



Rajnagar Marble: a Prominent Heritage Stone from Rajasthan, NW India

Sanchit Garg¹ · Pradeep Agarwal² · P. S. Ranawat³ · Parminder Kaur¹ · Amritpaul Singh¹ · Jaspreet Saini¹ · Manoj K. Pandit⁴ · Kireet Acharya⁵ · Gurmeet Kaur¹

Received: 12 May 2021 / Accepted: 14 October 2021 / Published online: 10 December 2021
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Abstract

The Rajnagar Marble deposits around Rajnagar and Kankroli towns in the Rajsamand District of south-central Rajasthan State make up an important marble occurrence in India. Although the Rajnagar Marble has been extensively used in monuments of Mewar region for centuries, it received recognition after its use in the stepped embankment and spectacularly carved pavilions (locally known as *Nau Chauki*) on the embankment of the Lake Rajsamand, built during 1662–1676 CE. Several components of the Udaipur City Palace Complex and various historical monuments in the region, such as *Moti Mahal* on the embankment of Fateh Sagar Lake in Udaipur, Eklingji Temple and two adjoining lake dams, Jagdish Temple, components of *Saheliyon-ki-Badi*, scores of step wells and deity idols in and around Udaipur and cenotaphs of the royal family members at Ahar (1620 CE onwards), were built of Rajnagar Marble. These architectural structures have sustained the vagaries of nature for over five centuries, with hardly any noticeable signs of weathering and damage. The Rajnagar Marble is generally coarse-grained, compact dolomitic marble with low water absorption, high bulk density and high compressive and tensile strength, which collectively make it technically suitable for monuments. A unique use of this marble is in the plastering technique, locally called *Ghutai*, which involves the use of ground marble and slacked lime paste, that gives an aesthetic, washable, marble finish to the exterior and interior surfaces of the built structures. Rajnagar Marble is currently being excavated at several open quarries using both conventional and mechanised operations in Rajsamand District, Rajasthan. The Rajnagar Marble entered the global market during the late twentieth century with its export to the Middle East countries and Japan. At present, it is extensively used in the building and handicraft industries as well as in contemporary artworks. In light of a great variety of applications of the Rajnagar Marble and its use in the monuments and several architectural structures, we propose Rajnagar Marble to be designated as a Global Heritage Stone Resource from India.

Keywords Rajnagar Marble · Aravalli Mountain Belt · Marble Heritage · *Ghutai* (marble-lime paste plastering) · India · Heritage Stone Resource

Introduction

The designation of heritage stones as Global Heritage Stone Resource (GHSR) by the International Union of Geological Sciences-International Commission on Geoheritage (IUGS-ICG) is a step forward where national heritage stones with cultural, historical and wide-ranging usage can be identified and accorded international/global status. This novel idea of the International Union of Geological Sciences-Heritage Stones Subcommittee (IUGS-HSS) allows all the nations with a record of historical stone-built monuments to come forward and document the geological attributes of their national heritage stones and their cultural connect (Pereira et al. 2015; Kaur et al. 2021a). The GHSR designation can

✉ Gurmeet Kaur
gurmeet28374@yahoo.co.in

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

² Department of Mines and Geology, Rajasthan, Udaipur, India

³ Department of Geology, Mohanlal Sukhadia University,
Udaipur, India

⁴ Department of Geology, University of Rajasthan, Jaipur,
India

⁵ Vardan EnviroNet, Jaipur, India

be granted only after the stone fulfils the requisite conditions mentioned in the Terms of Reference (ToR) of the Heritage Stone Subcommittee (<https://globalheritagestone.com/other-projects/ghsr/regulations/>; Pereira et al. 2015; Kaur et al. 2021a and references cited therein). European nations have been quick to identify such stones and have recommended several significant stones for GHSR designation, in stark contrast to African, Asian, Oceanian, North and South American nations, which are under-represented on the GHSR world map (refer Fig. 1.3 in Kaur et al. 2020a; Cardenes and Kaur 2021; Kaur and Cardenes 2021; Kaur et al. 2021a; <http://globalheritagestone.com/other-projects/ghsr/designations/>). Recent studies have highlighted several iconic stones of India with potential for the GHSR designation (Garg et al. 2019; Kaur et al. 2019a, b; Kaur et al. 2020a, b, c, d; Sreejith et al. 2021; Kaur et al. 2021b). The Makrana Marble of north-western India has recently been recognised by the IUGS-HSS as the first and only one to date, GHSR from entire South Asia (Garg et al. 2019; Kaur et al. 2020a; <http://globalheritagestone.com/other-projects/ghsr/designations/>).

Rajnagar Marble deposits occurring around Rajnagar and Kankroli towns in Rajsamand District of south-central Rajasthan represent significant marble deposits from the Aravalli Mountain Belt of India (Fig. 1 a, b). The marble

has been used for centuries in archaeological monuments, as evident by the eighth-century Eklingji Temple and numerous other temples in Udaipur City in particular and Mewar region in general. Besides temples, embankments and step well construction, the Rajnagar Marble has also been a preferred stone for carving idols of various Hindu deities, including the famous twelfth-century *Palasma* (the seven-horse drawn sun chariot idol with nine planets revolving around it). The Rajnagar Marble, on account of its pure white colour, was regarded as *Dev-Patthar* (meaning God's stone) as per Hindu cultural beliefs and was exclusively used in temples for carving idols of deities. Therefore, it was traditionally prohibited in flooring and private dwellings. However, it was indirectly used as ground-in-hand-mill and muslin cloth-sieved, marble-lime paste plastering (~ 50 µm size) to give the walls, pillars, lanterns, or even floors in residential buildings the 'marble-finish', through a unique heritage technique, locally called, *Ghutai*, typical of the erstwhile Rajputana (Ranawat 2016a, b). Most palaces and *Havelies* (mansions) in the Mewar region (the present-day Udaipur, Bhilwara, Chittaurgarh and Rajnagar; Fig. 1a) lying in the south-central part of Rajasthan State in NW India were built partly using the Rajnagar Marble and *Ghutai* plastering on the lime-sand-quartzite masonry works.

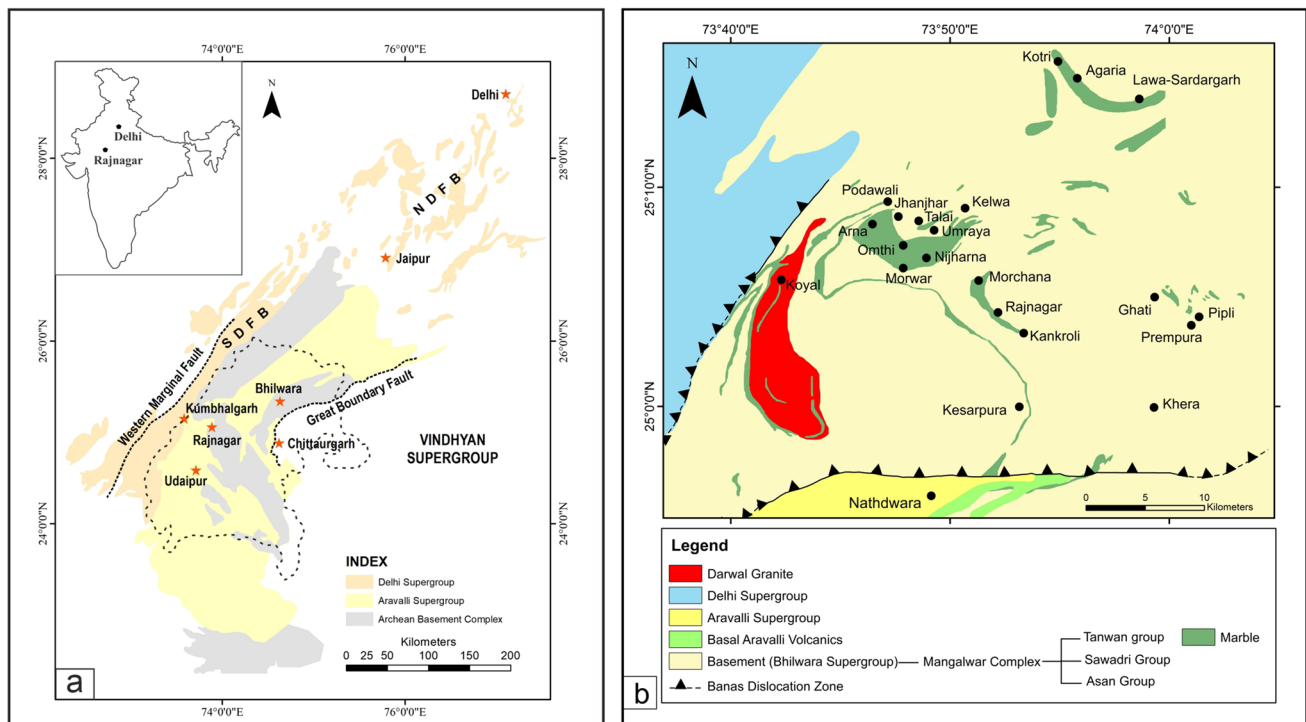


Fig. 1 a Geological map of the Aravalli Mountain Belt (Heron 1953; Kaur et al. 2021b). b Regional geological map showing marble occurrence and quarry sites in and around Rajnagar (compiled from Heron 1953; Mohanty and Guha 1995; Ahmed and Kumar 2016,

unpublished report; Ahmad et al. 2018). The Mewar region on the map (not to scale) is represented by a dotted outline comprising present-day Bhilwara, Chittaurgarh, Kumbhalgarh and Udaipur districts of Rajasthan

The objective of this paper is to bring to fore the Rajnagar Marble of India, which has been used in scores of historical monuments in the Mewar region of Rajasthan. This heritage marble was extensively used for *Ghutai* (a unique heritage marble-lime paste preparation and plastering technique) in historical monuments, which needs promotion and publicity.

Geological Setting

The Aravalli–Bundelkhand Craton represents the northernmost of several Archaean–Paleoproterozoic cratonic regions and enclosing mobile belts in Peninsular India that together constitute the Indian Shield (Meert and Pandit 2015 and references therein). Its northwestern domain (also called Aravalli Craton) comprises an Archaean basement, named Banded Gneissic Complex (BGC) (Gupta 1934; Heron 1953), over which, Proterozoic supracrustal rocks of Aravalli and Delhi supergroups [Aravalli Delhi Fold Belt (ADFB)] were deposited (Fig. 1a; Gupta et al. 1997; Sinha-Roy et al. 1998; Roy and Jakhar 2002). The BGC was subdivided by Gupta (1934) into two geographic domains, BGC I (amphibolite facies) in the east and BGC II (granulite facies) in the west, based on differences in litho-assembly, grade of metamorphism and basement–cover relationships. These are separated by the NE–SW-trending Banas Dislocation Zone (Fig. 1b; Sinha-Roy et al. 1998). Gupta et al. (1997) regrouped the basement rocks of the Aravalli Mountain Region into Bhilwara Supergroup (BSG) that also includes a notable Paleoproterozoic component. The BSG has further been subdivided into Mangalwar Complex (predominantly amphibolite facies), Sandmata Complex (granulite facies) and Hindoli Group (low-grade metapelites, metapsammities and volcanics).

The focus of the present study is the Rajnagar Marble, which has been used in numerous monuments of Mewar Region. This marble is exposed in the Kankroli–Rajnagar area in southern Rajasthan (Fig. 1a, b). These predominantly calcareous facies rocks were earlier classified by Heron (1953) as the ‘Raialo series’, a chronostratigraphic unit, younger than Aravalli and older than Delhi Supergroup (erstwhile ‘systems’). Although their basement character was highlighted by several workers (Ghosh and Naha 1962; Naha and Halyburton, 1974a, 1974b; Mohanty and Guha 1990; 1995), these rocks were included in the ambit of Aravalli Supergroup by Gupta et al. (1997) who described them as part of Kankroli and Dovda/Davura groups. In the current understanding, these ‘calcareous facies’ rocks in Kankroli–Rajnagar area are considered a part of the Mangalwar Complex (basement) (Fig. 1b; Table 1; see also Sinha-Roy et al. 1998; Ahmed and Kumar 2016, unpublished report; Ahmad et al. 2018). The Mangalwar Complex in this region is further subdivided into Asan Group (bimodal gneiss), Sawadari Group (mafic–ultramafic rocks, chert, basic tuffs and carbonates) and Tanwan Group (quartzite, mica schist, amphibolite and carbonates) (Fig. 1b; Table 1; see also Sinha-Roy et al. 1998). The Tanwan Group marble and calc gneisses of variable width display complex outcrop patterns in this region due to ductile deformation and fold interference (Sinha-Roy et al. 1998). The marble unit is best developed about 10 km NW of Rajnagar Town and also forms the main repository of *Rajnagar Marble* where it is excavated from several open quarries (Fig. 1b). The location of some prominent quarries is indicated in Fig. 1b.

Intrusive phases in the area include variably altered and metamorphosed granite, granodiorite and trondhjemite. A granite–granodiorite pluton (Ran Igneous Complex; see Guha and Bhattacharya 1995) intrudes at the contact between Sawadari and Tanwan groups while Anjana Granite

Table 1 Stratigraphic succession around Rajsamand District (source: Mohanty and Guha 1990; 1995)

Supergroup	Group	Lithology
Bhilwara Supergroup	Intrusives	Pegmatites and aplites
		Norite dykes
		Porphyritic granite gneiss (= Anjana Granite)
Mangalwar Complex	Tanwan Group	Tonalite and granodiorite gneiss
		Fuchsite quartzite
		Mica schist
	Sawadri Group	Marble, calc gneiss
		Amphibole/autoclastic conglomerate
		Quartzite (= Amet Quartzite)
Sandmata Complex	Asan Group	Mica schist
		Ultrabasics, amphibolite and chert
		Bimodal gneiss
		Garnet-sillimanite granulite gneiss

(gneiss), a post-Aravalli granitic pluton, represents the most prominent intrusive event in the region. Besides, a norite dyke is also exposed near Deogarh Town (Guha and Bhat-tacharya 1995). The marble deposits do not show any contact relationship with intrusive rocks.

Commercial Varieties of Rajnagar Marble

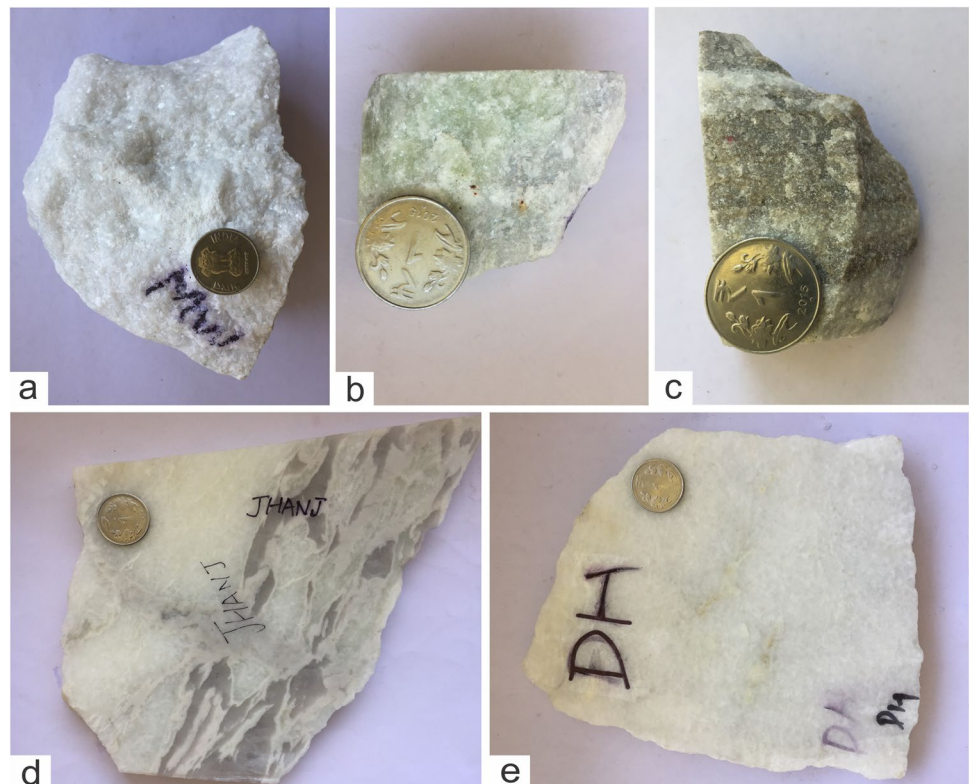
Rajnagar Marble is sold under different commercial/trade names based on the local village names, such as Morwad, Arna, Nijharna, Dharmeta and Jhanjhar (Fig. 1b). The Morwad variety is the most popular commercial variety due to its pure white colour. Arna, Nijharna, Dharmeta and Jhanjhar are relatively less common varieties of the Rajnagar Marble that are quarried for local use. These varieties can also be differentiated on the basis of appearance

(Table 2; Natani 2002, unpublished report; Agarwal et al. 2020, unpublished 36th IGC field guide). Morwad variety is coarse- to very coarse-grained, pure white, massive marble, devoid of any colouration and banding (Fig. 2a). Arna variety is coarse- to medium-grained with random green patches (Fig. 2b). Nijharna is fine- to medium-grained, foliated marble with centimetric-scale light to dark brown bands (Fig. 2c). Jhanjhar is medium- to coarse-grained, white coloured with light grey, discontinuous lenses (Fig. 2d). Dharmeta, another coarse-grained white variety, is characterised by yellow and green spots (Fig. 2e). The Rajnagar Marble is dominantly composed of calcite and dolomite and contains an accessory amount of clinopyroxene, tremolite, feldspar, biotite, sphene and magnetite that impart brown, green, yellow and grey colours to the rock (Basu and Arora 1968, unpublished report; Ahmed and Kumar 2016, unpublished report).

Table 2 A summary of macroscopic characteristics of the five trade varieties of Rajnagar Marble (source: Natani 2002, unpublished report)

S. No	Variety name	Macroscopic characteristics
1	Morwad	Blebs of smoky quartz in white background
2	Dharmeta	Variety having honey yellow and green web
3	Arna	White variety with parallel siliceous and greenish bands and lining
4	Nijharna	Medium- to coarse-grained variety with biotite and siliceous partings
5	Jhanjhar	Variety having black cloudy spots of silica (medium- to coarse-grained)

Fig. 2 Hand specimen photographs of different varieties of Rajnagar Marble. **a** Morwad. **b** Arna. **c** Nijharna. **d** Jhanjhar. **e** Dharmeta



Petrography, Physico-mechanical and Geochemical Characteristics of Rajnagar Marble

Five varieties of Rajnagar Marble, viz. Morwad, Arna, Nijharna, Dharmeta and Jhanjhar, were petrographically examined at the Department of Geology, Panjab University, Chandigarh using Carl Zeiss AXIO Imager and A2m microscope. The dolomite and calcite were distinguished using the Alizarin Red S staining method (Dickson 1965; 1966; Fig. 3a). The Morwad variety is coarse- to very coarse-grained dolomitic marble, displaying granoblastic texture. Mineralogically, the rock is composed of calcite and dolomite as the dominant carbonate phases and accessory (< 1 vol. %) quartz and amphibole (Fig. 3a, b). The other varieties of Rajnagar Marble such as Arna, Nijharna, Dharmeta and Jhanjhar are fine- to coarse-grained dolomitic marble, with subordinate amounts of quartz, biotite and amphibole (Fig. 3c, d). Arna variety contains dolomite and calcite with subordinate amphibole (Fig. 3c). The Nijharna variety mainly comprises dolomite and calcite with minor amounts of biotite, quartz and opaques. The fine biotite grains show preferred alignment and add brown streaks to the rock (Figs. 2c and 3d). Jhanjhar variety is characterised by the presence of dolomite, calcite and quartz imparting light colour to the vitreous lenses in the rock. Dharmeta variety contains dolomite and calcite and minor amounts of amphibole, quartz and opaque minerals.

Physico-mechanical properties of the Morwad variety of Rajnagar Marble are given in Table 3 (source: Annon 2011). The geochemical analyses of Morwad, Dharmeta and Nijharna varieties of Rajnagar Marble are given in Table 4 (person. comm.; Natani 2002, unpublished report).

Rajnagar Marble Mining and Processing

Rajnagar region of Rajasthan State is one of the most important marble repositories as well as marble-producing, processing and exporting regions in India (Ahmed and Kumar 2016, unpublished report; Ranawat 2016a; Agarwal et al. 2020, unpublished 36th IGC field guide). The marble occurrences of Morwad, Nijharna, Dharmeta, Arna, Jhanjhar, Agaria, Amet, Kelwa, Kotri, Morchana, Talai, Omthi, Khara, Kesarpura, Pipali, Umraya, Premura, Ghati and Koyal areas of Rajsamand District collectively constitute the Rajnagar Marble deposit (Fig. 1b; Agarwal 1979; Natani 2002, unpublished report; Ahmed and Kumar 2016, unpublished report; [http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20\(Advance%20Release\).pdf](http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20(Advance%20Release).pdf)). The Morwad variety is extensively quarried in comparison to other varieties and the most preferred one in the contemporary construction industry. RK Marbles is the biggest marble mining and supplier firm that operates several fully mechanised marble quarries and block processing units in Rajnagar (person. comm.). There are many small-scale local mining units operational in Rajnagar area which are semi-mechanised and

Fig. 3 Photomicrographs of different varieties of Rajnagar Marble. **a** Stained thin section of Morwad under plane-polarised light (PPL). **b** Morwad under PPL. **c** Arna under crossed-polarised light (XPL). **d** Nijharna under PPL. Abbreviations: Dol dolomite, Cal calcite, Amp amphibole, Qz quartz, Bi biotite, Cb carbonates, Opq opaques

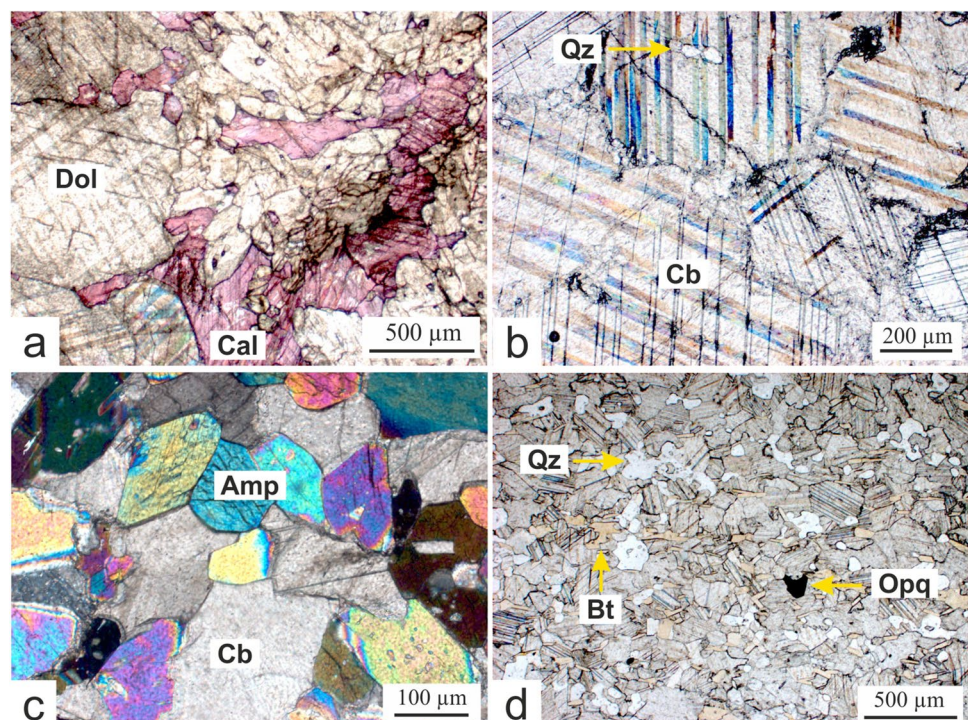


Table 3 Physico-mechanical properties of Morwad variety of Rajnagar Marble (source: Annon 2011)

Physico-mechanical properties	Test value Morwad	ASTM/Indian standards
Water absorption (% by weight)	0.04	ASTM C-97 ¹
Density (bulk specific gravity) (g/cm ³)	2.83	ASTM C-97 ¹
Modulus of rupture (N/mm ²)		
Dry	12	ASTM C-99 ²
Wet	13	
Compressive strength (N/mm ²)		
Dry	111	ASTM C-170 ³
Wet	80	
Abrasion (resistance to wear)		
Average wear (mm)	3.1	IS 1237 Guidelines ⁴
Maximum wear on individual specimen (mm)	3.2	
Flexural strength (N/mm ²)	13	IS 4860 Guidelines ⁵

¹ASTM C97/C97M-18 (2018)²ASTM C99/C99M-18 (2018)³ASTM C170/C170M-17 (2017)⁴IS 1237: 2012 (2012)⁵IS 4860:1968 (1969)**Table 4** Chemical composition of Morwad, Dharmeta and Nijharna varieties of Rajnagar Marble (source: test value of Morwad and Dharmeta varieties from RK Marble Pvt. Ltd., Rajsamand; test value of Nijharna variety from Natani 2002, unpublished report)

Major oxides (wt%)	Test value		Reference	Test value
	Morwad	Dharmeta		
CaO	32.27	32.45	IS 1760 (Part 3) ¹	31.89
MgO	20.60	20.14	IS 1760 (Part 3) ¹	24.57
Fe ₂ O ₃	0.16	0.63	IS 1760 (Part 3) ¹	0.95
Al ₂ O ₃	0.40	0.20	IS 1760 (Part 3) ¹	0.01
SiO ₂	1.67	0.83	IS 1760 (Part 2) ²	0.01
LOI	44.60	45.46	IS 1760 (Part 1) ³	43.09

¹IS 1760 (Part 3): 1992 (1992)²IS 1760 (Part 2): 1991 (1991b)³IS 1760 (Part 1): 1991 (1991a)

even use manual methods of quarrying. Large-scale quarrying of the Morwad (white) variety of Rajnagar Marble is currently being carried out at the Morwad Marble Mines of RK Marble Pvt. Ltd. in Morwad-Rajsamand mining division in Rajasthan (Fig. 4a, b). The marble block mining is done vertically by the benching method (bench width > bench height) after the removal of overburden by heavy earth-moving machinery or by drilling holes using jackhammers and slim drill machines ([http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20\(Advance%20Release\).pdf](http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20(Advance%20Release).pdf); Agarwal et al. 2020, unpublished 36th IGC field guide). The bench wall is usually formed by vertical drill holes, subsequently cut by diamond wire saw machines

to obtain marble blocks of the desired size. The excavated marble blocks are loaded onto trucks with the help of lifting cranes and transported to the block processing units. The marble blocks are unloaded at the processing unit of the marble tile plant using a gantry crane (Fig. 5a). Depending on the overall dimensions, the marble blocks are sliced into slabs and tiles of variable size using block cutting machines, multi-wire cutting machines and circular saws (Fig. 5b–d). The multi-wire cutter comprises diamond wires which slice the marble block vertically into several identical size slabs in one go (Fig. 5c). The block cutter comprises a single diamond saw wire which is used to cut a highly irregular marble block into strips that are subsequently dressed into desired size slabs (Fig. 5b; [http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20\(Advance%20Release\).pdf](http://ibm.nic.in/writereaddata/files/01102018101102Marble%202016%20(Advance%20Release).pdf); Agarwal et al. 2020, unpublished 36th IGC field guide). After processing, marble slabs are transported to the production unit for final polishing and finishing. The polished slabs are sold commercially and used for cladding and flooring. The Rajnagar Marble is a popular building material and also utilised for preparing *Ghutai* (Basu and Arora 1966, unpublished report; Ranawat 2016b).

***Ghutai*: a Unique Heritage Marble-Lime Paste Preparation and Plastering Technique Used in Historical Monuments**

Ghutai is a traditional and unique technique of preparing plastering material in Udaipur and surrounding regions, usually applied to interior and exterior surfaces of heritage

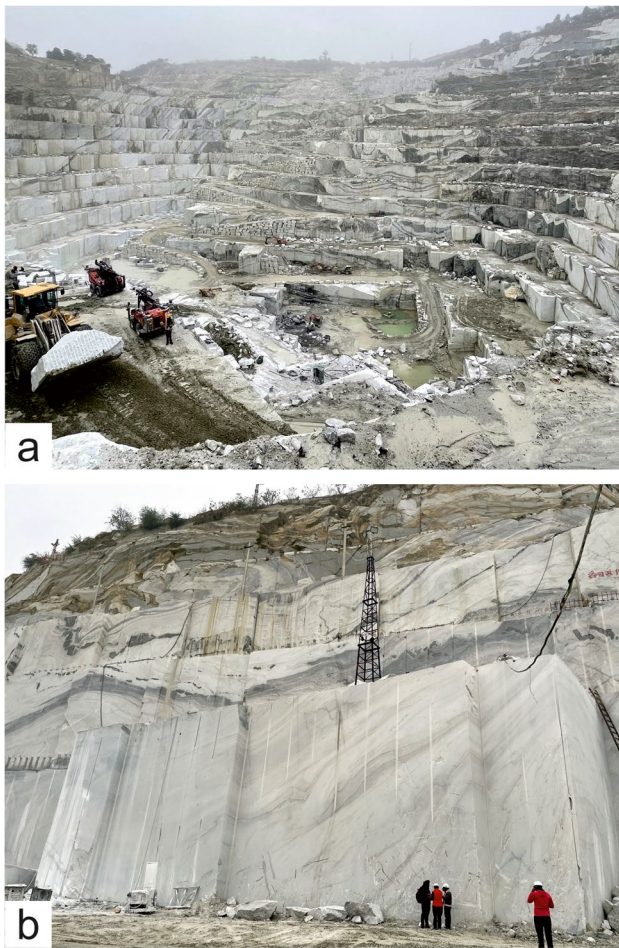


Fig. 4 **a** Panoramic view of Morward Marble Mines of RK Marble Pvt. Ltd. in Rajsamand District of Rajasthan. **b** Close-up view of bench wall in the same mine (photos by Sanchit Garg)

monuments or buildings (Ranawat 2016b; <http://toi.in/jlpyrY/a31ga8>). It includes plastering of the building surfaces with smooth paste (~50 μm size) obtained by grinding a mixture comprising one part of slacked lime (burnt lime mixed with water) and three parts of sand-sized ground marble (Ranawat 2016b). The sand-sized ground marble is prepared from hand-sorted stain-free white Rajnagar Marble through manual sizing and sieving methods to obtain a marble powder of ~0.5 to 0.7 mm diameter. This ground marble is then mixed with raw lime while pouring water and allowed to stale for some days. Thereafter, a smooth paste is obtained by grinding the mixture manually in millstones (<https://www.youtube.com/watch?v=EHADogYCjxo>). *Ghutai* plastering is applied on the surfaces which have been previously plastered with a burnt lime-river sand or cement-river sand mortar. Prior to 1960s, the burnt lime was conventionally prepared by burning limestone (CaCO_3) in kilns at ~825 $^\circ\text{C}$. The conventional process of *Ghutai* preparation is time-consuming and cumbersome, and the process

of treating the lime could take up to 2 years. In the current times, the slaking of lime is done for a shorter period. The present process of *Ghutai* preparation involves the use of portland cement in place of burnt lime (Ranawat 2016b). Nowadays, electrically operated stone mills are available and the final marble-lime paste is produced quickly in comparison to the traditional hand-operated mills. The *Ghutai* is usually applied in three consequent coatings. The first coating is done and allowed to settle for any kind of shrinkage due to the prevailing temperature. Subsequently, the second and third coating are applied after a gap of at least 1 month. Thereafter, the surface is polished with a fine-mesh polishing stone. The finish is given by applying coconut oil using a cloth to give a glossy marble-like appearance to the surface (<http://toi.in/jlpyrY/a31ga8>; Ranawat 2016b). This polish allows the coating to sustain for centuries with the least maintenance. Sometimes, the *Ghutai* paste is mixed with manually cleaned seashell powder ('mother of pearl') that gives the surface pearly lustre. At times, yellow ochre is a preferred addition to the *Ghutai* that imparts the paste a creamy yellow hue and enhances its aesthetic appeal. The technique of *Ghutai* becomes more relevant in the current times in utilising the marble waste in preparing sand-sized ground marble, thus an eco-friendly activity of reuse of marble waste (<http://toi.in/jlpyrY/a31ga8>).

The *Ghutai*-plastered surfaces were traditionally painted with motifs of dancing peacocks and various floral designs and, at times, with inlaid coloured glass pieces (Fig. 6a–c; Ranawat 2016b). The *Ghutai* plaster on the exterior surfaces and walls tends to develop grey algal patches after many years, which is manually scrubbed clean to maintain it.

Rajnagar Marble and *Ghutai* in Heritage Monuments

The architectural monuments of the Mewar region showcase the versatile use of the Rajnagar Marble that ranges from carved idols of deities, sculptures, flooring and the exquisite technique of *Ghutai* plastering, a secondary product of Rajnagar Marble. The earliest use of Rajnagar Marble can be traced to 734 AD (Erskine 1908) when it was used exclusively for carving idols of Hindu deities. Due to its pure white colour, it was considered *Dev-Patthar* and, therefore, was not used in flooring and private human dwellings (Ranawat 2016a, b). From the mid-sixteenth century onwards, the wider use of Rajnagar Marble in the carvings, pillars and flooring is seen in the heritage monuments. The sculptures of gods and goddesses in the eighth-century Eklingji Temple can be cited as the oldest carvings done in Rajnagar Marble (Sarda 1932). The remains of the sculptures of Hindu deities (eighth to sixteenth century), carved in the Rajnagar Marble, from the Eklingji Temple Complex

Fig. 5 Marble processing unit of RK Marble Pvt. Ltd. **a** Gantry crane used to unload marble block from the truck. **b** Block cutting machine. **c** Multi-wire cutting machine. **d** Circular saw used to cut the blocks of marble into slabs and tiles of variable sizes (photos by Sanchit Garg and Amritpaul Singh)



are now displayed at the City Palace Complex, Udaipur (Fig. 7a). The following historical excerpt highlights the use of marble in the Eklingji Temple:

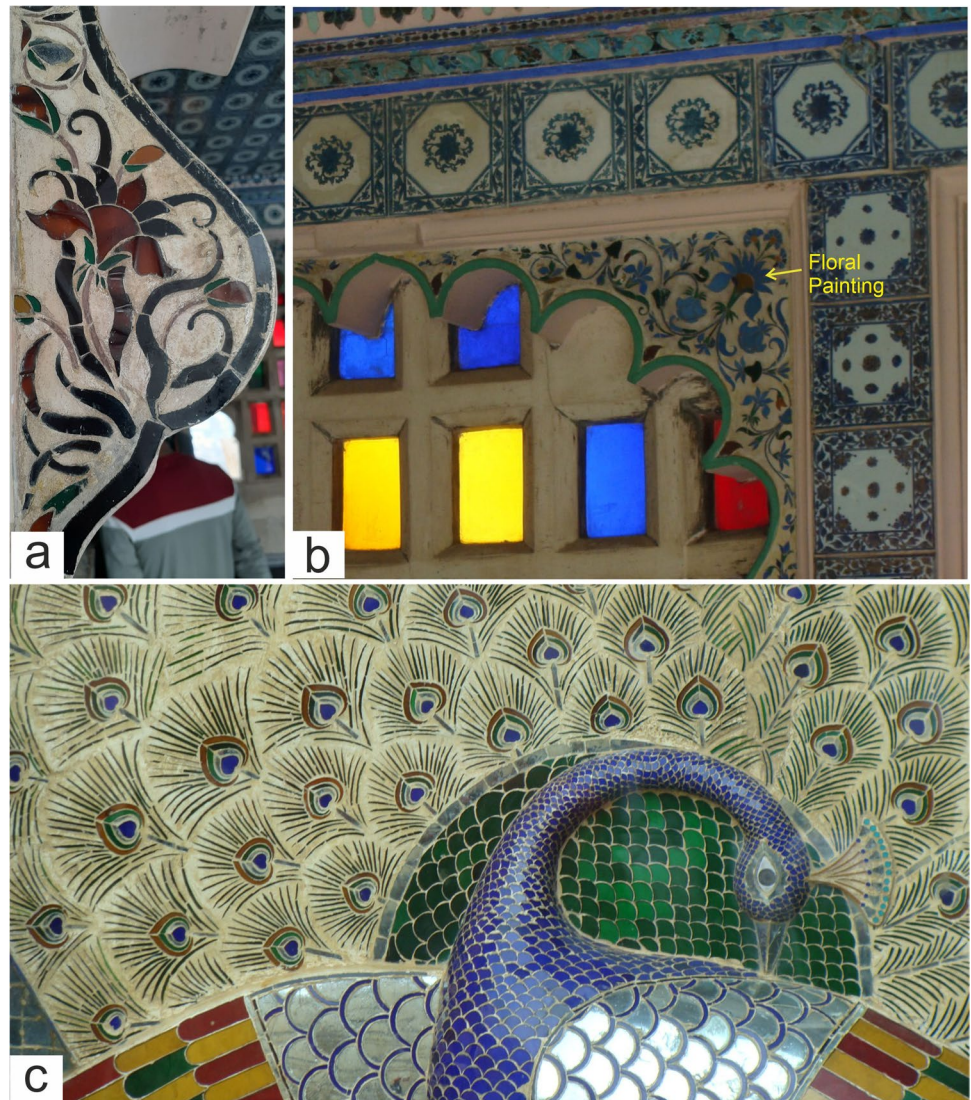
'Eklingji and Nagda—A shrine sacred to Mahadev...14 miles north of Oodeypore. The fane is of white marble and ample dimensions, under an open vaulted temple supported by columns, and fronting the four-faced divinity is the brazen bull, Nanda of natural size...' (Mehta 1888, p. 35)

The deity sculptures dedicated to the Lord Vishnu in the Kumbhshyam Temple of Chittaurgarh Fort were carved from Rajnagar Marble under the patronage of Rana Kumbha during the fifteenth century (Fig. 7b, c). The Rajnagar Marble-carved idols of Lord Krishna and Meera Bai were placed in the Kumbhshyam Temple at Chittaurgarh Fort (Fig. 7c). In the sixteenth century, the capital of Mewar was shifted from Chittaurgarh to Udaipur by Maharana Udai Singh (Shimazaki and Ranawat 2020) and the construction of the new palace, viz. the famous City Palace Complex of Udaipur, was started in 1559 which involved extensive use of Rajnagar Marble. The Rajnagar Marble was used in the idols and sculptures at *Ganesh Pol* (gateway dedicated to Lord Ganesha), flooring at the *Lakshmi Chowk* (courtyard dedicated to Goddess Lakshmi; Fig. 8a), *Badi Mahal* (Great Garden Palace; Fig. 8b), *Mor Chowk* (Peacock Courtyard) and *Chowmukha* (open pavilion) in the Udaipur City

Palace Complex. A jointless large water tank, carved out of a single marble slab, is placed in the cloisters of *Badi Mahal* (Fig. 8b, Table 5). The importance and popularity of Rajnagar Marble increased after its use in the stepped embankment and *Nau Chauki* (pavilions) of the Rajsamand Lake (Fig. 9a, Table 5; Ranawat 2016a, b). There are three pavilions, each consisting of twelve pillars of Rajnagar Marble, with intricate carvings that depict figures of gods and goddesses, animals and floral and geometrical designs, inspired from the *Krishna Lila* (Fig. 9b, c; Dorje and Dimri 2012). Apart from this, the three marble *torans* (typical Hindu architectural arched gateways) on the embankment also exhibit exquisite carving and ornamentation. The significance and beauty of the Rajsamand embankment can be appreciated in a historical incident: Aurangzeb, the Mughal Emperor destroyed many temples in Mewar region during late seventeenth century, but on his visit to Rajsamand, he was so mesmerised by the beauty of the *Nau Chauki* that he ordered no harm be inflicted to this 'Miracle in Marble', which represented numerous carved panels of Hindu culture (Shyamaldas 2017).

The Rajnagar Marble was also used in the construction of the *Moti Mahal*, a palace situated on the bank of Fateh Sagar Lake, which is the only palace in Udaipur built entirely using the Rajnagar Marble (Ranawat 2016a, b). A three-storey, Jagdish Temple, the largest Vishnu Temple in Udaipur, possesses eloquent carvings in white Rajnagar Marble (Fig. 10a,

Fig. 6 a, b The coloured glasswork and floral paintings and geometric designs on the *Ghutai* base adorning the walls and arches of the *Sheesh Mahal*. c Close-up view of peacock embellished with the mirror mosaic work on the *Ghutai* base in the *Mor Chowk* preserved in glass case, City Palace Complex, Udaipur (photos by Gurmeet Kaur)

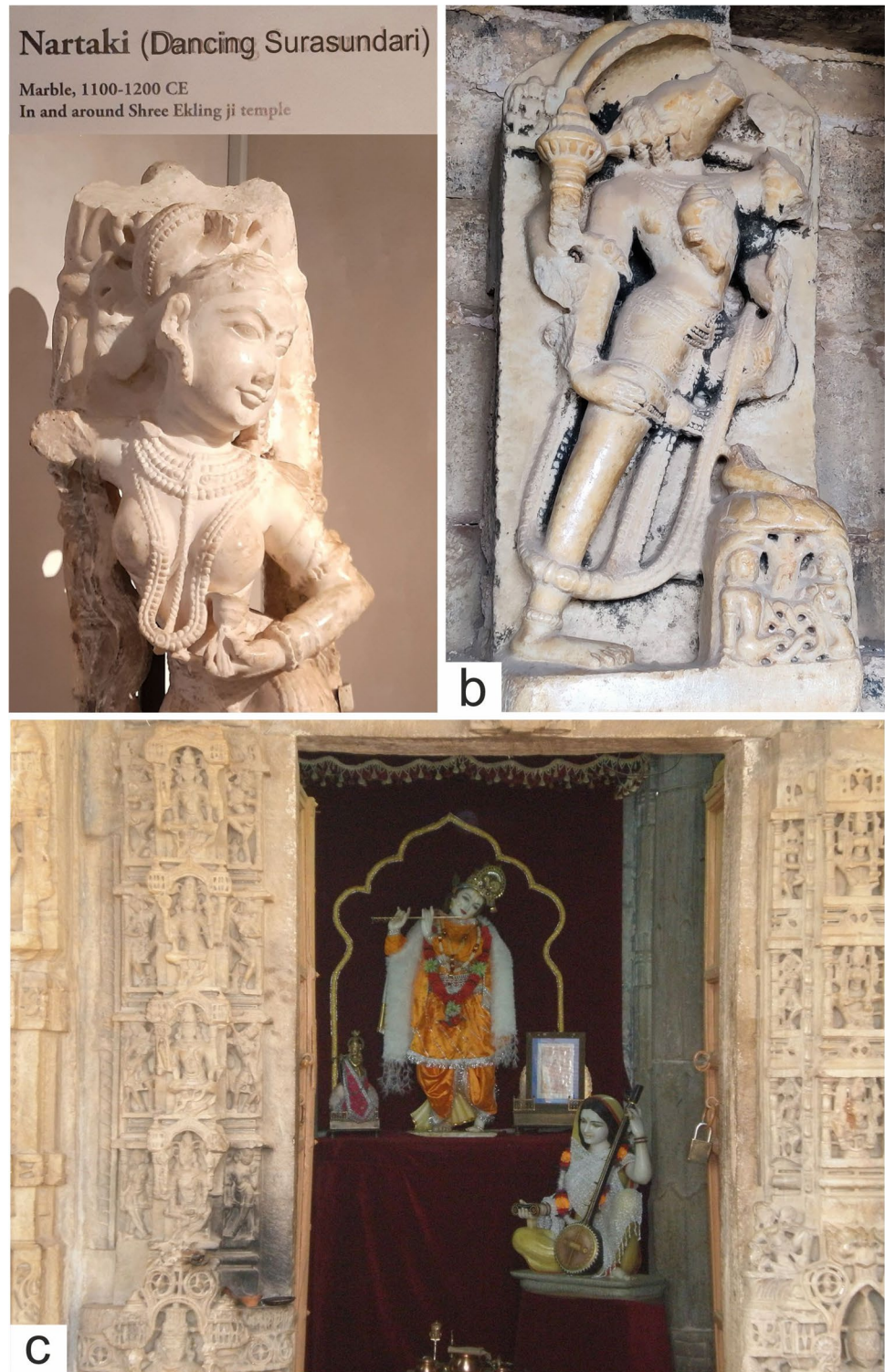


b; Purohit 1938; Shimazaki and Ranawat 2020). The exterior walls, ceiling and pillars of the temple are intricately carved with Hindu idols, elephants, floral patterns and other elements of Hindu culture. Two large elephants, carved from marble blocks, are placed on both sides of the stairway at the main entrance of the temple. Apart from this, Rajnagar Marble was used in the flooring and sculptures in the *Saheliyon-ki-Badi* (Garden of Maidens) in Udaipur, and several components of *Jagmandir* (Lake Garden Palace) and *Jagniwas* (now known as Taj Lake Palace Hotel), the two island palaces built in the Lake Pichola during the sixteenth to eighteenth centuries (Table 5). There is a row of elephants carved in Rajnagar Marble at the entrance of *Jagmandir*. The slabs of white Rajnagar Marble were used in the flooring and columns of the *Jagniwas*. The marble bust of Maharaja Sajjan Singh is placed in the middle of the central chamber of the Sajjangarh Fort (also known as the Monsoon Palace; Fig. 10c). The marble is also used in the flooring of the

palace. The capital of the pillars erected in Rajnagar Marble is intricately carved with floral designs (Fig. 10d).

Ghutai plastering has been extensively used on the exterior and interior walls of several heritage monuments, namely City Palace Complex, *Saheliyon-ki-Badi*, *Jagmandir*, *Jagniwas* and Sajjangarh Fort. The coloured glasswork, floral paintings, geometric designs and mirror mosaic work done on the *Ghutai* base adorn the walls and arches of the *Sheesh Mahal* (Palace of Glass and Mirrors, Fig. 6a, b) and the *Mor Chowk* (Fig. 6c) in the City Palace Complex, Udaipur. The outer walls of the City Palace Complex, entry gate named *Badi Pol* (Great Gate), the intricately carved brackets, pillars of the cloisters at *Lakshmi Chowk* (Fig. 8a) and *Badi Mahal* are all plastered with *Ghutai*. The *chhatris* (domed canopies), fountains, elephants and the walls around the main courtyard of *Saheliyon-ki-Badi* highlight the use of *Ghutai* (Fig. 11a, b; Table 5). *Jagniwas* is entirely plastered with pure white

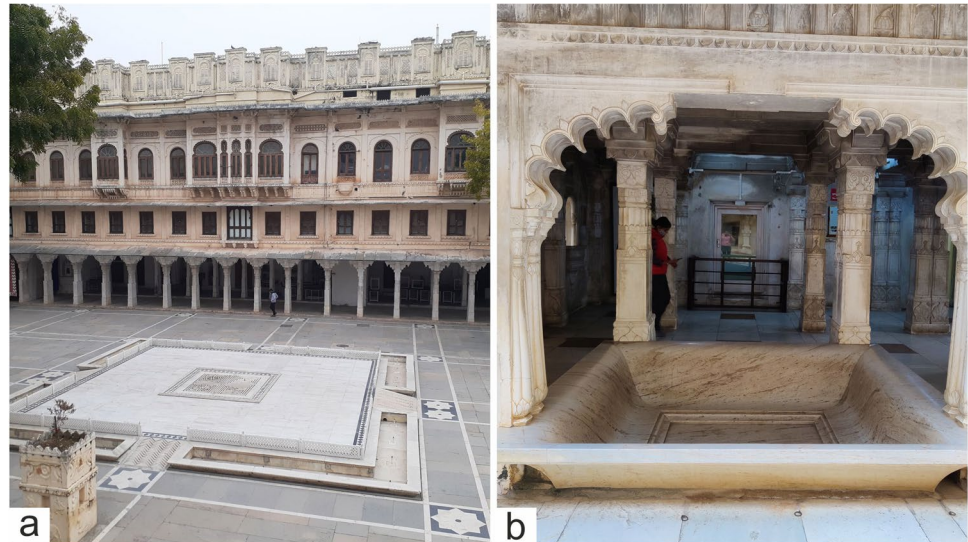
Fig. 7 **a** Close-up view of *Nartaki* (Dancing Surasundari/ Lady 1100–1200 C.E.), displayed at the City Palace Museum, Udaipur. **b** Rajnagar Marble-carved *Varaha* (incarnation of Lord Vishnu) at Kumbhshyam Temple, Chittaurgarh Fort, which was later vandalised by the Mughals (photos by Parminder Kaur and Jaspreet Saini). **c** Rajnagar Marble-carved idols of Lord Krishna and Meera Bai placed in the Kumbhshyam Temple at Chittaurgarh Fort (photo by Gurmeet Kaur)



Ghutai, giving it a marble-like finish (Fig. 11c; <https://ia802902.us.archive.org/10/items/fortspalaceshave00cent/fortspalaceshave00cent.pdf>). The exterior walls of the Sajjangarh Fort were all plastered with *Ghutai* (Fig. 12). The Rajnagar Marble *Ghutai* plastering was preferably used

in the *Badal Mahal* (Palace of Clouds) at Kumbhalgarh Fort (Dorje and Dimri 2012) and Fateh Prakash Palace at Chittaurgarh Fort, which are two of the six Hill Forts of Rajasthan, collectively designated as UNESCO World Heritage Site.

Fig. 8 a Use of Rajnagar Marble in the flooring and *Ghutai* plaster on the walls and the intricately carved brackets in cloisters at *Lakshmi Chowk*. **b** Jointless water tub carved out of single marble slab in the courtyard of the *Badi Mahal*, City Palace Complex, Udaipur (photos by Parminder Kaur and Jaspreet Saini)



Contemporary Usage of Rajnagar Marble

Due to its colour, appealing patterns and aesthetic charm, the Rajnagar Marble is extensively used in contemporary buildings and the handicraft industry (Fig. 13a–d). The white variety is the most favoured for carving idols of deities and sculptures. One such example is the idol of Lord Parshvanath at Chennai that was carved out of a single block of Rajnagar Marble (<https://udaipurtimes.com/around-town/rajsamands-marble-to-be-used-for-making-lord-parshvanath/c74416-w2859-cid136830-s10793.htm>). The Rajnagar Marble is commonly used for constructing temples for worship and prayers in homes. It is also used in crafting numerous artefacts, animal figures, jewellery boxes, garden accessories, decoration items (Fig. 13a) and several household and kitchen utensils, such as rolling boards, chopping boards, mortar, vases and coasters (Fig. 13b). It is a popular flooring material for offices, houses, schools, shopping malls, hotels, etc. (Fig. 13c). The Rajnagar Marble-carved sculptures are displayed in the middle of the roundabouts in Udaipur City (Fig. 13d). The Rajnagar Marble got international recognition during the twentieth century, with the export of slabs and tiles of various sizes to countries like Japan, Kuwait, USA, Nepal and Qatar (Cadène and Holmström, 1998; <https://www.zauba.com/export-rajnagar-hs-code.html>).

Conclusions

The iconic stones of India are being promoted for the GHSR designation by highlighting their historical usage and significance. The Rajnagar Marble of Rajsamand District of Rajasthan is one such stone that has been used in numerous architectural heritage structures constructed in the Mewar region during the last six centuries. The low water absorption, high bulk density and high compressive and tensile strength of the Rajnagar Marble render it technically suitable for monuments that have survived for centuries, with minor noticeable damage, except for slight yellowing of the stone. The Rajnagar Marble gained global acceptance during the late twentieth century with its export to various countries including the Middle East and Japan. At present, it is extensively used in the construction and handicraft industries, and contemporary artworks. Since Rajnagar Marble was considered God's stone as per the Hindu cultural beliefs, it was not used for private dwellings. As an alternative, it was used in producing *Ghutai* for plastering the walls, pillars, lanterns or even floors to give the marble-finish to the surfaces. *Ghutai* is a unique heritage technique, typical of the erstwhile Mewar. In light of its unique traditional significance and wide historical applications, we propose Rajnagar Marble for the designation of Global Heritage Stone Resource from India.

Table 5 List of some significant heritage monuments depicting the extensive use of Rajnagar Marble

S. No	Heritage buildings and monuments	Location	Description	Historical excerpts	References/weblinks
1	City Palace Complex, Udaipur	24.5764° N, 73.6835° E	The City Palace in Udaipur was built during the sixteenth century by the Maharana Amar Singh Ji-II. The extensive use of Rajnagar Marble is seen in the <i>Sheesh Mahal</i> (Fig. 6a, b), <i>Mor Chowk</i> (Fig. 6c), <i>Lakshmi Chowk</i> (Fig. 8a), <i>Badi Mahal</i> (Fig. 8b) and <i>Chowmukha Pavilion</i> in the City Palace Complex. The walls of the complex, the colonnades of the <i>verandah</i> and the arches are plastered with the white <i>Ghutai</i> to give it a marble finish	'The palace is the most imposing pile of a regular form, built of granite and marble...' (Mehta 1888, p. 14) ... a way goes on the left to <i>Bari Mahal</i> (or the Garden Palace) which is an open garden surrounded by marble trellis kiosques, and pavilions with some handsome doors inlaid with ivory... In the centre of the court is a tank encased with huge slabs of marble... and some curious slabs of marble, measuring three feet square cut with water channels in geometric devices...' (Mehta 1888, p. 17) 'The whole structure, which has been plastered with marble chunam, and which has been fitted with numerous balconies...' (Mehta 1888, ADDENDA-5-6) 'The palace with its marble stairs, marble pillars, marble pavements, ivory doors, and a fountain in the middle of the court-yard with well carved marble railing...' (Mehta 1888, ADDENDA-6)	Mehta (1888); Ranawat (2016b)
2	<i>Nau Chauki</i> at Rajsamand Lake, Rajsamand	25.0747° N, 73.8860° E	The embankment at the southern side of the Rajsamand lake was built in 1660 by Rana Raj Singh (Fig. 9a). The 3 pavilions, entirely made of Rajnagar Marble, comprising 12 pillars each. The pillars are thickly ornamented, and the ceilings of the pavilions are richly carved (Fig. 9b, c)	'On the south lies the town of <i>Rajnagar</i> and to the south-east the town of <i>Kankrauli</i> (with its celebrated temple on its embankment); the northern part of which, nearly 200 yards long and 70 yards thick, lies between two hills, and is entirely faced with white marble from the adjacent quarries, with flights of steps of the same material, from the summit to the water's edge. It is surmounted by handsome pavilions and exquisitely decorated with marble arches. These pavilions are beautifully carved...' (Mehta 1888, pp. 31-32)	Ranawat (2016a, b)

Table 5 (continued)

S. No	Heritage buildings and monuments	Location	Description	Historical excerpts	References/weblinks
3	<i>Moti Mahal</i> , Fateh Sagar Lake, Udaipur	24.6014° N, 73.6742° E	The Rajnagar Marble was also used in the construction of embankment of Fateh Sagar Lake. The <i>Moti Mahal</i> , situated on the bank of Fateh Sagar Lake, is the only palace in Udaipur that was entirely built using the Rajnagar Marble	'Fateh Sagar lake is nearly one and a-half mile long and the broadest part is nearly a mile. In its deepest average depth is nearly 20 feet. The Connaught Bund is 2,800 feet long, and the road which reaches the bund from the end of the Pichola lake is nearly a mile long, having a balustrade of stones on the side of the lake, and on the other side it is surrounded by hills. A marble pavilion has been built in the middle of the bund...' (Mehta 1888, ADDENDA-4)	Ranawat (2016a, b)
4	<i>Saheliyon-ki-Badi</i> , Udaipur	24.6030° N, 73.6858° E	Built during the eighteenth century, it constitutes a garden and a palace. The walls surrounding the main courtyard, fountains, <i>chhatris</i> and elephants are plastered with <i>Ghutai</i> (Fig. 11a, b). The use Rajnagar Marble can be seen in the sculptures, carvings and flooring	'Another place which is worth visiting is the <i>Saheliyon-ki-bari</i> below the embankment of the Fatehsagar lake...The main court yard of this palace contains a marble bathing pool surrounded on all sides by magnificent <i>Chhatris</i> and fountains' (Agarwal 1979, p. 604)	Ranawat (2016b)
5	<i>Jagmandir</i> and <i>Jagniwās</i> , Udaipur	24.5676° N, 73.6778° E; 24.5755° N, 73.6799° E	<i>Jagmandir</i> and <i>Jagniwās</i> are the 2 palaces in the Lake Pichola built partly in Rajnagar Marble with <i>Ghutai</i> plastering. The walls of the <i>Jagmandir</i> , <i>Jagmandir</i> and <i>Jagniwās</i> are entirely plastered with white <i>Ghutai</i> (Fig. 11c)	'The Pichola lake is said to have been constructed by a <i>Banjara</i> at the end of the fourteenth century, and the embankment was raised by <i>Rana Udaī Singh</i> in 1560. The lake is about 2¼ miles long by 1¼ broad, has an area of over one square mile..in the middle of which stand two island palaces, the <i>Jagmandir</i> and the <i>Jagniwās</i> ,...The little palace built for prince <i>Khurram</i> consists of a round tower of yellow Sandstone lined inside with marble slabs, three storeys in height and crowned by a handsome dome. ... <i>Fergusson</i> thought it the prettiest room he knew in India. Its floor is inlaid with black and white marbles...' (Erskine 1908, p. 109)	https://ia802902.us.archive.org/10/items/fortspalaceshave00cent/fortspalaceshave00cent.pdf ; http://www.bl.uk/onlinegallery/onlineex/apac/other/019wzz000004211u00008000.html

Table 5 (continued)

S. No	Heritage buildings and monuments	Location	Description	Historical excerpts	References/weblinks
6	Ahar Cenotaphs Complex, Udaipur	24.5877° N, 73.7199° E	The 'Royal crematory' at the Ahar village consists of the cenotaphs of 'Maharajas of Mewar' built in Rajnagar Marble	<i>"The cenotaph of the renowned Maharana Amer Singh is the most conspicuous; but the cenotaphs of all are very elegant,—vaulted roofs supported by handsome columns raised on lofty terraces, the architraves of enormous single blocks, all of white marble from the quarries of Rajnagar; a town in Meywar"</i> (Mehta 1888, p. 29)	Mehta (1888)

Fig. 9 **a** Rajnagar marble used in stepped embankment of Rajsamand Lake. **b** Intricately carved pillars of the pavilion of *Nau Chauki*. **c** Close-up view of one of the carved pillars at *Nau Chauki* (photos by Parminder Kaur)



Fig. 10 **a** The intricate carvings of Jagdish Temple, Udaipur, constructed in Rajnagar Marble. **b** Close-up view of carvings on the exterior wall of Jagdish Temple. **c** Rajnagar Marble bust of Maharana Sajjan Singh. **d** Floral carvings on the capital of pillars at Sajjangarh Fort, Udaipur (photos by Sanchit Garg)



Fig. 11 a, b *Ghutai*-plastered octagonal *chhatris*, elephant fountains and the boundary wall in the main courtyard at *Saheliyon-ki-Badi* (photos by Jaspreet Saini and Parminder Kaur). c In the background of Lake Pichola, *Ghutai*-plastered City Palace Complex and *Jagniwās* can be seen (photo by P.S. Ranawat)



Fig. 12 Sajjangarh Fort with *Ghutai*-plastered exterior (photo by P.S. Ranawat)

Acknowledgements The authors acknowledge the valuable support from Shri O.P. Jangid, Department of Mines and Geology, and Mr. Anurag Jangid, Mr. Madan and Mr. Prashant who accompanied us to the field and the quarry. We are grateful to Shri. Tapan Sharma, for escorting us during our visit to R. K. Marble Mines, Rajsamand, and for providing us the geochemical data of the Morwad and Dharmeta varieties of Rajnagar Marble. We are thankful to Shri. M.L. Paliwal,

R. K. Marbles, for helping us in the sample collection. We thank Mr. Rajeev, Department of Geology, Panjab University, Chandigarh, for his help in the thin-section preparation. PK, AS and JS (JRF's at Panjab University) thank CSIR for the financial support. We are thankful to the two anonymous reviewers for their valuable comments and suggestions that have helped in the improvement of the manuscript.

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Fig. 13 Contemporary usage of Rajnagar Marble in handicrafts and building industry. **a** Hand-painted white marble elephant statue. **b** Marble utensils. **c** Marble cladding and staircase at Head Office, Morward Marble Mines of RK Marble Pvt. Ltd. **d** Marble sculptures at roundabouts in Udaipur (photos by Sanchit Garg, Jaspreet Saini and Parminder Kaur)



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