lithology, stratigraphy, structure, tectonics, paleontology and paleogeography. Geomorphologically, Jodhpur is endowed with four prominent NNE-SSW trending ridges and old Jodhpur city is situated around the foothills of these ridges. Rocky outcrops withinthe 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).



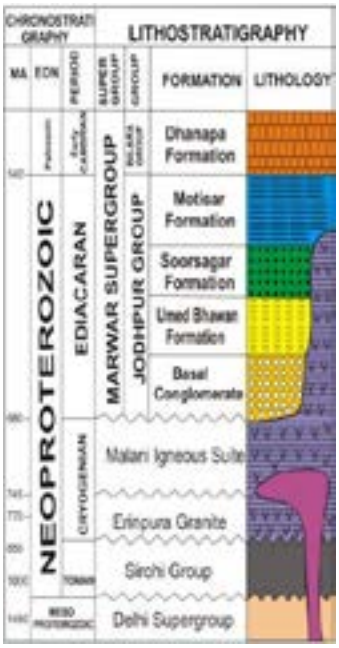


Fig. 1. DEM of Jodhpur city showing four prominent ridges and proposed Geopark area. **Fig. 2.** Lithostratigraphy of Jodhpur (Modified from Mathur et al., 2019b).

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 Mehrangar 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 occured 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. RasolaiTalab.

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 pyroclasic 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 torist 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 sacrified during *Navratra* by the kings of Marwar to pay homage to Ma Chamunda as per old traditions. Spectcular Chamunda temple is situated just upstair on western most part of Merangarh Fort. The small pond, surrounded by sandstone, fed water to the temple, staff quaters of the Mehrangarh Fort and Jail (in old time) situated on Pachetia hill. Religeously, 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, pillers 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) Najar ji ki Baori.

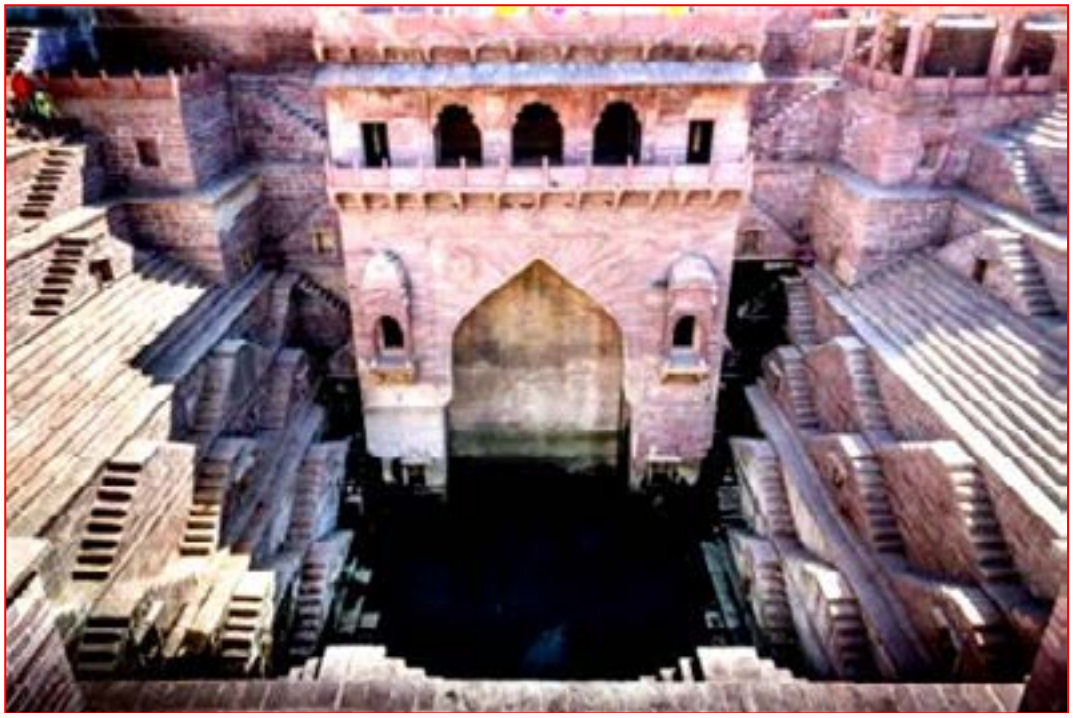


Fig. 25. Toorji Ka Jhalra.

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 varandas. 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 varandas 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 varandas 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 in1488. 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 Museuam Trust with HH. Gaj Singh ji II, as it 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.

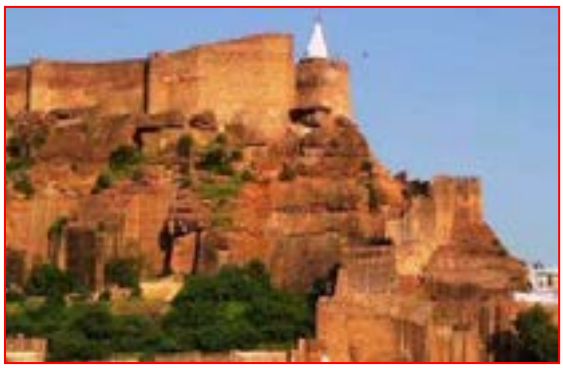


Fig. 34. Chamunda Temple and Pachetia hill.

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 museaum (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 Kukkuka of the Pratihara period. These temples, with one mosque sharing a common wall at Mandore near Ghoda Ghati sandstoe plateue (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-hector 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 (6^{th} to 13^{th} 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 museaum.

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 undoubtly 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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