



Eastern Son Valley, Uttar Pradesh, India: a Case for IUGS Geological Heritage Site Designation

Gurmeet Kaur¹ · Swtantra Kumar Singh² · Prabhakar Upadhyay³ · Parminder Kaur¹ · Jaspreet Saini¹ · Alok Kumar Pandey⁴ · Meenal Mishra⁵ 

Received: 30 April 2022 / Accepted: 18 October 2022 / Published online: 2 November 2022

© The Author(s), under exclusive licence to International Association for the Conservation of Geological Heritage 2022

Abstract

The part of Eastern Son valley of India displays a unique geographical location and geology endowed with diversity, distinctiveness and uniqueness. This region is significantly rich in socio-cultural, historical, spiritual and natural heritage. The Salkhan Fossil Park, the Kaimur sandstone terrane, numerous waterfalls, water reservoirs and geological features together represent the gorgeous landscape that evolved since Palaeoproterozoic. The mountainous region is also marked by a number of historical forts, buildings, rock shelters, prehistoric cave paintings, captivating wildlife and rich mineral resources. Son Echo Point is a significant geotourism site located on the steep scarp of Markundi hill in the Sonbhadra district. It has been developed as the consequence of the Markundi–Jamwal Fault. From Son View Point, one can enjoy a panoramic and breathtaking/spectacular view of Son valley carved along the Son–Narmada lineament. The Markundi hills become a popular tourist destination during the monsoon season because of the stunning landscape and numerous seasonal waterfalls. Another major geotourism location is Veer Lorik Pathhar (stone), which is located on Markundi hill around 100 m from Son Echo Point. In addition to the geologists' point of view of its origin, it is also shrouded in captivating local folklore. The antiquity of human activity in this area goes back to the Lower Palaeolithic period. Numerous archaeological sites, such as cave monuments and cave paintings, have been uncovered, depicting the cultural and religious beliefs of the local population. Archaeological remains in the form of tools and pottery have been discovered in a number of locations throughout the region. The region is important for its geology as well as for the sociocultural beliefs of the local population. We suggest that the eastern Son valley be recognised as an IUGS global geological heritage site from India based on the noteworthy geoheritage and geotourism sites.

Keywords Eastern Son valley · Salkhan Fossil Park · Son Echo Point · Veer Lorik Pathhar (stone) · Temples · Forts · Ghats (steps) · Geoheritage

This article is part of the Topical Collection on Indian Geoheritage:
From the Precambrian to the Present

✉ Meenal Mishra
meenalmishra@ignou.ac.in

¹ Department of Geology, Panjab University,
Chandigarh 160014, India

² Bharat Kala Bhavan (Museum), Banaras Hindu University,
Varanasi 221005, India

³ Department of Ancient Indian History, Culture &
Archaeology, Banaras Hindu University, Varanasi 221005,
India

⁴ School of Earth and Environmental Science,
Central University of Himachal Pradesh,
Shahpur Campus, Kangra 176206, India

⁵ School of Sciences, Indira Gandhi National Open University,
New Delhi 110068, India

Introduction

The world as a whole is a one-of-a-kind and stunning example of biodiversity and geodiversity. In recent decades, the worldwide geoscientific community has become more cognizant about the importance of protecting and conserving the significant natural components of the Earth, which speak volumes about the evolution of the Earth's history vis-à-vis biodiversity and geodiversity. In particular, geoheritage, an important component of geodiversity, preserves evidence that can be used to reconstruct the Earth's history, genesis and evolution (Sharples 1993; Gray 2019 and references cited therein). Geoheritage refers to geosites, geoparks and geomaterials that are scientifically, educationally, culturally and aesthetically significant enough to be considered

for Global designation and geoconservation (Brilha 2018; Gray 2019). According to the International Union for Conservation of Nature (IUCN), “Geoheritage is the abbreviated version of the term geological heritage. It is part of the natural heritage of a certain area constituted by geodiversity elements with particular geological value and hence worthy of safeguard for the benefit of present and future generations. Geoheritage can include both in situ elements (geosites) or ex situ elements (collections of geological specimens) with paleontological, geomorphological, mineralogical, petrological or stratigraphical significance, among others” (https://www.iucn.org/sites/dev/files/progeo_leaflet_en_2017.pdf).

Through one of its initiatives launched in 2001, the United Nations Educational, Scientific and Cultural Organization, or UNESCO, now has a specific mandate on Global Geoparks. In 2015, the International Geoscience and Geoparks Programme (IGGP) and the official global designation of “UNESCO Global Geoparks (UGGp)” were created as a result of the joint efforts of the United Nations Educational, Scientific and Cultural Organization (UNESCO), the International Union of Geological Sciences (IUGS), and Global Geoparks Network (GGN). UGGps can be defined as below:

“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.”

The natural World Heritage Sites and Global Geoparks (UGGps) programmes of the UNESCO in partnership with the IUCN, the GGN and the IUGS have brought issues regarding identifying and preserving geoheritage for future generations to the attention of the global geoscientific community, policymakers and governments of almost all nations. UNESCO has recognised 176 UGGps from 46 countries as of April 2022, based on the outstanding universal value of natural sites with significant geological and socio-cultural value (<https://en.unesco.org/global-geoparks>; <https://unesdoc.unesco.org/ark:/48223/pf0000377255>; <https://en.unesco.org/global-geoparks/list>).

The IUGS is the worldwide geological organisation dedicated to geosciences and geological issues, as well as international Earth Science cooperation. Through joint programmes, research, awareness and teaching, IUGS promotes the conservation of the Earth’s natural environment and resources. Geoheritage site identification and designation are very much in line with the goals of IUGS (<https://www.iugs.org/commissions>; https://geoheritage-iugs.mnhn.fr/media/pays/terms_of_reference_of_commission_on_geoheritage_final.pdf). In 2016, at the 35th International Geological Congress in Cape Town, South Africa, IUGS recognised the International Commission on Geoheritage (ICG) with two subcommissions: Subcommission on Geoheritage Sites and Collections (HSCS; <https://geoheritage-iugs.mnhn.fr/>) and Subcommission on Heritage Stones (HSS; <https://globalheritagestone.com/>).

The rejuvenated ICG in 2022 has three subcommissions now, viz., Subcommission on Geoheritage Sites, Subcommission on Heritage Stones, and Subcommission on geocollections (Kaur 2022a, b). A geological site with global significance in the areas of tectonics, stratigraphy, sedimentology, petrology, mineralogy, hydrogeology, palaeontology, geomorphology and the history of the geological sciences might be proposed for designation of an IUGS geological heritage site. To understand better the significance of an IUGS Geological Heritage Site, the definition from the website (<https://iugs60.org/100-geosites/>) is given below:

“An IUGS Geological Heritage Site is a key place with geological elements and/or processes of scientific international relevance, used as a reference, and/or with a substantial contribution to the development of geological sciences through history”

The IUGS Geological Heritage Site designation will promote geological heritage conservation, geotourism and educational endeavours. The current IUGS’s International Commission on Geoheritage (ICG) is working diligently to identify outstanding geoheritage locations all across the world. Thanks to its newly established executive and experts, its initiative on identifying and global designation of IUGS Geosites will position it as a global leader in discovering and recognising geoheritage locations of global significance (Kaur 2022b). The first 100 IUGS geosites will be announced at an IUGS-ICG big event in October 2022 in Zumaia, Spain (<https://iugs60.org/100-geosites/>).

Some countries’ efforts and activities in protecting geoheritage have been exceptional, while others are still in their infancy and a few need to awaken. India, a land of natural bounties with numerous geologically significant sites, is yet to open an account on a global platform (Kaur 2022b). The concepts of geoheritage are slowly picking up in India, and numerous articles have now been written identifying Indian Geoheritage sites (Kale 2014; Bhosale et al. 2021; Pandit and Master 2021; Bhargava et al. 2021; Mathur et al. 2017, 2021; Chauhan et al. 2021; Ghosh et al. 2021; Grover and Mahanta 2018; Prabhakar and Radhika 2022). However, due to lack of awareness and urbanisation, many important geological sites have been lost (SES–INSA Report 2019; Bhosale et al. 2021). An action plan from the Government of India is urgently required to bring a bill to protect these geologically significant sites (Bhosale et al. 2021 and references cited therein). The Geological Survey of India (GSI) declared 26 geologically important sites as national geological monuments (Bhosale et al. 2021 and references cited therein). However, these 26 geological monuments are in a state of despair owing to the paucity of stringent laws protecting such sites in India. India, on the other hand, was successful in having Makrana marble recognised as

an IUGS-Global Heritage Stone Resource “GHSR” (Garg et al. 2019). Numerous other stones from India have been documented and proposed for IUGS heritage stone designation (Kaur et al. 2019a, b, 2021a; Kaur et al. 2020a, b, c, d; Sreejith et al. 2021; Garg et al. 2021; Sen et al. 2022; Kaur 2022a, b).

The eastern Son valley region comprising districts of Varanasi, Mirzapur, Sonbhadra and Chandauli of Uttar Pradesh state is known for important geological and socio-cultural findings. Here, we attempt to highlight important geological and geotourism sites in part of eastern Son valley from Central India which we propose for designation of IUGS Geological Heritage Site.

Geological Setting

Geologically, the study area falls in Kaimur and Semri groups of Vindhyan Supergroup and Mahakoshal Group (Prakash and Dalela 1982; Nair et al. 1995). Extensive fieldwork was carried in the study area, in the eastern part of Son valley, to understand the geology of the area. The stratigraphic succession (Table 1; Fig. 1) comprises (i) Vindhyan Supergroup, (ii) Mahakoshal Group and (iii) Chhotanagpur Granitic Complex (CGC). Chhotanagpur granitic complex comprises dominantly granitic gneiss, nonfoliated massive granite and migmatites (GSI 2012). The rocks of Mahakoshal Group of Paleoproterozoic age

are in contact with DGC along Son–Narmada South Fault (SNSF). Mahakoshal Group can be divided into three formations. Dudhmaniya Formation being the youngest is composed of Banded Iron Formation (BIF), chloritic phyllite and greywacke. This is underlain by Parsoi Formation (predominantly argillite facies), and the oldest one is the Agori Formation composed of argillite-arenite facies along with chemogenic rocks (Nair et al. 1995; Roy and Devarajan 2000). Mahakoshal Group is unconformably overlain by rocks of Semri Group along Son–Narmada North Fault (SNNF). Semri and Kaimur groups belonging to Vindhyan Supergroup ranging in age from Paleoproterozoic to Mesoproterozoic are classically exposed in Son valley. Semri Group has been stratigraphically divided into nine formations (Ramakrishnan and Vaidyanadhan 2010; Table 1) with conformable contacts (Prakash and Dalela 1982). Patherwa Sandstone consisting of conglomerates and pebbly sandstone is conformably overlain by Arangi Shale. The conformably overlying Kajrahat Formation dominantly consists of limestone and dolomitic limestone, with stromatolitic structures. Porcellanite Formation comprising volcanoclastic tuffaceous deposit of felsic affinity conformably overlies Kajrahat Limestone (Mishra and Sen 2010). Porcellanite Formation is conformably overlain by Olive Shale which is overlain by Fawn Limestone (stromatolitic limestone) and further by Glauconitic Sandstone. Rohtas Limestone conformably overlies Glauconitic Sandstone. Rohtas Limestone is overlain by the Kaimur Group along a normal/faulted contact classically exposed along the Agori railway cutting. The Kaimur Group comprises rocks of siliciclastic composition and is predominantly quartz arenite, arkose and litharenite (Sen et al. 2014). It has been divided into six formations—Sasaram Formation, Ghurma Shale, Markundi Sandstone, Bijaigarh Shale, Mangesar Formation and Dhandraul Sandstone, in the order of superposition from older to younger age. Physiographically, the area covered by the three districts falls under two broad divisions, the middle Ganga Plain in north and Vindhyan plateau region in the south. The northern regions of Varanasi, Mirzapur and Chandauli districts are concealed by Indo-Gangetic flood-plain sediments with the basement consisting of Kaimur Group rocks. The southern plateau has been abruptly uplifted from the northern alluvial or Ganga plain and forms a number of escarpments. Sonbhadra district exhibits more geological diversity. Its northern part consists of Kaimur Group, and as one descends down the Markundi hill (moving from Varanasi) in the western part (towards the south) of the Sonbhadra district, the soft rocks of Semri Group are classically exposed. Further south Dudhi Gneissic Complex is exposed juxtaposed with Mahakoshal Group along Son–Narmada South Fault.

Table 1 Generalised stratigraphy in the eastern part of Son valley (adapted from Prakash and Dalela 1982; Roy and Devarajan 2000). Thickness is in metre given in parentheses

Supergroup	Group	Formation (thickness in metres)
Vindhyan Supergroup	Kaimur (400 m)	Dhandraul Sandstone (100)
		Mangesar Formation (155)
		Bijaigarh Shale (50)
		Markundi Sandstone (40)
		Ghurma Shale (16)
		Sasaram Formation (30)
		Rohtas Limestone (480)
		Glaucconitic Sandstone (150)
		Fawn Limestone (250)
	Semri (3000–4000 m)	Olive Shale (120)
		Porcellanite Shale (500)
		Kajrahat Limestone (130)
		Arangi Shale (120)
		Patherwa Sandstone (80)
Mahakoshal Group	Dudhmaniya Formation	
	Parsoi Formation	
	Agori Formation	
Chhotanagpur Granite Complex (CGC)		

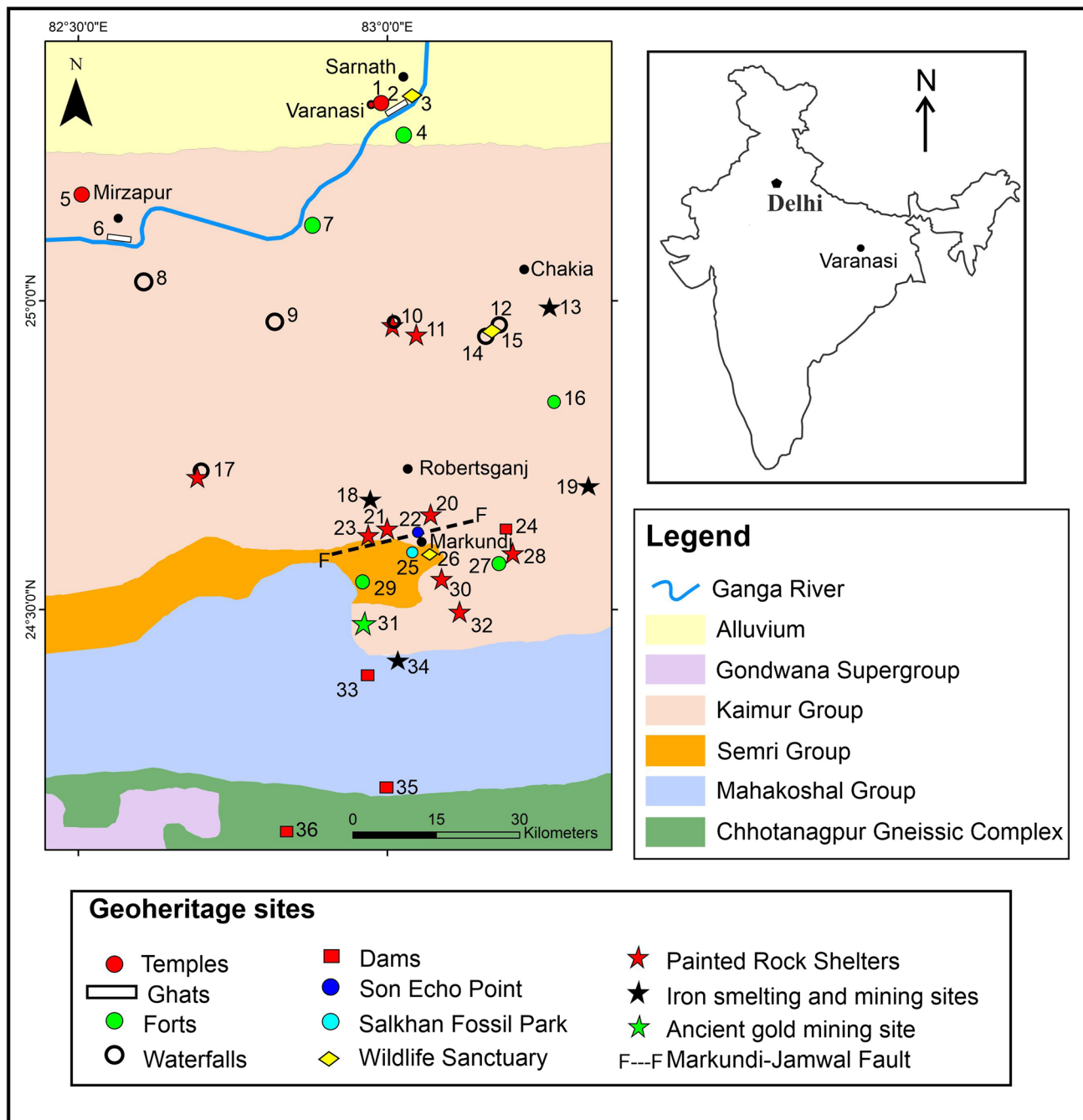


Fig. 1 Geological map of Kaimur and Semri groups exposed in the Son valley sector of the Vindhyan Basin, mainly covering the Varanasi, Sonbhadra, Mirzapur and Chandauli districts of Uttar Pradesh (modified after Sen 2010). The geoheritage sites are marked on it with different symbols. Temples: Temples of Varanasi (1), Temple of Mirzapur (5), Vindhyavasini Temple (7); Ghats: Ghats of Varanasi (2), Ghats of Mirzapur (6); Forts: Ramnagar fort (4), Chunar fort (7), Naugarh fort (16), Vijaygarh fort (27), Agori fort (29). Waterfalls: Wyndom falls (8), Siddnath Ki Dari falls (9), Lakhaniya waterfalls (10), Devdari waterfalls (12), Rajdari waterfalls (14), Mukkha falls

(17). Dams/Reservoir: Dhandraul dam (24), Obra dam (33), Rihand dam (35), Govind Ballabh Pant Sagar reservoir (36). Wildlife Sanctuary: Turtle Wildlife Sanctuary (3), Chandraprabha Wildlife Sanctuary (15), Kaimur Wildlife Sanctuary (26). Painted rock shelters: Lakhaniya Caves (10), Bhaldariya (11), Mukkha Caves (17), Panchmukhi Pahari (20), Kanda Kot (21), Likhaniya (23), Maukhurd (28), Kerwa Ghat (30), Kauva Khoh (32). Iron smelting and mining sites: Malhar (13), Raipura (18), Raja-Nal-Ka-Tila (19), Ningha (34); Ancient gold mining site: Son Pahari Gold Mines (31); Son Echo Point (22) Salkhan Fossil Park (25)

Mineral Resources

The area under study is the centre of attraction for exploration activities of the Geological Survey of India for multiple reasons (Kumar 2005). It has yielded economic minerals like silica sand, china clay, gold, low-grade iron, cement-grade limestone, dolomite and andalusite and building stones. Chandraprabha area is reported to have bauxite deposits, and clay beds have been explored in Indo-Gangetic alluvium. Good occurrences of silica sand occur within Kaimur sandstone at Chakia in Varanasi district. Agori Formation of Mahakashal Group hosts marble deposits at Ningha and Kauria. Apart from this, china clay deposits occur at Ramgarh-Naudiha in Sonbhadra district. At Ramgarh, south of Son river, china clay bands are traceable over 7.6 strike length with a reserve of 13.5 million tons (Annon 1999). Rich source of potash (5.09%) in Glauconitic Sandstone (Semri Group) has been investigated around Ghoriya, Kurcha and Munib-ki-Pahadi having an estimated reserve of 6 million tons (Kumar 2005). Lead mineralisation associated with gold from quartz veins from Parsoi Formation at Gulpahar from Agori Formation at Guladih in Sonbhadra district has been reported. The old workings at both places provide excellent evidences of ancient mining activities. Large deposits of low-grade iron ores occur in Banded Hematite–Magnetite–Quartzite in the Parsoi Formation of Mahakoshal Group South of Obra. The bulk of limestone comes from Kajrahat and Rohtas Limestone formations of Semri Group in Uttar Pradesh. They are being quarried for cement grade limestone in Churk (since 1956) and Dala (since 1971) areas of Sonbhadra district (Fig. 2a). Kajrahat belt contains both cement and BF (blast furnace) grade limestone and is quarried for Dalla Cement factory by Jaypee Group. It occurs over a distance of 13.5 km in a 200–400 m wide zone. Around Ghurma, the Rohtas limestone is being quarried, extending over 5.7 km in length with an average thickness of 50 m. Banded–Magnetite–Quartzite of Agori and Parsoi formations at Sona Pahadi in Sonbhadra district host the occurrences of gold and show the evidences of ancient mining activities (Figs. 2b–c; Dwivedi et al. 1995). The chemical analysis indicates gold up to 3.87 ppm along with the 5–55 ppm silver (Bajarangi 1995). Apart from that, Hardi and Bagisoti areas have been reported for gold placers in Patherwa Sandstone of Semri Group. About 0.70 tonnes of placer gold deposit has been proved by the Department of Geology and Mines in district Sonbhadra. “The GSI has estimated a probable category resource of 52,806.25 tonnes of ore with 3.03 g per tonne gold (average grade) for a strike length of 170 m in Sub- Block-H, Son Pahadi of Sonbhadra district of Uttar Pradesh” (<https://economictimes.indiatimes.com/news/politics-and-nation/gold-depos>

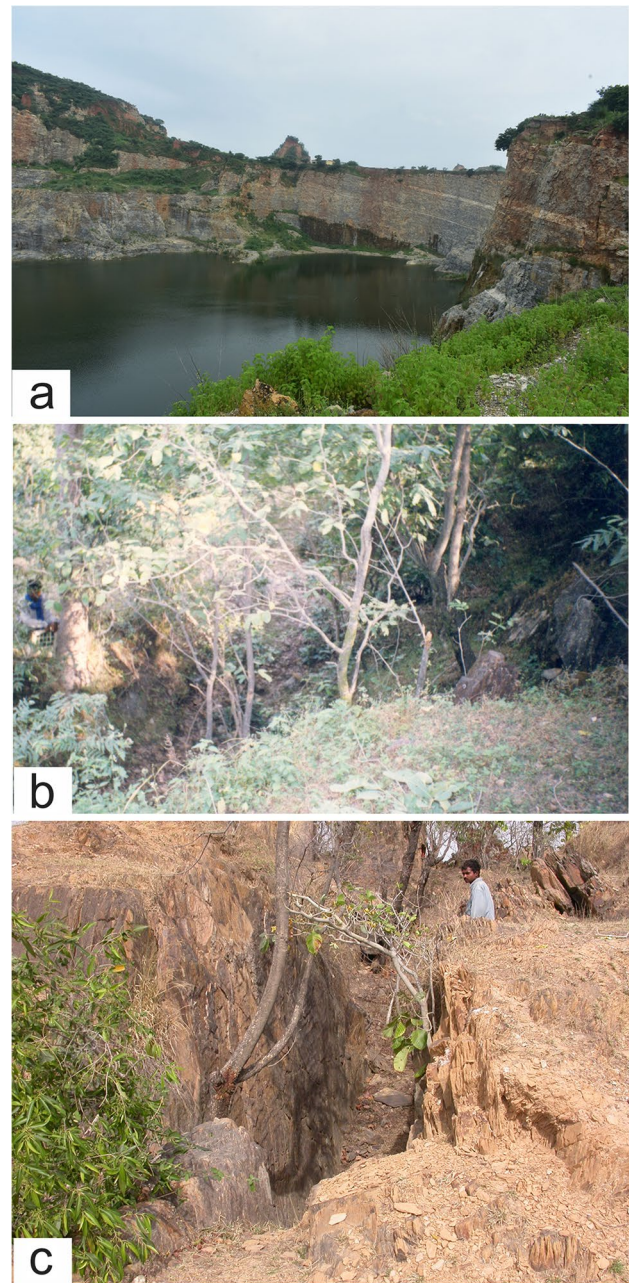


Fig. 2 Field photographs showing **a** a section of Rohtas Limestone at Dala mine; **b** old working site for Iron ore at Kirwani; and **c** old working site for gold at Son Pahari, Sonbhadra District, Uttar Pradesh

[its-found-in-uttar-pradesh-sonbhadra/articleshow/74244767.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst](https://economictimes.indiatimes.com/news/politics-and-nation/gold-deposits-found-in-uttar-pradesh-sonbhadra/articleshow/74244767.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst).

Besides, the Wyndhyamganj area has occurrences of andalusite (grade 24–26%) as porphyroblast in phyllites of Parsoi Formation. Six hundred meters wide zone of sillimanite bearing quartz-biotite-muscovite-garnet schist has been reported Dudhi gneiss complex with an estimated reserve of

10 million tons. Coal deposits are also located in the Sonbhadra district. Bhattacharya et al. (2008) reported uranium mineralisation along Markundi–Jamwal Fault. National Coal Ltd. (NCL- branch of Coal India Limited) has its headquarters and many coal mines in the Sonbhadra region. Hindalco has a major aluminium plant for refining- Hindalco aluminium plant (HINDALCO), Renukoot which was established in 1962 (<https://sonbhadra.nic.in/about-district/>). Hindalco is having smelting capacity of 410,000 tpa at present (<http://www.hindalco.com/operations/aluminium-smelting/renukoot>). The cement factory at Dala and Hindalco is providing employment to many people in these regions.

Geoheritage Sites in the Proposed Area

The study area is the host for a multitude of geoheritage sites, viz. fossil parks, geotourism sites, temples, river fronts (*ghats*), forts, waterfalls, wildlife sanctuaries, dams and reservoirs (Fig. 1; Table 2).

Salkhan Fossil Park

The Salkhan fossil park is located 12 km from Robertsganj town near Salkhan village on the Varanasi–Shakti Nagar highway in Sonbhadra district (Fig. 3). The park is located adjacent to Kaimur Wildlife Sanctuary spreading over an area of about 0.25 sq. km. Fawn Limestone belonging to Semri Group is classically exposed around Salkhan village. The fawn-coloured Fawn Limestone (thickness ~40 m) being dolomitic limestone and siliceous in nature comprises stromatolites (Fig. 3) and microbial laminites. Thus, Sonbhadra district has been gifted to preserve the first evidence of life on Earth, and the scientists consider it one of the most important destinations to investigate the geological past. Geologists became aware of the fossils in the Salkhan park area when Auden (1933) first time reported these fossils. Formally, it was designated as a fossil park in August 2002. The fossils are estimated to be nearly 1500 million years old, thus, making the park an invaluable possession not for Sonbhadra but for the entire world. Recently, the stromatolites have been reported from Badagaon in Chopan Vikas Khand. Here, the fossils are found in greater abundance than those in Salkhan village. Stromatolites record the evolutionary signature of earliest forms of life on earth and are considered building blocks of life. Walter (1976) defined stromatolites as “organo-sedimentary structures” developed due to the significant impact of cyanobacteria considered to be the oldest oxygenic phototrophs on the planet. The stromatolites generally appear as rings on the scattered boulders in Salkhan Fossil Park. The stromatolites consist of laminated carbonate or silicate rocks. They are formed over geologic time by trapping, binding or precipitation of sediments primarily by

microorganisms such as blue-green algae (cyanobacteria). Cyanobacteria are the evidence of the primitive (prokaryotic) forms of life on Earth. The outer layer or cells of blue-green algae is a sticky layer that binds the particles of sediment leading to the formation of stromatolite fossils (Golubic et al. 2000). Salkhan fossil park has two stromatolite outcrops of dimension: 110 m (E-W) × 25 m (N-S) and 30 m (E-W) × 12 m (N-S) are well exposed on the slopes of the hillock. Stromatolites are columnar/cylindrical in form, and the colonies attain a maximum height of 110 cm and a diameter of 30 cm. The stromatolites at Salkhan fossil park have been identified as *Colonella columnaris*, *Conophyton garganicus* (*Ephyaltes myriocranus*) and *Collenia clapii* (Kumar 1976, 1978; McMenamin et al. 1983). Chert samples from Salkhan were studied for the diversity of microbial life, including the akinetes (*Archaeoellipsoides*) by Sharma and Singh (2019) and coccoids. The biggest cyanobacteria *Gloeodiniopsis mikros* has been recorded from the Fawn limestone (Shukla and Sharma 2016). This fossil park has been maintained by the local government. Presently, Salkhan Fossil Park is lying in a deplorable state due to the neglected attitude of administration and ignorance of the local people (Singh 2012). Thus, sensitising policymakers, the industry as well as the common masses (tribals) towards conserving this valuable key geoheritage is very important.

Son Echo Point and Veer Lorik Pathhar

Son View Point or Son Echo Point, also known as Eco Point, was inaugurated in 2003 and is situated on Markundi hill. It is about 6 km from Robertsganj (district headquarters) in Sonbhadra district. This geotourism spot is maintained by the local government. While moving from Chopan to Varanasi along state highway SH5A, near Markundi hills, there is a sudden rise in elevation scaling to 300 m. This has been attributed to the displacement by Markundi–Jamwal Fault (Fig. 4b). This fault results in the omission of rocks of Semri Group. Lower Kaimur Group is seen directly resting over the rocks of Semri Group (Prakash and Dalela 1982; Singh et al. 2019). Along this fault, Mangesar and Dhandraul Sandstone formations have been severely crushed, and its evidences are manifested as the fault gouge, fault breccia, slickensides, water seepages and the steep dips of beds (Fig. 4b). The horizontally bedded, compact, quartz arenites of Dhandraul sandstone form the resistant top layer due to which the Kaimur plateau remains at highest elevations in the area even though it lies towards the downthrown (northern) side of an ENE–WSW striking Markundi–Jamwal Fault (Tewari et al. 1996; Mohan et al. 2007). The differential weathering between soft rocks (dominantly shale) of the Semri Group and hard and compact quartzites (*aka* sandstone) of Kaimur Group also causes the development of

Table 2 List of proposed 36 prospective geosites, grouped under 4 Geo-stations, for the Eastern Son valley

Geostation	Geosite no	Name of the geosite	Coordinates	Geosite type	Geological aspects
1. Varanasi, Uttar Pradesh	1	Temple of Varanasi	25° 18' 38.79" N, 83° 0' 38.21" E	Cultural/religious/heritage site	Built using Kaimur sandstone
	2	Ghats of Varanasi	25° 19' 9.48" N, 83° 1' 26.04" E	Cultural/religious/heritage site	Built using Kaimur sandstone
	3	Turtle Wildlife Sanctuary	25° 16' 48" N, 83° 0' 57.6" E	Wildlife Sanctuary	-
	4	Ramnagar Fort	25° 16' 48" N, 83° 1' 48" E	Historical/heritage site	Built using Kaimur sandstone
2. Mirzapur, Uttar Pradesh	5	Temples of Mirzapur	25° 8' 45.6" N, 82° 34' 8.4" E	Cultural/religious/heritage site	Built using Kaimur sandstone
	6	Ghats of Mirzapur	25° 9' 3.6" N, 82° 33' 48.24" E	Cultural/religious/heritage site	Built using Kaimur sandstone
	7	Chunar Fort	25° 7' 31.8" N, 82° 52' 28.92" E	Historical/heritage site	Built using Kaimur sandstone
3. Chandauli, Uttar Pradesh	8	Wyndom Falls	25° 1' 49.51" N, 82° 36' 36.42" E	Natural site	Geomorphology
	9	SiddnathKi- Dari Falls	24° 57' 51.26" N, 82° 49' 18.85" E	Natural site	Geomorphology
	10	Lakhaniya Caves and Waterfalls	24° 57' 33.07" N, 83° 0' 31.49" E	Natural and Archaeological site	Geomorphology
	11	Bhaldariya (painted rock shelter)	24° 56' 36.26" N, 83° 2' 46.62" E	Archaeological site	Geomorphology
	12	Devdari Waterfalls	24° 57' 2.38" N, 83° 10' 21.40" E	Natural site	Geomorphology
	13	Malhar (iron smelting site)	24° 59' 16.00" N, 83° 15' 46.00" E	Archaeological site	Economic geology
	14	Rajdari Waterfalls	24° 56' 48.43" N, 83° 10' 7.07" E	Natural site	Geomorphology
	15	Chandraprabha Wildlife Sanctuary	24° 56' 46.28" N, 83° 10' 11.98" E	Wildlife Sanctuary	-
4. Sonbhadra, Uttar Pradesh	16	Naugarh Fort	24° 50' 12.51" N, 83° 16' 15.56" E	Historical/heritage site	Built using Kaimur sandstone
	17	Mukkh Falls	24° 42' 58.15" N, 82° 41' 34.00" E	Natural site	Geomorphology
	18	Raipura (iron smelting site)	24° 40' 40.00" N, 82° 58' 20.00" E	Archaeological site	Economic geology
	19	Raja-Nal-Ka-Tila (iron smelting site)	24° 41' 55.00" N, 83° 19' 26.00" E	Archaeological site	Economic geology
	20	Panchmukhi Pahari (painted rock shelter)	24° 39' 5.75" N, 83° 4' 9.71" E	Archaeological site	Geomorphology
	21	Kanda Kot (painted rock shelter)	24° 37' 55.26" N, 82° 59' 59.38" E	Archaeological site	Geomorphology
	22	Son Echo Point and Veer Lorik Pathhar	24° 37' 15.27" N, 83° 3' 1.90" E	Historical/heritage site, fault	Geomorphology and structural geology
	23	Likhaniya (painted rock shelter)	24° 37' 6.29" N, 82° 58' 3.79" E	Archaeological site	Geomorphology
	24	Dhandraul Dam	24° 37' 32.34" N, 83° 11' 30.09" E	Hydropower plant	Hydrogeology
	25	Salkhan Fossil Park	24° 35' 18.48" N, 83° 2' 27.11" E	Fossil Park	Palaeontology
	26	Kaimur Wildlife Sanctuary	24° 54' 27.00" N, 83° 31' 53.98" E	Wildlife Sanctuary	-

Table 2 (continued)

Geostation	Geosite no	Name of the geosite	Coordinates	Geosite type	Geological aspects
	27	Vijaygarh Fort	24° 34' 37.37" N, 83° 10' 53.09" E	Historical/heritage site	Built using Kaimur sandstone
	28	Maukhurd (painted rock shelter)	24° 35' 32.27" N, 83° 12' 0.79" E	Archaeological site	Geomorphology
	29	Agori Fort	24° 32' 48.03" N, 82° 57' 43.33" E	Historical site	Built using Kaimur sandstone
	30	Kerwa Ghat (painted rock shelter)	24° 32' 56.03" N, 83° 5' 20.94" E	Archaeological site	Geomorphology
	31	Son Pahari Gold Mines	24° 31' 33.68" N, 83° 10' 57.99" E	Mining site	Economic geology
	32	Kauva Khoh (painted rock shelter)	24° 29' 41.04" N, 83° 7' 0.39" E	Archaeological site	Geomorphology
	33	Obra Dam	24° 26' 21.83" N, 82° 57' 56.74" E	Hydropower plant	Hydrogeology
	34	Ningha (iron smelting and mining site)	24° 25' 0.08" N, 83° 1' 0.88" E	Archaeological site	Economic geology
	35	Rihand Dam	24° 12' 34.88" N, 83° 0' 10.11" E	Hydropower plant	Hydrogeology
	36	Govind Ballabh Pant Sagar Reservoir	24° 8' 33.51" N, 82° 50' 33.08" E	Artificial lake	Hydrogeology

steep escarpment. Because of the faulting together with differential weathering, the formations of Upper Kaimur appear as a wall from a distant place. Son View Point is built on a steep cliff/scarp of hard compact Dhandraul sandstone, and the valley comprises weatherable rocks of Semri Group, mostly shales. Thus, a panoramic and picturesque view of Son valley can be witnessed (looking south) from Son View Point (Fig. 4c). The evidences of uranium mineralisation have been reported along the Markundi–Jamwal Fault (Bhattacharya et al. 2008).

Veer Lorik Patthar or stone is situated on Markundi hill about 100 m from Son Echo Point. Veer Lorik Patthar is a giant boulder of about more than 15 m in height fragmented into two pieces (Fig. 4a). This boulder constitutes off-white coloured, medium-to coarse-grained, hard and compact, thickly bedded Dhandraul sandstone. Geologically, this huge fallen boulder seems to have been split apart along the bedding plane or a joint plane. Sonbhadra region suffers high diurnal temperature fluctuations during summer season, another possibility is that this sandstone boulder underwent spheroidal weathering. However, an inspiring and interesting story of valour and bravery is associated with Veer Lorik Patthar. According to a folklore, the Veer Lorik stone symbolises the love and bravery of Ahir Raja Lorik Yadav and his Queen Manjari.

Panoramic Son Valley

Son valley has been a cradle of human civilization since time immemorial. Son River is a tectonically controlled flowing along the Son–Narmada lineament. Ghosh (2015) suggested that the tectonic processes and rejuvenation of the Son–Narmada lineament cause the Son River to change its course. Lineaments generally represent the major fault and fracture system indicating the brittle deformation. Son–Narmada lineament is the well-known mega-lineaments of the country passing through the study area. Research has been carried out to unravel geological, geomorphological, geophysical, petrological and mineralisation evidences to show that the Narmada–Son line is a line of dislocation from Precambrian to recent times (Murty and Mishra 1981). The major tributaries of the Son River are Rihand and Kanhar rivers in the study area. The Son River principally flows through rocks of Semri, Kaimur and Mahakoshal groups (Ramakrishnan and Vaidyanadhan 2010). The river provides good quality water for irrigation and drinking purposes, and amongst important resources on the river and its tributaries are many dams, reservoirs (Fig. 4c) and hydropower generation plants serving in the region for irrigation and electricity generation. The middle Son valley possesses a long and rich record of hominin occupation from all periods of the Palaeolithic, which is rare for the other sites of India (Jones and Pal 2009).

Waterfalls

The study area broadly consists of six geomorphological units (Mohan et al. 2007): (i) Kaimur Plateau consisting of subhorizontal and horizontal bedded rocks of Kaimur Group in the northern part, Kaimur escarpment signifies the tectonic contact between rocks of Semri and Kaimur groups along the Markundi Fault in the northern part; (ii) the coalesced deposits of alluvial and colluvial fans apparently resembling a broad plain are found downhill side of the Kaimur escarpment; (iii) river terraces occurring on either side of the Son river; (iv) Son river flows in the eastern and western sectors of area along strike cum fault valley; (v) Mahakoshal Group of rocks exhibit ridge and valley system; and (vi) Flood plain deposits of Ganga River in Varanasi and Mirzapur districts. Thus, the area is drained by two major rivers like Ganga and Son along with their tributaries Karmnasa, Chandraprabha, Belan, Rihand, Kanhar, Garai and Ghaggar and exhibits a lot of diversity in elevation. The study area has been adorned by many waterfalls especially draining the rocks of Kaimur Group. These rocks are very highly jointed. Mostly, the joints are at right angles to the subhorizontal and horizontal bedding planes (Auden 1933). The joints are nearly vertical or vertical as the dips are very low. These joint patterns along with an abrupt change in the elevation of escarpments play a favourable role in the formation of a waterfall in Kaimur range in the study area. Thus, several small and big waterfalls are naturally formed along the scarp faces of horizontally bedded Kaimur sandstone in this region which can be developed into important geotourism spots. Rajdari (Fig. 5a), Devdari, Lakhania Dari (Fig. 5b), Wyndom, Siddhanath-Ki-Dari, Mukka Falls and several others were used as a source of water during the prehistoric time. Through hundreds of painted rock shelters and stone tools from Mirzapur, Chandauli and Sonbhadra districts (Fig. 6), it is evident that these waterfalls and other sources of water such as seasonal springs, *nala*, water ponds and rivers like Ganga, Son, Karmanasa, Belan and their tributaries were of great importance.

Wildlife Sanctuaries

The Chandra Prabha Wildlife Sanctuary is located in Chandauli, and Sonbhadra districts approximately 70 km from the holy city of Varanasi, spread out on the Kaimur range. The wildlife sanctuary is well known for its lush forests and is home to many wild animals and birds. It includes umpteen tourist spots including breathtaking waterfalls like Rajdari, Devdari and Naugarh fort (<https://chandraprabhawildlife.com/>). The Kaimur Wildlife Sanctuary is part of Kaimur hills known for horizontal bedded sandstone beds covering

the districts of Mirzapur and Sonbhadra. It covers an area of approximately 1342 sq. km. The sanctuary encloses waterfalls, namely, Karkat and Telhar. The sanctuary preserves ancient cave paintings and a fossil park (<https://upecotourism.in/KaimoorWildlife.aspx>).

Dams and Reservoirs

Rihand Dam, Obra Dam, Dhandraul Dam, Latif Shah Dam, Chakia, Balui band (Sonbhadra) and Musakhand Dam (Chandauli) are important sustainable power generation centres in this region and provide employment to local and indigenous population in the region. In fact, Sonbhadra is commonly known as the Power Capital of India. The Dhandraul and Govind Ballab Pant Sagar reservoirs provide water for drinking and irrigation purposes in the region.

Socio-Cultural Heritage

The region under study covers a large area with varied and unique geographical location and geology endowed with diversity, distinctiveness and uniqueness in terms of historical, spiritual, social, cultural and natural heritage. The study area is also well known for its archaeological importance. The antiquity of human activity in this area goes back to the Lower Palaeolithic period, and the sites have been reported from the southern part of the Sonbhadra district (along Son valley; Fig. 7) and Adwa valley in Mirzapur (Cockburn 1899). Middle Palaeolithic sites have yielded cores, flakes and various types of scrapers, points and blades made from quartzite, chert and quartz (Fig. 6d). All the archaeological data indicate that Sonbhadra and Mirzapur regions were inhabited by hunter-gatherer communities during the Early and Middle Palaeolithic periods (Narain and Pant 1965; Mishra 1977; Pant 1982; Tewari et al. 1995). The Early and Middle Palaeolithic tools have been found mostly at factory sites or buried in the river beds. Microlith assemblages consisting mostly of micro-blades, fluted cores, triangular, trapeze and points dominated the tool kit in the next cultural phase known as Mesolithic. This can be corroborated with the necessities arisen due to the climatic changes in the region. The microliths and associated lithic assemblage have been found at floors of the rock shelters and nearby areas and also at many factory sites. These inferences point to the increased activity of the human population in the whole of the region. The next stage of human development is marked by Neolithic tools. Polished stone celts have been found at many sites including Kon, Agori, Barank, Bajauli, Chatara, Deori, Kamauli, Kanda Kot, Lasda, Nai Dih, Raja Nala-Katila and Latif Shah (Fig. 1). The ancient sites encompassing different types of pottery and other archaeological remains

Fig. 3 a–d In situ dolomitic limestone containing preserved stromatolites and microbial laminites located at the Salkhan Fossil Park, Robertsganj, Sonbhadra district. Stromatolites are columnar/cylindrical in form



on the surface are located mainly in the fertile alluvial area of the upper Belan valley and near the Karamnasa River. According to the traditional and old literature, Puranas and Epics, the area under discussion was known as Karusha Desh (a troubled area) consisting of autonomous people (Mishra 1988).

Due to the unique hard, compact and jointed nature of geological formations, there are more than a thousand natural rock shelters in the Kaimur range of the Sonbhadra, Mirzapur and Chandauli districts (Fig. 7). Out of these, more than a hundred painted rock shelters are of utmost importance for the cultural study. Sometimes, it is art alone that gives evidence of the cultural development of early humanity in its true dimensions as it provides an overview of early man's daily life activity and social condition. It has been observed that the motifs depicted in these paintings are mostly of animals and birds, hunting scene, sambhars, chinkara, rhinoceros, bison, wild boars, peacock, porcupine, humped bull, ostrich (?), fish and sometimes mythical animals (Fig. 6 a, b). Besides animals, human figures mostly engaging in hunting with bow and arrow, group dance holding hands with others and various other symbols are also depicted. Kauva Khoh, Panchmukhi, Likhaniya etc. are the important painted rock shelter for history of early human culture. Kauva Khoh rock shelter (Fig. 6c), located 11 km south of Robertsganj, is the largest painted rock shelter of the region.

Traditionally, the colour preparation was done with the help of powdered *geru* (hematite ore), ochre, *sindur*

(vermillion), mineral ochre, oil, juice of the beans or bark and other vegetable material etc. This practice of colour-making is still prevalent amongst the tribes of this region. However, according to the folklore, the colours of the rock paintings were prepared with the blood of tigers and other animals. On the basis of this belief, names like “Rakat-Ki-Putari” (figures of blood) have been coined. Based on the emission spectrographic analysis of pigment collected from painted rock shelters, it was concluded that the different shades of red colour were obtained from the oxides of the iron, like hematite, black from manganese oxides and white from kaolin or limestone (Tewari 1990).

Civilizations flourish with geological consent, in the proximity of water. Besides mighty rivers such as Ganga and Son, several small rivers such as Karamnasa, Garai, Chandraprabha, Kanhar, Rihand, Bijul, Belan, Jhirgo and Adwa and many natural waterfalls such as Lakhania Dari, Wyndom falls, Siddhanath-Ki-Dari, Rajdari-Devdari and Mukka falls are also found in this region. The archaeological sites and painted rock shelters located near these waterbodies also indicate the importance of natural water resources. Some of the waterfalls near the painted rock shelters are still the only sources of water for villagers and wild animals.

The Vindhya–Kaimur hills are rich both in iron ore deposit and in ethnic iron-working population. The sites like Latif Shah and Malhar in districts Chandauli and Raipura and Raja Nal-Ka-Tila in district Sonbhadra (Tewari 1998) have provided early evidence of the Iron Age. The tradition of iron smelting originated in circa 1800 BCE or even earlier

Fig. 4 **a** Veer Lorik Pathhar located on Markundi hill. **b** Markundi–Jamwal Fault showing Mangesar and Dhandraul Sandstone formations with evidences of faulting. **c** Son Echo View point built on a steep cliff showing panoramic and picturesque view of Son valley and beautiful landscape, Robertsganj, Sonbhadra district



continued till the middle and in some cases till the last quarter of the twentieth century. Evidences of iron smelting have been recovered from Malhar and Raipura, datable to circa 1800 BCE (Upadhyay 2013).

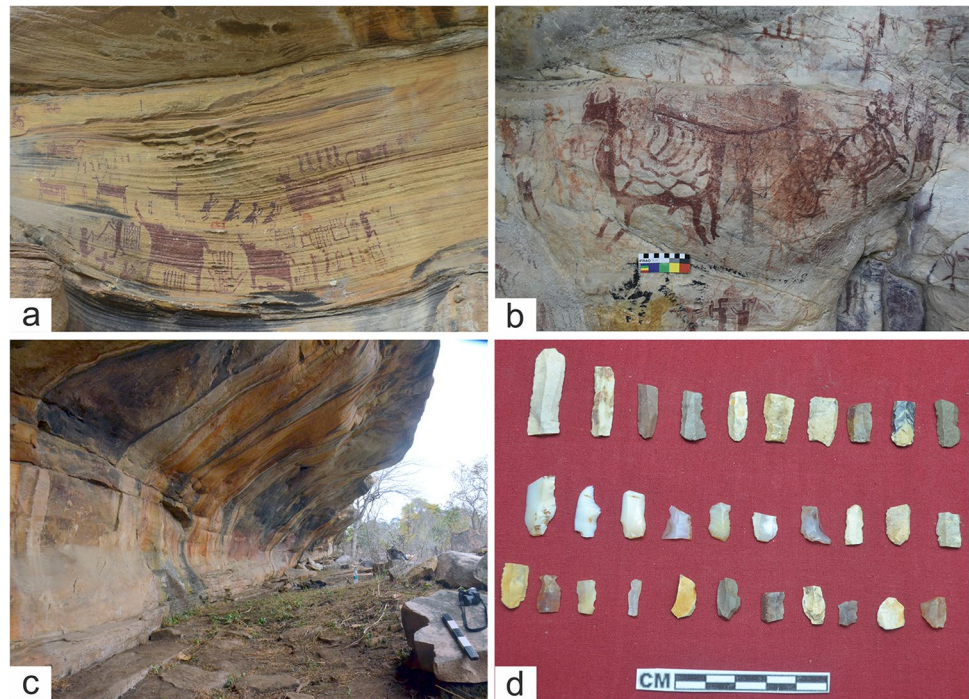
The area is also gifted with a rich historical heritage. There are numerous evidences to prove that the study area has been a cradle for human civilization. It was inhabited by early humans since Lower Palaeolithic and then by medieval and ancient kings. Raja Nala-Ka-Tila is located at a loop-like turn of the Karamnasa River in Nagwa block. Raja Nala was a legendary hero mentioned in Mahabharata. Local villagers believe that his capital was located on this mound. Varanasi has been a centre of excellence in education and learning in subjects like philosophy, astrology, religion and Sanskrit since times immemorial even for international students. This is evidenced by around 3000 temples along with worshipping places from various faiths like Jainism, Buddhist and Islam. Varanasi is associated with four Jain Tirthankars—Suparshvanath, Chandraprabhu, Shreyanshnath and Parshvanath as their birthplace. Buddhism originated here as Buddha preached his first sermon at Sarnath. King



Fig. 5 Waterfalls draining through the rocks of Kaimur range: **a** Rajdari falls and **b** Lakhania Dari falls

Ashoka erected a monolithic polished pillar made up of the Chunar sandstone at Sarnath. The four-seated polished lion capital of this pillar is now the national emblem of India. Traditionally, the construction of Vijaygarh fort is believed

Fig. 6 In situ painted rock shelters located at **a** and **b**. Lakhania Dari; **c** Kauva Khoh (Robertsganj) Sonbhadra district, Uttar Pradesh. Stone blade tools from near Raja ki Baithaka (100 m North-east from Likhaniya painted rock shelters), Sonbhadra district, Uttar Pradesh



to have been done by Asuras (demons), perhaps later on its construction was attributed to Kolas (tribal people). The presence of Gupta inscriptions of the circa fifth century CE in a rock shelter located below the western scarp of the Vijaygarh fort (Fig. 10a) indicates that this region was under the control of Gupta rulers. The traditional and inscriptional evidence indicates that the Agori fort in Sonbhadra district was being ruled by Baland Kings (Kharwars) during the twelfth century CE. Presently, Naugarh fort in Chandauli district from where pottery of the sixth century BCE was discovered is being used by the forest department as a rest house. Chunar fort in Mirzapur district (Fig. 10b) is situated on the right bank of the river Ganga. This fort is associated with Hindu mythology that of the Vamana Incarnation of Lord Vishnu. Not only do Hindu beliefs are associated with this fort, Jataka also described that the Buddha passed his 8th *Chaumasa* (rainy season) on the Chunar hill. The importance of this locality is very well known and famous for sandstone mining. Chunar sandstone was quarried by King Ashoka in the third century BCE to construct the monolithic pillars and transported them to different parts of India. Ramnagar fort located on the right bank of the Ganges in Varanasi (Fig. 10c) was built by Kashi Naresh Maharaja Balwant Singh in 1750 in Mughal style from the Chunar sandstone.

The study area is the home of mixture of diverse ethnicities. Gond, Kola, Kharwar, Agaria, Bhuiya, Panika, Parahiya, Bhunia, Baiga, Khairwar, Chero, Dhuria, Pankha etc. are some important tribes and semi-tribes of the study area (Drake-Brockman 1911). Their religion is a mixture of totemism, animism and polytheism, and supremacy and

dominance are echoed in their traditions, folklores and mythological stories. Each tribe and subtribe has its own peculiar customs. However, the overall cultural pattern of the life of all the communities is now gradually attaining uniformity under the socio-economic changes of modern life. They take interest in painting motifs on the walls of their homes on the occasion of marriage and festivals even today. This tradition has continued since prehistoric times. Several paintings and motifs on the walls of homes are quite similar to the paintings of the rock shelters of the area in terms of styles, technique, subject and colour composition. Some important Indian festivals celebrated by them are *Ram Navami*, *Nag Panchami*, *Shitala Ashtami*, *Diwali* and *Bhaiya Dooj*.

In Sonbhadra district, considerable deposits of iron ore are found in the Kunwar, Ningha and Bargawan-Bharhari areas (Upadhyay 2007). The iron ores in the district occur in association with banded hematite–jasper and quartzite, belonging to the Agori Formation of Mahakoshal Group. The inhabitants were involved in the smelting of iron ores in the southern part of Sonbhadra district for many centuries. Many of these sources of ore are of no importance at present because of their low grade and insignificant size. But for the ancient iron smelters like the Agaria community, the iron ore was abundantly available in the form of nodules and lumps scattered everywhere. Several small ancient mining pits along with the shafts used for the extraction of gold have been reported from Sonkorwa (the digger of gold) or Sonpahari (gold hill) near Gurmura in Chopan block. There are archaeological evidences to show that the rocks were ground and washed for gold panning by ethnic society till recent past (Upadhyay 2007).

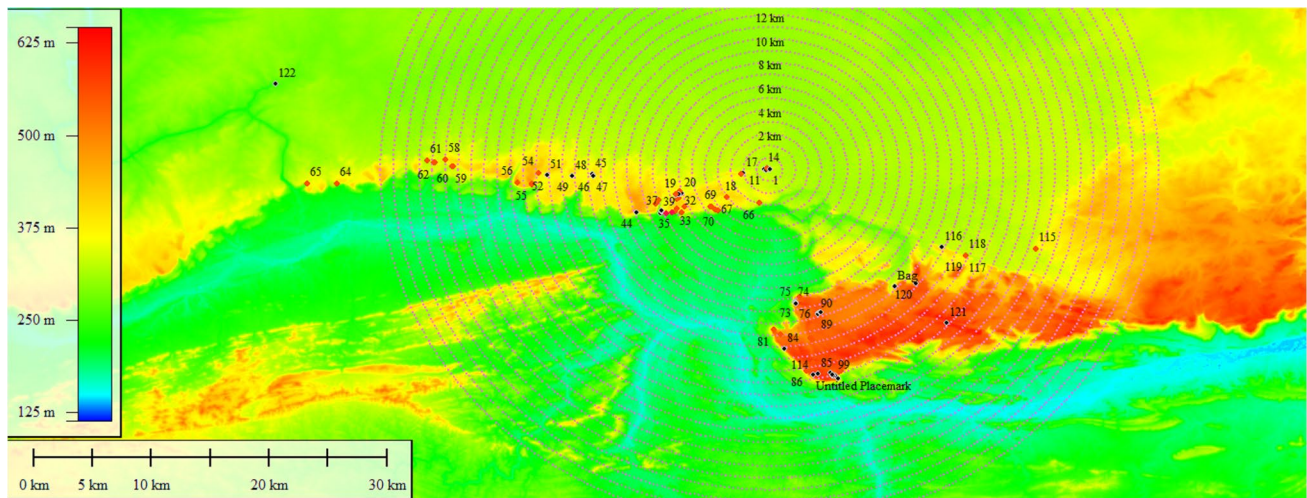


Fig. 7 Map showing the distribution of ancient painted rock shelters along the Son River

Varanasi is famous for its different characteristic features. Amongst them, ghats are the most important element. Without the ghats, it is very difficult to imagine the settlement of Varanasi city. The word “Ghat” is derived from the Sanskrit word “ghatta”, meaning a landing place or quay, or steps by a riverside. At present time, there are a total of 84 ghats on the left bank of River Ganga extending about 6 km. All these ghats have been constructed from time to time by many rulers and kings using Kaimur sandstone (Fig. 8).

The exact date of construction of many temples located along the Ganga River in Varanasi and Mirzapur districts (Fig. 10) is unavailable. Shivadwar in Ghorawal block is one of the most important and popular Shiva temples in the Sonbhadra district and the centre of attraction in the month of Savan. Gothani group of temples in the Chopan block was built in the seventeenth century. Vindhyavasini temple located in Mirzapur district was completed in ca. 1589, but it seems that the present structure is much older. This is one of the important Hindu pilgrimage centres. State Tourism department has recently sanctioned the amount of Rs 140 crores for the construction of the Vindhya Dham Corridor Project. For the devotees, construction of the ropeway has also been planned (<https://www.news18.com/news/india/amit-shah-to-lay-foundation-of-vindhya-dham-corridor-project-in-up-on-aug-1-4031255.html>). Kardameshvara temple is considered one of the oldest temples of Varanasi. It is the first night halt for the devotees of the 80 km Panchakroshi yatra of the cosmic circuit. Varanasi has been considered a “cosmocised sacred city”, and its different cosmic axes represent the universe (Singh 1994a, b). The centre of this sacred geometry is the Shiva temple of Madhyameshvara which is surrounded by a mythic or sacred field (*khestra*) referred to as the Kashi Mandala (<https://www.sawdust.online/expert-speak/panchakroshi-yatra-cosmic-circuit-of-varanasi-rana-p-b-singh-pravin-s-rana/>).

The region has witnessed the extensive use of the different varieties of Chunar sandstone as in situ rock shelters, carved sculptures of deities, building material in temples, forts, heritage buildings and monuments and also as art and architectural elements (Figs. 8, 9 and 10). From the third century BCE, the Chunar sandstone was the favourite medium of sculptures. The seated Buddha sculpture of Sarnath of the Gupta period is considered one of the best sculptures of the Indian art. Even today, Chunar sandstone has been widely used in the architecture and monuments across the country. This sandstone is widely used in India and also exported to other countries (Sen et al. 2022). Commercially, it is known as *Balua Pathhar* and has been granted GI Tag. In order to honour this, a special cover on the *Chunar Balua Pathhar* (Chunar sandstone) and a postal stamp was released on 13th October 2021, at Mirzapur (Fig. 9). The geographical area of production of Chunar sandstone is Mirzapur, Chandauli and Sonbhadra districts of Uttar Pradesh. The GI certificate (No-339), the tag has been issued in the name of the Consortium of Handicrafts and Artisans Society, facilitated by Human Welfare Association Varanasi (<https://timesofindia.indiatimes.com/city/varanasi/chunar-sandstone-second-natural-good-to-get-gi-tag/articleshow/68568263.cms>). Pottery is one of the significant medium for humans to express their sentiments. Chunar, a small city in Mirzapur district, is famous for the production of glazed red clay pottery for generations and is also providing employment to the youth. Chunar has emerged on the commercial map of India attributable to its glazed pottery business after independence. Water was possibly carried in woven baskets lined with the river clay in pre-historic times. Some of the important professions in the study area would possibly have been mining, sculpturing and pottery making in addition to agriculture.

Fig. 8 Chunar sandstone (*Balua Pathhar*) used in **a** Ganga Mahal Ghat; **b** Assi Ghat situated on the banks of River Ganga, Varanasi; **c** Vais-hano Devi temple; and **d** temple at Mirzapur Ghat



The government is planning to start a boat service between Varanasi and Chunar in Mirzapur and extend it to Vindhyaachal in order to boost tourism and development activities in this region (<https://www.thestatesman.com/india/varanasi-mirzapur-connected-cruise-service-1503011780.html>). The government has decided to develop Sonbhadra, Mirzapur and Chandauli and adjoining regions to promote eco-tourism (<https://www.mangalorean.com/yogito-promote-eco-tourism-in-sonbhadra-mirzapur/>).

Concluding Remarks

Sustainable development programmes in favour of conserving and safeguarding geoheritage and related tangible and intangible cultural components linked to these locations are emphasised by global organisations such as UNESCO, IUCN and IUGS. The geoheritage contains significant geological information that document the Earth's past. Many countries have recognised such places

Fig. 9 A stamp issued by the government of India for Chunar sandstone (*Balua Pathhar*) which has been granted GI Tag



Fig. 10 Historic forts built in Chunar sandstone (*Balua Pathhar*). **a** Vijaygarh fort, **b** Chunar fort and **c** Ramnagar fort



as geoheritage sites and have enacted strict geoconservation legislation. As of today, no geoheritage site has been designated as UGGp due to a lack of stringent geoconservation regulations in India. However, Indian geoscientists have been documenting key geoheritage sites with the intent of drawing the attention of the government to frame a law to preserve these sites for posterity. In an effort to support the identification of the eastern Son valley as an IUGS Geological Heritage Site, this study attempts to list all important geological and geotourism sites in the Varanasi, Mirzapur, Sonbhadra and Chandauli districts of Uttar Pradesh. In order to submit a proposal for the designation of the eastern Son valley as an IUGS Geological Heritage Site, this paper makes an effort to catalogue all noteworthy geological and geotourism sites in the region, which includes the districts of Varanasi, Mirzapur, Sonbhadra and Chandauli in the Uttar Pradesh state of India.

Acknowledgements GK is thankful to Panjab University, Chandigarh for allowing her to work on heritage stones and heritage sites of India. This research was supported by University Grants Commission, New Delhi through grant F. 31-196/2005 (SR) and Council of Scientific and Industrial Research, New Delhi through grant 24/0310/10/EMR-II provided to MM. SKS and PU are thankful to the IoE Scheme of Banaras Hindu University for funding this research. PK and JS thank CSIR for providing fellowship for research. We thankfully acknowledge Mrs. Asha Shukla for sharing photographs of various monuments.

Funding PK and JS, research scholars at Panjab University Chandigarh, are thankful to CSIR for providing fellowship to carry out

research work. MM is thankful to CSIR(24/0310/10/EMR-II) and UGC [31-196/2005 (SR)] for providing financial support.

Data Availability The datasets used or analysed during current study are available with the corresponding author and can be obtained on reasonable request, and all data generated or analysed during this study are included in the manuscript.

Declarations

Conflict of Interest The authors declare no competing interests.

References

- Annon (1999) Progress of geological mining investigations during the Year 1998–99. Directorate of Geology and Mining, U.P (Unpublished)
- Auden JB (1933) Vindhyan sedimentation in the Son Valley, Mirzapur District. *Mem Geol Surv India* 62(2):141–250
- Bajrangani (1995) Preliminary report on the presence of placer gold in Basal conglomerate of Vindhyan Supergroup exposed in Hardi, Naudiha and Bagisoti areas, Distt. Sonbhadra, U.P. Directorate of Geology and Mining, U.P. (Unpublished)
- Bhargava ON, Singh BP, Dhatwalia N (2021) Renukaji: an ideal site for geoheritage and geopark. In: Reddy DR (ed) *A Monograph on Potential Geoparks of India*, Intach, New Delhi, pp 37–52
- Bhattacharya D, Joshi GB, Sharma GS, Sen DB (2008) A note on the Uranium Mineralisation along Jamual-Markundi Fault, Sonbhadra and Sidhi Districts, Uttar Pradesh and Madhya Pradesh. *J Geol Soc India* 71:125–128

- Bhosale S, Chaskar K, Pandey DK, Lakhote A, Thakkar A, Chauhan G, Bhandari S, Thakkar MG (2021) Jurassic geodiversity and geomorphosite of Kanthkot area, Wagad, Kachchh, western India. *Int J Geoheritage Parks* 9(1):51–68
- Brilha J (2018) Geoheritage and geoparks. In: Reynard E, Brilha J (eds) *Geoheritage assessment, protection, and management*. Elsevier, Amsterdam, The Netherlands, pp 323–335
- Chauhan G, Biswas SK, Thakkar MG, Page KN (2021) The unique geoheritage of the Kachchh (Kutch) basin, Western India, and its conservation. *Geoheritage* 13:23
- Cockburn J (1899) Art. V.—Cave drawings in the Kaimur Range, North–West Provinces. *J R Asiat Soc Great Britain and Ireland* 31(1):89–97
- Drake-Brockman DL (1911) Mirzapur a Gazetteer, Vol. XXVII of the District Gazetteers of the United Provinces of Agra and Oudh. Superintendent Government Press, Allahabad
- Dwivedi GN, Tripathi AK, Yadav (1995) Appraisal for gold in banded iron Formation of Sonbhadra district, Uttar Pradesh. *Rec Geol Surv India* 128 (8):155–158
- Garg S, Agarwal P, Ranawat PS, Kaur P, Singh A, Saini J, Pandit MK, Acharya K, Kaur G (2021) Rajnagar Marble: a prominent Heritage Stone from Rajasthan. *NW India Geoheritage* 14(1):1–20
- Garg S, Kaur P, Pandit M, Fareeduddin KG, Kamboj A, Thakur SN (2019) Makrana marble: a popular heritage stone resource from NW India. *Geoheritage* 11:909–925
- Geological Survey of India (2012) *Geology and mineral resources of the states of India*, Miscellaneous Publication No. 30, Part-XIII: Uttar Pradesh and Uttarakhand, 2nd edn, Geol Surv India
- Ghosh A, Mukhopadhyay S, Chatterjee S (2021) Assessment of geoheritage and prospects of geotourism: an approach to geoconservation of important geological and geomorphological sites of Puruliya district, West Bengal. *India Int J Geoheritage Parks* 9(2):264–283. <https://doi.org/10.1016/j.ijgeop.2021.03.001>
- Ghosh GK (2015) Interpretation of gravity anomaly and crustal thickness mapping of Narmada-Son lineament in Central India. *J Geol Soc India* 86:263–274
- Golubic S, Seong-Joo L, Browne KM (2000) Cyanobacteria: architects of sedimentary structures. In: Riding, RE and Awramik SM (eds) *Microbial Sediments*. Springer, Berlin, Heidelberg, pp 57–67. https://doi.org/10.1007/978-3-662-04036-2_8
- Gray M (2019) Geodiversity, geoheritage and geoconservation for society. *Int J Geoheritage Parks* 7(4):226–236
- Grover AK, Mahanta BN (2018) Geotourism potential in Arunachal Pradesh – a preliminary appraisal. *Indian J Geosci* 72(4):345–360
- Jones SC, Pal JN (2009) The palaeolithic of the Middle Son valley, North-Central India: changes in Hominin lithic technology and behaviour during the Upper Pleistocene. *J Anthro Archaeol* 28:323–341
- Kale VS (2014) *Geomorphosites and geoheritage sites in India. Landscapes and landforms of India*. Springer, Dordrecht, pp 247–267
- Kaur G (2022a) Heritage stone subcommission: an IUGS subcommission of the International Commission on Geoheritage. *J Geol Soc India* 98:587–590. <https://doi.org/10.1007/s12594-022-2030-1>
- Kaur G (2022b) Geodiversity, geoheritage and geoconservation: a global perspective. *J Geol Soc India* (In Press)
- Kaur G, Agarwal P, Garg S, Kaur P, Saini J, Singh A, Pandit M, Acharya K, Rooprai VS, Bhargava ON, Kumar M, Ahuja A (2021) The Alwar Quartzite Built Architectural Heritage of North India: a Case for Global Heritage Stone Resource Designation. *Geoheritage* 13(55):1–17
- Kaur G, Ahuja A, Thakur SN, Pandit M, Duraiswami R, Singh A, Kaur P, Saini J, Goswami RG, Prakash J, Acharya K, Singh S, Garg S (2020) Jodhpur Sandstone: an Architectonic Heritage Stone from India. *Geoheritage* 12(16):1–17
- Kaur G, Bhargava ON, Ruiz de Argandoña VG, Thakur SN, Singh A, Saini J, Kaur P, Sharma U, Garg S, Singh JJ, Cardenes Van den Eynde V (2020) Proterozoic Slates from Chamba and Kangra: a Heritage Stone Resource from Himachal Pradesh. *India Geoheritage* 12(79):1–20
- Kaur G, de Oliveira Frascá MHB, Pereira D (2021) Natural stones: architectonic heritage and its global relevance. *Episodes* 44(1):1–2
- Kaur G, Kaur P, Ahuja A, Singh A, Saini J, Agarwal P, Bhargava ON, Pandit M, Goswami RG, Acharya K, Garg S (2020) Jaisalmer Golden Limestone: a Heritage Stone Resource from the Desert of Western India. *Geoheritage* 12(53):1–16
- Kaur G, Makki MF, Avasia RK, Bhaskar B, Duraiswami RA, Pandit MK, Fareeduddin KS (2019) The late Cretaceous–Paleogene Deccan traps: a potential global heritage stone province from India. *Geoheritage* 11:973–989
- Kaur G, Singh S, Kaur P, Garg S, Fareeduddin PMK, Agrawal P, Acharya K, Ahuja A (2019) Vindhyan Sandstone: a Crowning Glory of Architectonic Heritage from India. *Geoheritage* 11:1771–1783
- Kaur G, Singh SN, Ahuja A, Singh ND (2020) *Natural Stone and World Heritage: Delhi–Agra*. CRC Press, India
- Kumar G (2005) *Geology of Uttar Pradesh and Uttaranchal*. Geol Soc India, Bangalore
- Kumar S (1976) Significance of Stromatolites in the correlation of Semri Series (Lower Vindhyan) of Son Valley and Chitrakut area, U.P. *J Palaeont Soc India* 19:24–27
- Kumar S (1978) Stromatolites and environment of deposition of the Vindhyan Supergroup of Central India. *J Palaeont Soc India* 21–22:33–43
- Mathur S, Sharma S, Singh S, Mathur SC (2021) Qualitative assessment of geoheritage for geotourism promotion: a case study from Mehrangarh Ridge in Jodhpur City, Western Rajasthan, India. *Geoheritage* 13:80. <https://doi.org/10.1007/s12371-021-00604-5>
- Mathur SC, Pradip K, Rathore SS, Mathur S (2017) Mehrangarh ridge of Jodhpur City, Western Rajasthan, India: its geoheritage and geotourism sites. In: *Proceedings of International Geopark Conference in Taiwan*, pp 45–51
- McMenamin DS, Kumar S, Stanley AM (1983) Microbial fossils from the Kheinjua Formation, Middle Proterozoic Semri Group (Lower Vindhyan)~ Son Valley area, Central India. *Precamb Res* 21:247–271
- Mishra M, Sen S (2010) Geochemistry and Origin of Proterozoic porcellanitic shales from Chopan, Vindhyan basin, India. *Indian J Geol* 80(1–4):157–171
- Mishra P (ed). (1988) *Mirzapur Gazetteer. District Gazetteers of the Uttar Pradesh*, Lucknow
- Mishra VD (1977) Some Aspects of Indian Archaeology. Prabhat Prakashan, Allahabad
- Mohan K, Srivastava V, Singh CK (2007) Pattern and genesis Of lineaments in and across son-Narmada lineament zone in a part Of Central India Around Renukoot, District Sonbhadra, U.P. *Photonirvachak. J Indian Soc Rem Sens* 35(2):193–200
- Murty TVVGRK, Mishra SK (1981) The Narmada-Son Lineament and the structure of the Narmada Rift System. *J Geol Soc Ind* 22(3):112–120
- Nair KKK, Jain SC, Yedekar DB (1995) Stratigraphy, structure and geochemistry of the Mahakoshal greenstone. *Mem Geol Soc India* 37:403–432
- Narain AK, Pant PC (1965) A summary account of archaeological exploration in East U.P. 1962–63. *Bharati Bulletin of the College of Indology, Banaras Hindu University, Varanasi* 8(1):116–135
- Pandit MK, Master S (2021) The Ramgarh Terrestrial impact structure in Rajasthan State: a ‘Geoheritage Site and Geopark’ Candidate from North-Central India. *Geoheritage* 13(3):1–16
- Pant PC (1982) *Prehistoric Uttar Pradesh—a study of Old Stone Age*. Agam Kala Prakashan, Delhi
- Prabhakar BC, Radhika KN (2022) Recognizing New Geoheritage Sites in Karnataka. *India Geoheritage* 14(3):1–24. <https://doi.org/10.1007/s12371-021-00626-z>

- Prakash R, Dalela S (1982) Stratigraphy of Vindhyan in Uttar Pradesh: a brief review. In Valdiya KS (ed) *Geology of Vindhya*. A volume in honour of Prof. R.C. Mishra, Hindustan Publishing Corp. (India), New Delhi, pp 55–79
- Ramakrishnan M, Vaidyanadhan R (2010) *Geology of India* (vol. 1 & 2). Geol Soc India, Bangalore
- Roy A, Devarajan MK (2000) A reappraisal of the stratigraphy and tectonics of the Palaeoproterozoic Mahakoshal supracrustal belt, central India. *Geol Surv India*, Spl Pubs 57:79–97
- Sen S (2010) *Geochemistry and provenance of the siliciclastics from Kaimur group, Vindhyan supergroup, Mirzapur and Sonbhadra Districts, Uttar Pradesh, India*. PhD Thesis, Banaras Hindu University
- Sen S, Kaur P, Saini J, Kaur G, Mishra M (2022) Kaimur Sandstone of Vindhyan Supergroup: a prevalent prehistoric and Ancient Monumental Heritage Stone from Son Valley of Central India. *Geoheritage* 14(62):1–21. <https://doi.org/10.1007/s12371-022-00687-8>
- Sen S, Mishra M, Patranabis-Deb S (2014) Petrological study of the Kaimur group sediments, Vindhyan supergroup, central India: Implications for provenance and tectonics. *Geosci J* 18(3):307–324
- SES-INSA (The Society of Earth Scientists, Lucknow and Indian National Science Academy), New Delhi (2019) Status report on geoheritage and geoparks: Indian and International Scenario & Draft Legislation 2019
- Sharma M, Singh VK (2019) Megascopic carbonaceous remains from Proterozoic basins of India. In: Mondal M (ed) *Geological Evolution of Precambrian Indian Shield*. Society of Earth Scientist Series, Springer, Cham, pp 725–749. https://doi.org/10.1007/978-3-319-89698-4_27
- Sharples C (1993) A methodology for the identification of significant landforms and geological sites for geoconservation purposes. Forestry Commission, Tasmania
- Shukla B, Sharma M (2016) A new assemblage of large-sized microfossils from the Salkhan Limestone (> 1600 Ma), Semri Group, Vindhyan Supergroup, India. *J Palaeontol Soc India* 61(2):287–299
- Singh A (2012) Salkhan Fossil Park cries for protection. *Curr Sci* 103(5):469
- Singh R P (1994a) Sacred geometry of India's holy city, Varanasi: Kashi as cosmogram. *National Geogr Soc India*
- Singh RPB (1994b) Sacred Geometry of Varanasi. *Nat Geogr J India* 40:189–216
- Singh S, Kanhaiya S, Singh A, Chaubey K (2019) Drainage network characteristics of the Ghaghghar River Basin (GRB), Son Valley, India. *Geol Ecol Landsc* 3(3):159–167. <https://doi.org/10.1080/24749508.2018.1525670>
- Sreejith C, Del Lama EA, Kaur G (2021) Charnockite: a candidate for 'Global Heritage Stone Resource' designation from India. *Episodes* 44(1):19–29
- Tewari R (1990) *Rock Paintings of Mirzapur*. Monograph on the Rock Paintings of District Mirzapur, U.P. State Archaeological Organization, Lucknow
- Tewari R (1998) In quest of Early Iron Age sites in Karamnasa valley. *Pragdhara Journal of the UP State Archaeology Department, Lucknow* 8:57–67
- Tewari R, Singh PK, Srivastava RK, Singh GC (1995) Archaeological investigations in district Sonbhadra, Uttar Pradesh, *Pragdhara Journal of the UP State Archaeological Organization* 5:55–132
- Tiwari RN et al. (1996) *Geology of the Son valley Vindhyan (Martkundi-Dala sector)*. Excursion Guide. Dep Geol, BHU
- Upadhyay P (2007) *Minerals and Mining in Ancient India (From the earliest times to the beginning of Christian era)*. Kala Prakashan, Varanasi
- Upadhyay P (2013) A note on the excavation at Raipura, district Sonbhadra, Uttar Pradesh, *Bharati Bulletin of the Department of AIHC and Archaeology, Banaras Hindu University, Varanasi* 37:146–158
- Walter MR (1976) *Stromatolites*. In: Walter MR (ed) *Developments in sedimentology*, 20. Elsevier, Amsterdam

Further Reading

- <http://www.hindalco.com/operations/aluminium-smelting/redukoot>. Accessed 15 Mar 2022
- <https://chandraprabhawildlife.com/>. Accessed 20 Apr 2022
- https://economictimes.indiatimes.com/news/politics-and-nation/gold-deposits-found-in-uttar-pradeshs-sonbhadra/articleshow/74244767.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst. Accessed 25 Mar 2022
- <https://en.unesco.org/global-geoparks>. Accessed 25 Apr 2022
- <https://en.unesco.org/global-geoparks/list>. Accessed 25 Apr 2022
- <https://geoheritage-iugs.mnhn.fr/>. Accessed 25 Apr 2022
- https://geoheritageiugs.mnhn.fr/media/pays/terms_of_reference_of_commission_on_geoheritage_final.pdf. Accessed 25 Apr 2022
- <https://globalheritagestone.com/>. Accessed 25 Apr 2022
- <https://iugs60.org/100-geosites/>. Accessed 13 Jul 2022
- <https://sonbhadra.nic.in/about-district/>. Accessed 17 Mar 2022
- <https://timesofindia.indiatimes.com/city/varanasi/chunar-sandstone-second-natural-good-to-get-gi-tag/articleshow/68568263.cms>. Accessed 17 Mar 2022
- <https://unesdoc.unesco.org/ark:/48223/pf0000377255>. Accessed 25 Apr 2022
- <https://upecotourism.in/KaimoorWildlife.aspx>. Accessed 28 Apr 2022
- https://www.iucn.org/sites/dev/files/progeo_leaflet_en_2017.pdf. Accessed 25 Mar 2022
- <https://www.iugs.org/commissions>. Accessed 25 Mar 2022
- <https://www.sawdust.online/expert-speak/panchakroshi-yatra-cosmic-circuit-of-varanasi-rana-p-b-singh-pravin-s-rana/>. Accessed 6 Apr 2022
- <https://www.news18.com/news/india/amit-shah-to-lay-foundation-of-vindhya-dham-corridor-project-in-up-on-aug-1-4031255.html>. Accessed 10 April 2022
- <https://www.thestatesman.com/india/varanasi-mirzapur-connected-cruise-service-1503011780.html>. Accessed 10 Apr 2022
- <https://www.mangalorean.com/yogi-to-promote-eco-tourism-in-sonbhadra-mirzapur/>. Accessed 29 Apr 2022

Springer Nature or its licensor (e.g. a society or other partner) holds exclusive rights to this article under a publishing agreement with the author(s) or other rightsholder(s); author self-archiving of the accepted manuscript version of this article is solely governed by the terms of such publishing agreement and applicable law.