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ORIGINAL ARTICLE

Vindhyan Sandstone: a Crowning Glory of Architectonic Heritage from India

Gurmeet Kaur[1] · Seema Singh[1] · Parminder Kaur[1] · Sanchit Garg[1] · Fareeduddin[2] · Manoj K. Pandit[3] · Pradeep Agrawal[4] · Kireet Acharya[5] · Anuvinder Ahuja[6]

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Abstract

Sandstones belonging to the Vindhyan Supergroup (Proterozoic age) adorn several architectonic heritage structures in northern and north-western India. The Mesolithic Bhimbetika rock shelter, a UNESCO World Heritage site, represents the oldest record of its use by the pre-historic man. The Sanchi Stupas, Qutub Minar, Humayun's Tomb, Tomb of Safdarjung, Agra Fort, Red Fort, Chittorgarh Fort, Buland Darwaza (gate) in Fatehpur Sikri and Jama Masjid, to name a few, are also heritage monuments built of Vindhyan sandstone. Most of these structures are also listed as UNESCO World Heritage sites. India Gate, Rashtrapati Bhawan, Central Secretariat, Parliament Building in Delhi and many more such buildings made with Vindhyan sandstone are some of the more popular architectonic heritage sites in the capital of India. These architectonic heritage structures still stand in their pristine form and bear testimony to the lasting endurance. Vindhyan sandstone, used extensively as dimension stone, is monomineralic in composition with chemically (acids and alkalis) resistant quartz as the dominant mineral. Vindhyan rocks include well-bedded, undeformed and unmetamorphosed sandstone, limestone and mudstone; however, the sandstone has been the most favoured stone for architectural (heritage) structures. Vindhyan sandstones exhibit a range of colours from dark red to brown, earthy buff, yellow, off-white to spotted types, etc. The most popular are the off-white varieties owing to their aesthetic appearance and resistance to weathering. Amongst all the stratigraphic units, the Vindhyan Supergroup alone is the major contributor of masonry sandstone reserves in India; the rocks are quarried throughout the Vindhyan Basin. The Vindhyan (Supergroup) sandstones are known by numerous local trade names, such as Agra Red/Pink, Dholpur Red/Pink/Beige and Bansi Pink. In modern times, Vindhyan sandstone has also been put to numerous other uses such as garden furniture, sculpturing, carving, floor tiling, paving and cladding, owing to its resistance to weathering and ease of workability. The current and/or curved bedding patterns, spots due to iron staining, further enhance appearance and demand of finished Vindhyan sandstone as dimension stone. It meets all the requisite criteria for according the status of a Global Heritage Stone Resource.

Keywords Sandstone · Vindhyan · Bhander Group · Architectonic heritage stone · India

✉ Manoj K. Pandit
manoj.pandit@gmail.com

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

[2] Geological Society of India, Bangalore, India

[3] Department of Geology, University of Rajasthan, Jaipur 302004, India

[4] Department of Mines and Geology, Govt. of Rajasthan, Udaipur, India

[5] JM Environet (Ensyscon) Pvt. Ltd., Jaipur, India

[6] F-90D, Sec-57, SL3, Gurgaon, India

Introduction

'Dimension stone' is defined as a quarried natural rock material that can be split/cut into blocks and slabs of desirable dimensions (Dolley 2007 and references therein). It is imperative to mention that texture, mineralogical composition and colour of the rock play an important role in the selection of rock material as a dimension stone. The mineralogical and textural attributes of a rock are very important in utilising its strength, durability, sustainability and suitability for use as a dimension stone. Other important parameters of a dimension stone are the ability of the rock to take a good polish and surface finish (Dolley 2007). The previously mentioned are essential parameters for dimension stone. Popular building

stones used since the advent of civilization in construction of forts, palaces, religious places, epitaphs, tombs, mausoleums, etc. are granite, granulite, sandstone, marble, limestone and slate. However, it largely depends upon the locally available material, and quartzite has been used for its strength and ease of access. These rocks were used in architectonic heritage structures, even before formal quantification of physical attributes for dimension stones. The aesthetics, availability and cultural and religious sentiments related to a particular rock/stone probably made the choice for these rocks/stones for construction of ancient architectonic structures. These rocks also fulfil the criteria of a dimension stone and are widely used in contemporary constructions, in spite of alternative options and availability of a variety of synthetic material. The International Commission on Geoheritage (IUGS/IGC), through its Subcommission on Heritage Stone, encourages documentation of information on heritage stones from different countries to be designated as Global Heritage Stone Resource (GHSR). A heritage stone is broadly defined as a stone/rock, which has been used over a long period by communities/societies to build architectonic heritage structures, providing a glimpse of their varied cultures and traditions. The Heritage Stone Subcommission (HSS), through its stringent protocols and procedures, designates a stone as GHSR that fulfils the parameters defined in their terms of reference (ToR; Cooper et al. 2013; Pereira et al. 2015).

India is one of the leading producers of sandstone in the world with a wide array of sandstone reserves across the country. The Vindhyan Basin, in particular the largest repository of sandstone in India, extends in an E-W direction in north-central India across Rajasthan, Madhya Pradesh, Uttar Pradesh and Jharkhand states. Therefore, the most widely and commonly used sandstone in India, since historic times, geologically belongs to the Vindhyan Supergroup. This paper focuses on the Vindhyan sandstone from eastern Rajasthan State. This has been the most common dimension stone in several heritage (both medieval and modern) buildings in northern and north-western India, signifying its cultural and traditional connection. Geological setting, mineralogy, textural and other attributes of Vindhyan sandstone are discussed and evaluated to present a case for Vindhyan sandstone to be designated as a Global Heritage Stone Resource. It has been used in several architectonic heritage structures and fulfils the HSS criteria specified for Global Heritage Stone Resource.

Regional Geology of the Vindhyan Basin

The Proterozoic Vindhyan Supergroup rocks were deposited in an intracratonic basin, popularly known as the 'Vindhyan Basin'. It is an E-W trending basin, extending from eastern Rajasthan in the west to the Son Valley region in eastern India (Fig. 1). Its western limit is constrained by the Great Boundary Fault, southern and south-western limits by the Deccan Traps, south-eastern one by the Bijawar and Mahakoshal groups and northern one by the basement rocks of Bundelkhand Craton and the Gangetic alluvium (Fig. 1). The Bundelkhand Craton/Massif in a way divides the sickle-shaped Vindhyan Basin into the north-western Rajasthan sector and south-eastern Son Valley sector, respectively (Fig. 1; see also Prasad 1984). The rocks of the Vindhyan Supergroup in the north-western sector are exposed in eastern Rajasthan State whereas rocks in the south-eastern segment are exposed in parts of Madhya Pradesh, Uttar Pradesh and Jharkhand states. These rocks represent the largest, thickest, almost undeformed and unmetamorphosed sedimentary succession of India, primarily deposited in a shallow marine environment (Oldham 1856; Mallet 1869; Auden 1933; Valdiya et al. 1982; Prasad 1984, Bhattacharyya 1996; Verma 1996; Srivastava and Sahay 2003; Banerjee et al. 2006; Bose et al. 2001, 2015; Gilleaudeau et al. 2018 and references cited therein). The sandstone deposits of Marwar Basin in western Rajasthan were earlier considered trans-Aravalli Vindhyans; however, some recent studies have shown that the Marwar Supergroup is geologically younger than the Vindhyan Supergroup (Malone et al. 2008, Davis et al. 2014, Turner et al. 2014).

The Vindhyan Supergroup rocks attain a maximum thickness of about 4.5–5 km and have an areal spread over 100,000 km^2 (Bhattacharyya 1996; Gilleaudeau et al. 2018 and references cited therein). It is subdivided into Lower and Upper Vindhyans, both separated by a break of unknown period (Prasad 1984; Bose et al. 2001; Gilleaudeau et al. 2018 and references cited therein). The Vindhyan Supergroup is stratigraphically subdivided into four groups, namely, from the oldest to the youngest, Semri Group belonging to the Lower Vindhyan and Kaimur and Rewa and Bhander groups belonging to the Upper Vindhyan. These groups are further subdivided into several stratigraphic formations (Table 1). The Vindhyan Supergroup consists of two distinct sedimentary facies:

(i) The dominantly calcareous and argillaceous facies of the Lower Vindhyan Semri Group and
(ii) The dominantly arenaceous facies Upper Vindhyan Kaimur, Rewa and Bhander groups (Prasad 1984; Bhattacharyya 1996)

The Vindhyan sandstones belong to the Kaimur, Rewa and Bhander groups. The Bhander Group sandstone has been the most widely used dimension stone in the past due to its conspicuous colour, with shades varying from dark red-brick red and brown to pink.

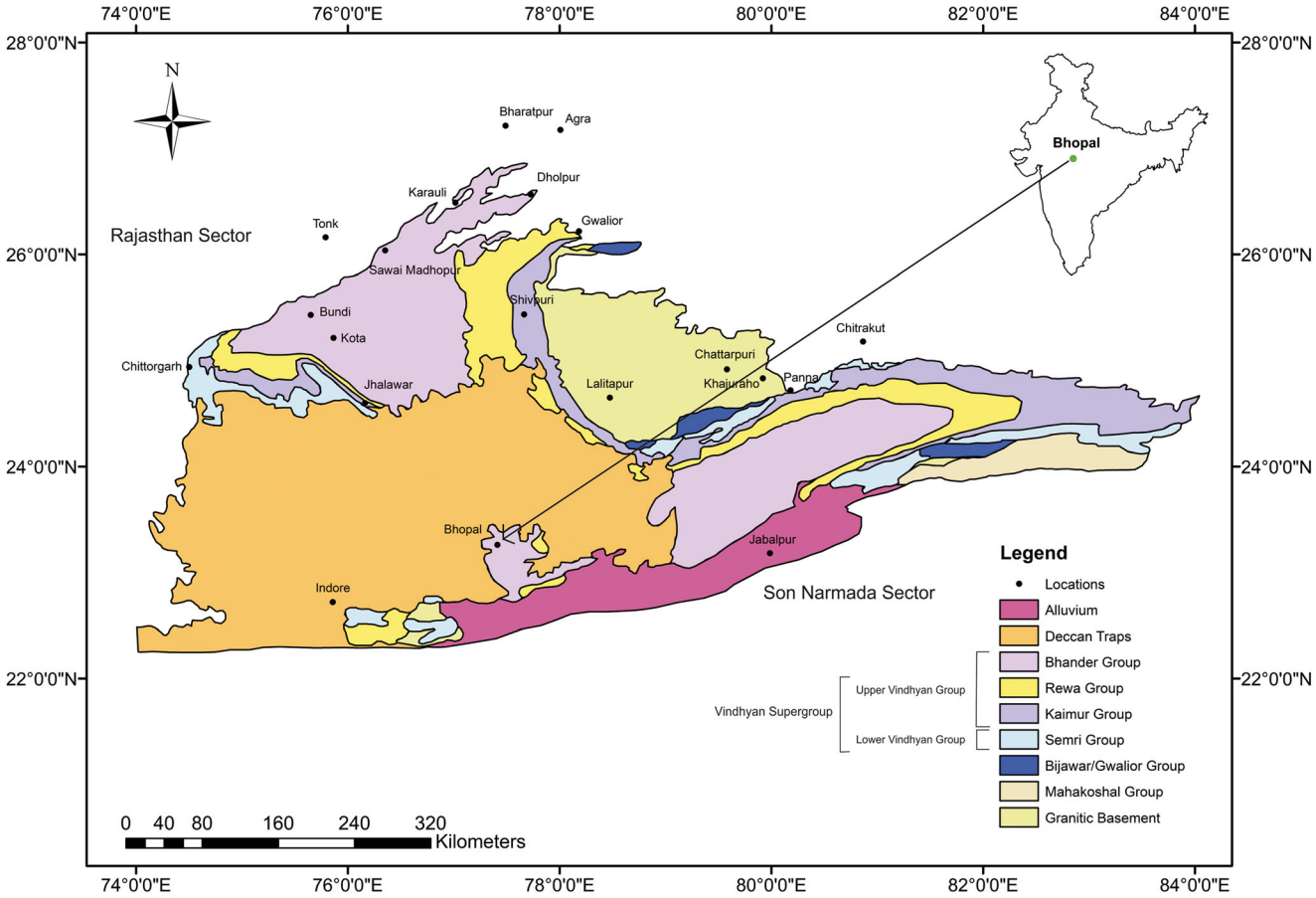

Fig. 1 Map showing extent and stratigraphic subdivisions of the Vindhyan Supergroup (adapted from Prasad 1984; Malone et al. 2008). Outline map of India is given in the inset

Bhander Group

The Bhander Group is the youngest stratigraphic unit of the Vindhyan Supergroup, separated from the underlying Rewa Group by a minor disconformity (Table 1). It is mostly composed of sandstones with subordinate shale and limestone. Bhander sandstone is fine grained and compact and displays hues of red and yellow and streaks as a result of minor lithological contrast originated during the deposition of sand grains and subsequently by lithification and diagenesis. The Bhander Group sandstone has been the preferred choice for several architectonic heritages, mainly because of its monomineralic (mostly quartz) composition, imparting durability, resistance to chemical alteration, regular bedding and easy workability. The Bhander Group sandstones are well exposed in Dholpur, Kota, Bharatpur, Sawai Madhopur, Tonk, Bundi, Jhalawar, Karauli, Bhilwara and Chittorgarh districts in eastern Rajasthan State. The Son Valley occurrences of white, creamy and red sandstone are known from Shivpuri, Panna, Rohtas, Keinjua and several other localities. The Bhander sandstone,

Table 1 Geological succession of the Vindhyan Supergroup in Rajasthan sector (after Prasad 1984)

Vindhyan Supergroup (Rajasthan sector)		
Major stratigraphic division	Group	Age
Upper Vindhyan	Bhander Group (~ 1200 m)	Ediacaran (De 2003, 2006)
	Rewa Group (285 m) Kaimur Group (180 m)	> 1100 Ma (Gregory et al. 2006; Malone et al. 2008)
Lower Vindhyan (erstwhile Semri series)	Khorip Group (475 m) Laswaran Group (272 m)	1630 Ma (Ray et al. 2002, 2003; Rasmussen et al. 2002)
	Sand Group (210 m)	
	Satola Group (885 m)	

particularly the red variety, has been used as a dimension stone, over many centuries for architectonic heritage not only in Rajasthan, Uttar Pradesh and Madhya Pradesh states but also in more distant parts of India.

Vindhyan Sandstone Deposits of Eastern Rajasthan

The Vindhyan Supergroup rocks are extensively developed in eastern Rajasthan and define a tectonic contact, the Great Boundary Fault, with the basement rocks (Prasad 1984). The region is the major contributor of masonry sandstone, quarried from several Upper Bhander Group (Maihar Formation) deposits. A compilation prepared by the Rajasthan State Mines and Geology Department mentions the occurrence of splittable sandstone from a 16-000 km^2 area (including Marwar sandstones) in Rajasthan. Major production of Vindhyan sandstone comes from quarries (Fig. 2) located in Bharatpur, Karauli, Dholpur, Kota, Sawai Madhopur, Bundi, Baran, Bhilwara, Jhalawar and Chittorgarh districts in eastern Rajasthan (Fig. 1). The sandstone in these areas is thinly to thickly bedded, fine- to medium-grained, variegated, mainly pink and red to creamish pink in colour. Manual to semi-mechanical methods of mining are generally practiced in these areas except for some quarries in Bansi Paharpur (Bharatpur district) and isolated ones in Dholpur district where mechanised quarrying is being adopted. Further details, based on personal observation and data compiled from local offices of the Department of Mines and Geology, Government of Rajasthan, are given hereunder.

Karauli District The splittable sandstone quarries in Karauli district are located at villages Makanpur-Batda, Garhi Ka Gaon, Bhankri in Mandrayal Tehsil, Lotda, Mahua Khera, Behrai in Masalpur Tehsil, Atewa-Kalyani-Mamchari in Karauli Tehsil and Bahadurpur of Sapotra Tehsil. A total of 131 sandstone mining leases are operational in this district. Most of the sandstone leases are between 1 and 10 ha, except 20 leases that are 50 to 1000 ha.

Bharatpur District In Bharatpur district, the splittable/blockable sandstone is mostly found in Roopwas Tehsil at Sirondh (19 leases), Bansi Paharpur (3 leases), Rajpura (2 leases), Chaikora (3leases) and at Churari Dang, Basai Khori, Mahalpur Chura, Kharga Ka Nagla (single lease each). The total number of leases is 31, mostly between 1 and 10 ha except four leases between 45 and100 hectares.

Dholpur District In Dholpur district, the splittable/blockable sandstone is mostly found in Bari, Sar Mathura and Baseri Tehsils. The main mining areas are Chilachondh, Naksoda, Sanaura of Bari Tehsil, Kachhpura, Tarwa, Math Pipraundh, Barauli, Liloti, Khurdia, Amanpura, Badagaon, Khushalpura, Chandpura, Kota, Sar Mathura. Kanchanpura and Maharpur in Sar Mathura Tehsil and Vijayapura, Bansrai, Tajpura, Nadaripur and Tilua in Baseri Tehsil. The total number of mining leases in this district is 188, most of them between 1 and 4 ha except four leases that are between 5 and 100 ha.

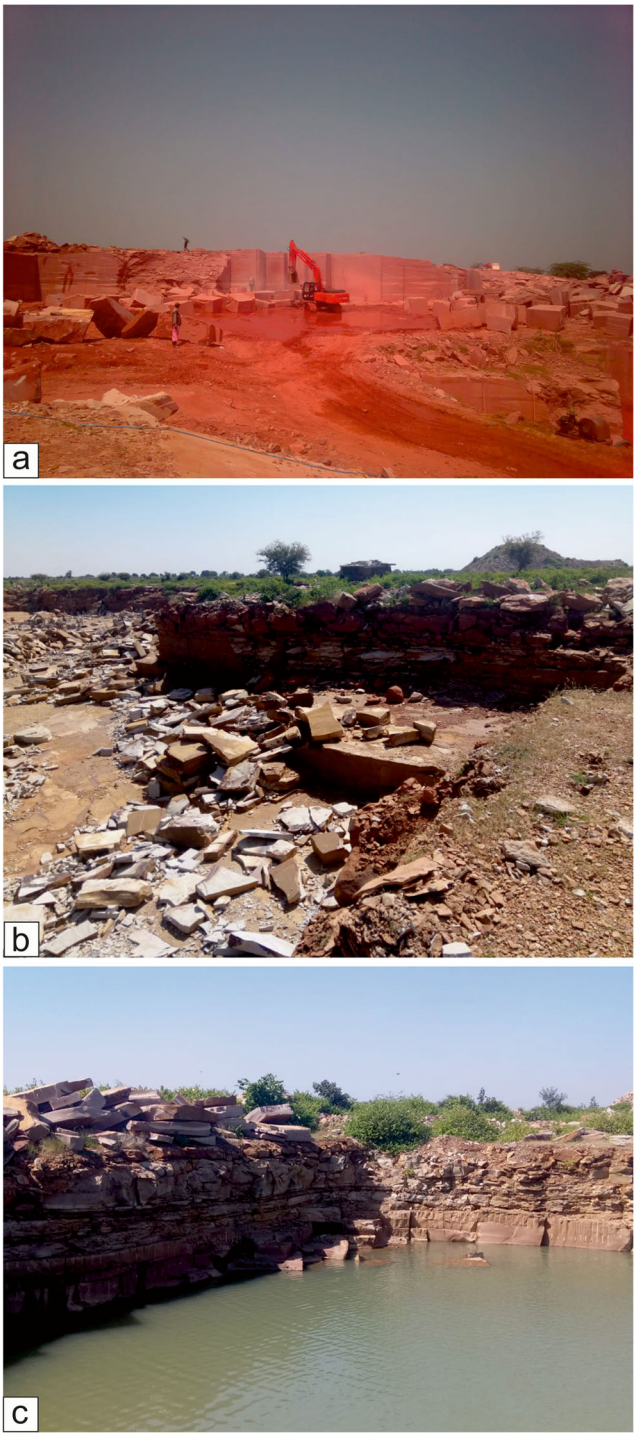

Fig. 2 **a**–**c**. Photographs showing (Bhander) sandstone quarries in eastern Rajasthan. The mining activity in these quarries is largely manual or semi-mechanical

There are no specific trade names given to Vindhyan sandstones, unlike the exotic trade names in vogue for marble and granite to specify different types on the basis of colour, texture, pattern, purity, etc. The Vindhyan sandstones show a rather limited variation and range in colour from various shades of red to off-white (pale-pink) and dark brown (chocolate coloured). The most abundant type is the spotted red; however, it is not a favourite dimension stone and used in buildings of lesser significance and for pavements. The trade names of Vindhyan sandstone are more realistic and location specific to the deposit and its colour, such as Karauli Red, Dholpur White (Beige)/Red/Pink, Bansi Red/Pink and Agra Red.

Petrography and Mineralogy of Vindhyan Sandstones

According to Folk's (1980) petrographic classification scheme, majority of Vindhyan Supergroup sandstones classify as 'quartz arenite' with volumetrically subordinate subarkose and sublitharenite varieties (Bhardwaj 1970; Bose and Chakraborty 1994; Banerjee and Banerjee 2010; Khan 2013; Sen et al. 2014; Verma and Shukla 2015; Quasim et al. 2017 and references therein). Amongst various Vindhyan sandstone varieties, the red, beige and chocolate brown sandstones (Fig. 3) are commonly and most popularly used as facade as well as interior building stone/material. Their petrographic details are illustrated in Fig. 4 and described hereunder. The red and beige sandstone varieties are quartz arenites whereas the chocolate brown variety is classified as sublitharenite. All the varieties have quartz as the most dominant framework mineral, followed in abundance by rock/lithic fragments and feldspars (orthoclase > microcline), wherein the matrix (< 15%) consists of silt and clay. In comparison with red and beige varieties, the chocolate brown sandstone has a relatively higher proportion of shale, siltstone and chert fragments (~ 10%). The dominant framework mineral is monocrystalline, colourless to off-white, subangular to subrounded, well-sorted, fine-grained and low to medium sphericity quartz grains. The monocrystalline quartz grains show undulatory as well as unit extinction. The grains have commonly long to point contacts whereas few polycrystalline and other quartz grains show concavo-convex contact, interpenetrated as sutured contacts. In general, three types of cement have been identified: the dominant one being ferruginous and siliceous cement in red sandstone, dominant siliceous with traces of ferruginous in beige sandstones and dark-ferruginous and siliceous cement with traces of argillaceous content in chocolate brown sandstone. The cement is the dominant binding material, and in places, the framework quartz grains appear as angular to subangular in shape due to silica overgrowth in the form of cement, which, perhaps, occurred during compaction. In the beige sandstones, the siliceous cement is the most abundant and responsible for its colour. The iron-oxide cement is dark brown to opaque in places, indicating a mix of manganese and other sesquioxides in the red and chocolate brown sandstone varieties, which also justifies their colour. The iron-oxide cement is present as thin, regular coating around framework grains, as isolated patches and as pervasive pore fillings. Petrographic examination of sandstones indicates a high textural maturity while monomineralic quartz composition indicates a high compositional maturity, thereby explaining strength and durability of the rock.

Fig. 3 Semi-polished slabs of red-, beige- and chocolate-coloured Vindhyan sandstones

Vindhyan Sandstone in Ancient and Contemporary Monuments

The oldest record of use of Vindhyan sandstone comes from Bhimbetika in central India (Mathur 1986), an archaeological site for cave shelters (Fig. 5a, b). The Sanchi Stupas (Fig. 5c) and Khajuraho Temple (Fig. 6a, b), the World Heritage sites in central India, also record the use of Vindhyan sandstone. Forts and palaces built from the fifth to eighteenth century in eastern

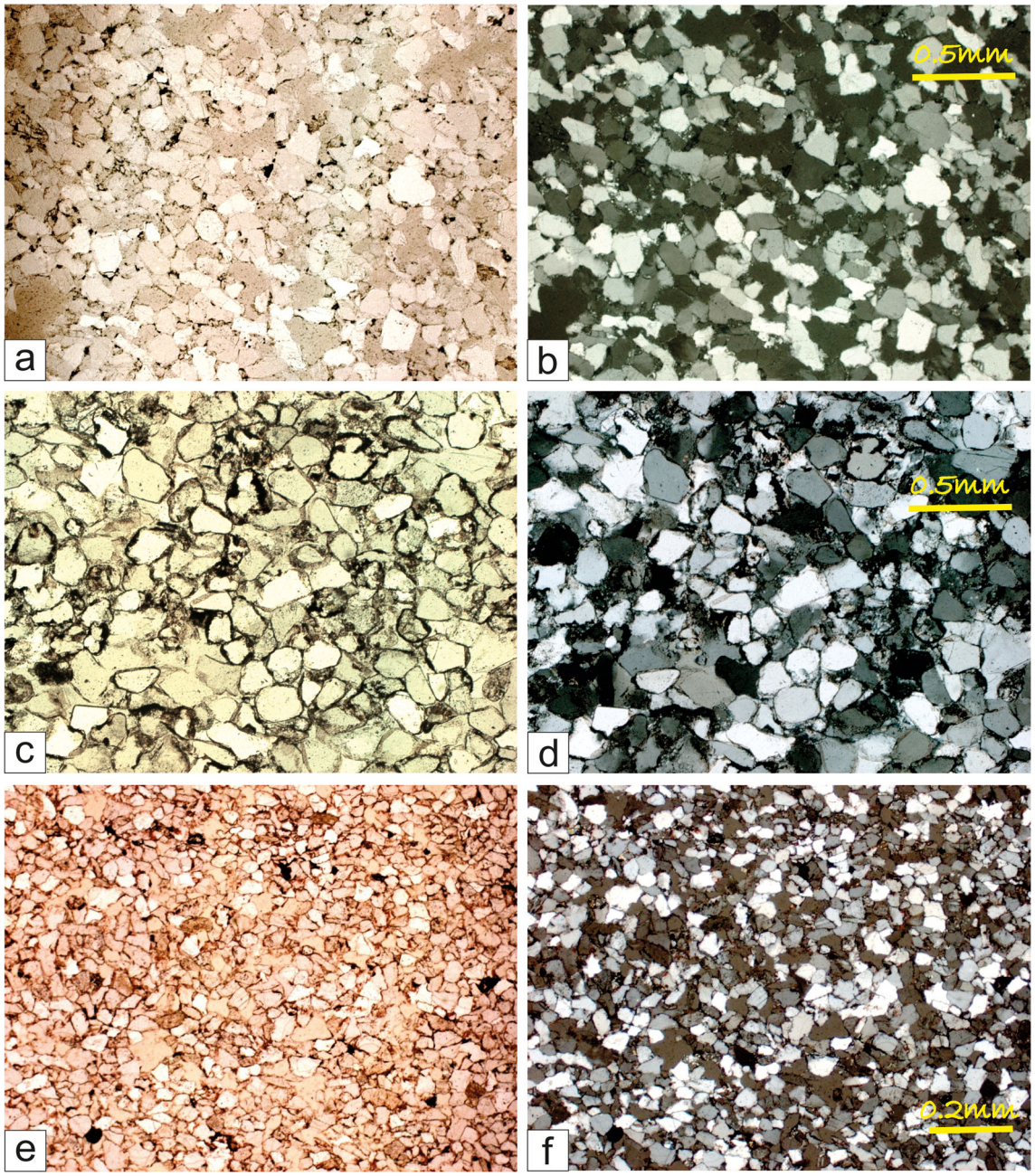

Fig. 4 Textural attributes of Vindhyan sandstones. Photomicrographs of chocolate brown (**a**), beige (**c**) and red (**e**) sandstone samples (under plane-polarized light). The right side shows corresponding crossed nicol view of photomicrographs

Rajasthan State also used the Vindhyan sandstone. The forts are normally enclosed within defensive walls made up dominantly of Vindhyan sandstone. The Chittorgarh Fort (Fig. 7a, b), Bundi Fort (Fig. 8a–c), Jal Mahal or the Water Palace and Hawa Mahal or the Palace of Winds in Jaipur (originally made in pink sandstone and later painted pink) are some of the examples of medieval Rajput architectonic heritage structures made of Vindhyan sandstone. These structures exhibit fine craft of those periods and suitability of these rocks for fine carvings and intricate motif and *jali* (latticed screen) work. Many of these forts are listed as UNESCO World Heritage sites. Several temples in and around these forts and old historic cities/towns of eastern Rajasthan are constructed of Vindhyan sandstone (Fig. 8a). The Qutub Minar of Delhi (Fig. 9a), another World Heritage site, built in the year 1193 AD during the reign of Qutab-ud-din Aibak, is an example of Mughal architecture utilising Vindhyan sandstone during the beginning of Delhi Sultanate era in India. It is a

Fig. 5 **a**, **b** Bhimbetika cave shelter in central India. **c** A carved sandstone pillar

five-storey tower with the first three storeys are built in in red sandstone and the upper two in marble and sandstone. Humayun's Tomb (Fig. 9b) in Delhi and Agra Fort, the latter also called Fort Rouge/Lal Quila/Qila-i-Akbari (Fig. 9c), are examples of Mughal architectonic heritage structures in northern India. Delhi, the capital city of India, showcases numerous architectonic heritage buildings made in red sandstone during British colonial times, namely the Rashtrapati Bhawan (official residence of the President of India), Parliament House, the Vidhan Sabha (State Assembly Building), the Central Secretariat (Fig. 10a) and India Gate (Fig. 10b). The Panjab

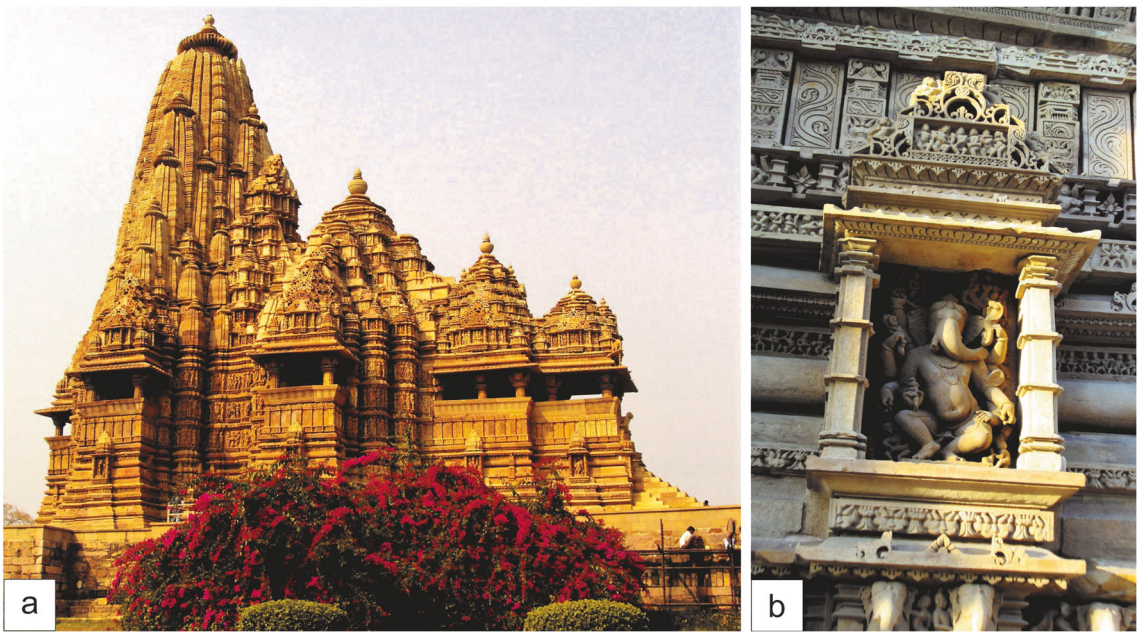

Fig. 6 **a**, **b** Khajuraho Temple in west-central India

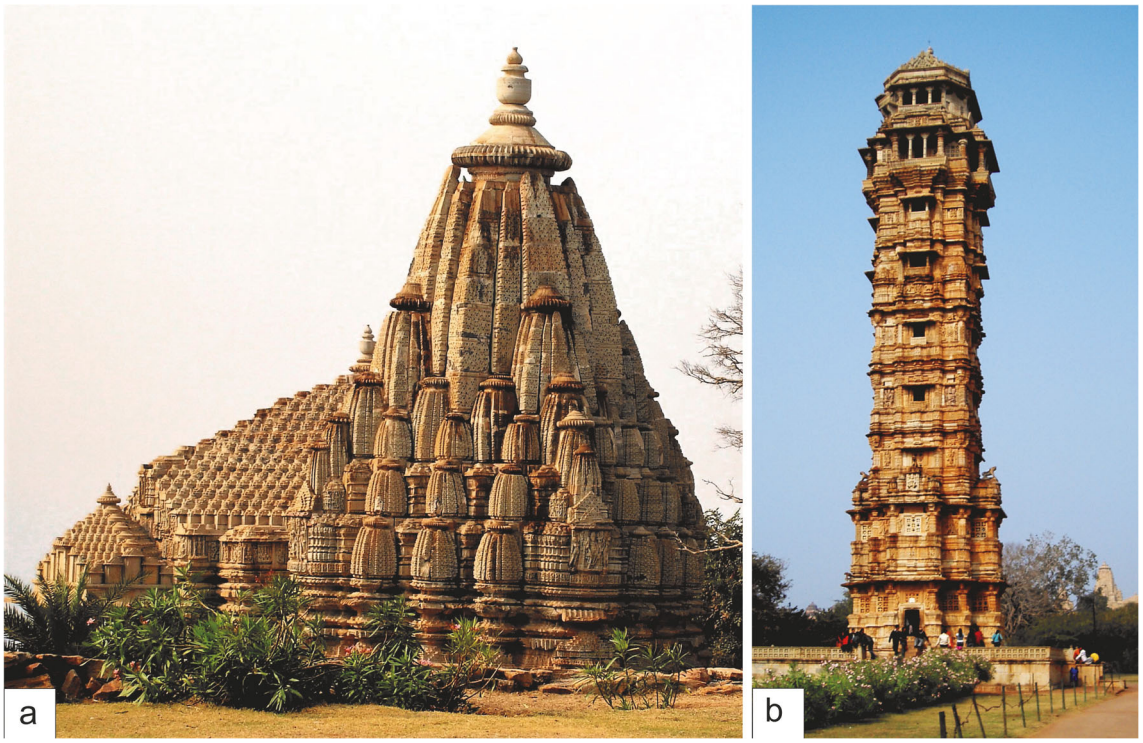

Fig. 7 Photographs of a temple (**a**) and Victory Tower (**b**) in Chittorgarh Fort, eastern Rajasthan

University campus in Chandigarh is also made in red sandstone like scores of other buildings in modern-day north-western India (Fig. 10c). Architectonic heritage buildings and monuments constructed of Vindhyan sandstone along with their specific attributes are documented in Tables 2 and 3.

Fig. 8 **a**–**c** Photographs of Bundi Fort in eastern Rajasthan

Fig. 9 Photographs of Qutub Minar (**a**) and Humayun's Tomb (**b**) in Delhi and main entrance of Red Fort in Agra

Contemporary Usage of Vindhyan Sandstone

Vindhyan sandstone has been extensively used in ancient monuments and continues to be much in demand as the preferred building stone in several contemporary buildings, mansions, hotels, temples, etc. In modern times, Vindhyan sandstone has been put to use as a paving, cladding and flooring (Fig. 11a, b) material owing to its resistance to weathering and easy workability. It has been traditionally used as roof slabs and can be split into slabs of desirable thickness. Nowadays the 2′×2′×12-mm dimensions are quite popular for facade panelling. It is also used in garden furniture and fixtures, sculptures, handicrafts, household pestle and mortar (popular for grinding spices in Indian kitchens), etc. The Vindhyan sandstone from Kota district is also compared with the York Stone from England.

Vindhyan Sandstone as Heritage Stone

The strength, durability and sustainability of sandstone against weathering, in general, make this rock a suitable dimension stone. The patterns and varying thickness of laminae add to the aesthetic appeal of this rock. Various colours and hues in red, buff, yellow, cream and spots make them one of the most desirable stones in the contemporary masonry stone industry in India. The sandstones show a wide range of geological ages, depositional environment, texture (fabric and structure) and mineralogical composition; therefore, not all sandstone types possess the same characteristics. Sandstone, a terrigenous clastic sedimentary rock, consists primarily of quartz grains in the size range of 63 μm to 2 mm and shows a wide compositional range owing to the presence of feldspar, lithic/rock fragments, fine-grained matrix between framework grains, authigenic minerals and cement. The presence and variable proportions of the above-mentioned contents result in abrasion resistance, durability and sustainability of sandstone that make it a suitable dimension stone. The term 'sandstone' (sediment size based) does not imply the amount of quartz present in the rock, and some sandstones may contain insignificant quartz (Nichols 2009). These do not have the durability and are unsuitable as dimension stones. Therefore, the quartz arenite type of sandstone is the most suitable and sought-after dimension stone. It is the cementing material that largely defines the colour of the specific sandstone. Iron oxides, silica, clay/calcite and glauconite impart shades of red, white, yellow-grey and green colour, respectively. Likewise, the mode of deposition and depositional environment

Fig. 10 Photographs showing use of Vindhyan sandstones in contemporary buildings. **a** Central Secretariat, (**b**) India Gate in New Delhi, and (**c**) Panjab University campus, Chandigarh

define its bed thickness that is responsible for a variety of patterns in the sandstone.

The Bhander sandstone of the Upper Vindhyan Supergroup possesses the desired geological properties of a good quality dimension stone, as discussed in the preceding sections. It is a moderate to well-sorted, compact sandstone with low to moderate porosity, chemical resistance to acids and alkalis, insignificant matrix, ferruginous to siliceous cement (Table 2) and

Table 2 Chemical and technical properties of Vindhyan sandstone

Composition (%)	Sector/locality		
	Karauli	Dholpur	Bijoliya
SiO_2	96.20	98.20	97.24
Fe_2O_3 (total)	0.80	0.84	0.96
Al_2O_3	1.20	0.32	0.84
CaO	0.40	0.28	0.28
MgO	0.20	Nil	Nil
L.O.I	0.60	0.20	0.20
Physical attributes			
Density (kg/m^3)	2.38	2.40	2.44
Water absorption (%)	1.20	1.20	1.20
Modulus of Rupture (kg/cm^3)	210	208	204
Compressive strength (kg/cm^3)	358	460	750
Colour	Red/pink/buff/brown		

Table 3 List of major architectonic structures made in the Vindhyan sandstone. The World Geodetic System (WGS84) is used for GPS coordinates

	Heritage buildings and monuments	GPS coordinates	Type of product used	History/age	Significant attributes	Source
1	Humayun Tomb	28° 35′ 35.75″ N 75°15′2.17″ E	Outdoor, façade and pillars	Built in 1570	First garden tomb in India	https://whc.unesco.org/en/list/232
2	Safdarjung Tomb	28° 35′ 21.36″ N 77° 12′ 37.82″ E	Indoor, outdoor and facade	Built in 1754	Mughal architecture	https://www.indianholiday.com/best-of-india/heritage-historic-sites/sdafarjungs-tomb.html
3	Agra Fort	27° 10′ 46″ N 78° 01′ 16″ E	Construction material, indoor, outdoor, flooring and facade sandstone	Built in 1573	Red fort of Agra	https://whc.unesco.org/en/list/251
4	Red Fort (Delhi)	28° 39′ 21.6″ N 77° 14′ 27.6″ E	Construction material, indoor, outdoor, flooring and facade sandstone	Built in 1546	Mughal architecture with fusion of Persian, Timurid and Hindu traditions	https://whc.unesco.org/en/list/231
5	Chittorgarh Fort	24° 53′ 10.68″ N 74° 38′ 49.2″ E	Construction material, indoor, outdoor, flooring and facade sandstone	Built in the seventh century AD by the Mauryans	Largest fort in India	https://www.rajasthandirect.com/world-heritage-sites-in-rajasthan
6	India Gate, New Delhi	28° 36′ 46.31″ N 77° 13′ 45.5″ E	Facade panelling, flooring and garden	Foundation stone laid in 1921 Continued till 1931	Indian war memorial, gateway to New Delhi	https://www.britannica.com/topic/India-Gate
7	Rashtrapati Bhawan, New Delhi	28° 36′ 51.63″ N 77° 11′ 59.29″ E	Construction material, indoor, outdoor, flooring facade and pavement	Completed in 1929	H-shaped building, official residence of the President of India	https://rashtrapatisachivalaya.gov.in/rbtour/about-us https://lighteddream.wordpress.com/2015/05/26/rashtrapati-bhavan-lutyens-empire-in-stone/
8	Central Secretariat, New Delhi	28° 36′ 54″ N 77° 12′ 21″ E	Construction material, outdoor, indoor, and flooring	Construction started in 1912 and completed in 1927	Indo-Saracenic architecture	Roy (2011)
9	Parliament House, New Delhi	28° 37′ 1.88″ N 77° 12′ 29.1″ E	Main building, facade panelling, flooring, pillars and garden	Construction began in 1921 and ended in 1927	Circular building to symbolize Ashoka Chakra Fenced by sandstone railings	http://www.discoveredindia.com/delhi/attractions/architectural-buildings/parliament-building.htm https://www.thehindu.com/opinion/op-ed/government-should-have-confidence-in-this-house/article3742955.ece
10	Buland Darwaza, Fatehpur Sikri	27° 5′ 39.48″ N 77° 39′ 46.8″ E	Constriction material, facade, walls and inside floor	Built in 1575	Victory gate	https://www.britannica.com/place/Fatehpur-Sikri#ref111689
11	Jama Masjid (mosque), Fatehpur Sikri	27°05′ 42″ N 77° 39′ 46″ E	Main building and flooring for prayer courtyard	Built in 1571	540 ft in length	https://whc.unesco.org/en/list/255
12	Qutub Minar, Delhi	28° 31′ 27.68″ N 77° 11′ 6.89″ E	Front panelling and construction as well as for staircase	Built in 1311	Indo-Muslim architecture	https://whc.unesco.org/en/list/233
Ancient monuments						
	Bhimbetika Rock shelters	22° 56′ 18″ N 77° 36′ 47″ E	Sandstone	Mesolithic period	Natural rock shelters	https://whc.unesco.org/en/list/925
	Khajuraho Temples	24° 51′ 16″ N 79° 55′ 17″ E	Sandstone	Built between 950 and 1050 AD	Built by Chandela rulers Largest group of Hindu and Jain temples in the world	http://whc.unesco.org/en/list/240/
	Sanchi Stupas	23° 28′ 45.98″ N 77° 44′ 22.99″ E	Sandstone	Built during the second and first centuries B.C. by King Ashoka	Buddhist architecture preserving ancient history and art of the Mauryan period	https://whc.unesco.org/en/list/524

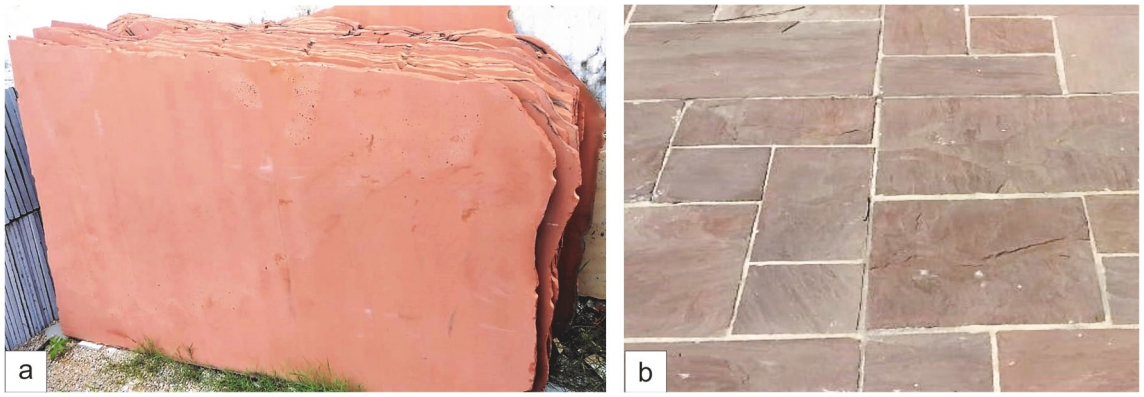

Fig. 11 Photographs showing Vindhyan sandstone slabs (**a**) used in flooring (**b**)

anti-slip properties due to granular texture imparted by its monomineralic nature (comprising predominantly quartz). As a well-bedded rock, it can be split along regular bedding planes. Some of the most popular Vindhyan sandstones produced in the country include Dholpur/Agra Red, Dholpur Beige, Dholpur Pink and Tint Mint. The different colours and patterns of Vindhyan sandstone have found extensive application in historic, pre-historic and modern-day structures, monuments, sculptures, tombstones, artefacts, landscape stones, etc.

Concluding Remarks and Recommendations

India epitomises the use of a wide variety of dimension stones in its architectonic heritage that portrays its diverse cultures and traditions vis-a-vis abundant stone resources. The north-western Indian architectonic sites, usually manifested in the form of palaces, forts, monuments, mausoleums, temples and mosques, are predominantly built from a range of sandstones belonging to the Vindhyan Supergroup, the major repository of masonry sandstone reserves in India. The Upper Vindhyan, Bhander Group sandstones have been the most widely used dimension stones as seen in majority of architectonic heritage buildings and continue to be the most favoured ones in modern-day monuments. The Bhander sandstone, being composed largely of monomineralic quartz, is chemically inert, and its compact texture and cement impart its resistance against physical weathering. It occurs as undeformed, unmetamorphosed and well-bedded deposits, exhibiting a range of colours from dark red to brown, earthy buff, yellow and off-white to spotted types. The most popular amongst these is the red sandstone, owing its colour to the ferruginous cementing material. These characteristics have rendered strength and aesthetic appeal to Vindhyan (Bhander) sandstone and facilitated its extensive use in medieval architectonic and modern structures. The important quarries of Vindhyan sandstone in eastern Rajasthan State are located in Dholpur, Bharatpur, Kota, Sawai Madhopur, Tonk, Bundi, Jhalawar, Karauli and Chittorgarh districts. As enumerated and discussed in preceding sections, the Vindhyan sandstone makes a strong case for being credited with the status of Global Heritage Stone Resource. In conclusion, we propose the candidature of Vindhyan sandstone for recognition as the Global Heritage Stone Resource from India, as it fulfils the requisite characteristics for the same.

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