There is some evidence to show also that more metabolic energy is required to produce 1 g of root than 1 g of shoot[2]. Ultimately the plant tries to survive by adopting two divergent dehydration postponement mechanisms; one resulting in a 'warmer canopy' and the other maintaining a 'cooler canopy'. A plant surviving under a twenty-day drought in the field would probably have done a balancing act maintaining these two strategies, simultaneously or at different rates separated by a narrow time frame. The efficiency of the balancing act decides whether the plant survives or succumbs to the soil–plant dehydration syndrome.

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Derivatives of ultramafic rocks as decorative and dimensional stone in Rajasthan

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The Precambrian formations of southern Rajasthan host the unique and the largest deposits of 'green marble' in India located mainly around Rikhabdev, Kherwara, and Dungarpur areas. Field study coupled with mineralogic and petrologic studies indicate that the deep green and massive bodies of serpentinite are mainly composed of antigorite with subordinate amounts of carbonates and iron oxides. These serpentinite bodies occur as large sheet-like masses, emplaced concordantly within the Proterozoic formations of Aravalli Supergroup. These deposits are being utilized by fully mechanized, open-cast, block-bench mining methods for their extensive use as decorative and dimensional stone. About 70% of the recovered 'green marble' is being exported to various countries either in the form of well dressed blocks or in the form of finished products as slabs or tiles of suitable sizes. The highly fractured deep green serpentinites are also being exploited by small-scale, manual, open-cast mining methods to manufacture immensely popular flooring mosaic chips for civil engineering works. A very small quantity of steatitized serpentinite (steatite and chlorite schist) is also being used to manufacture different types of carved items and idols.

ULTRAMAFIC (UM) rocks, specially serpentinites have attracted the attention of geoscientists as well as common men not only because of their geologic significance but also because of their economic significance. Geologically, they reveal valuable information about the composition of the underlying mantle while, economically, they host a number of metallic as well as industrial mineral deposits. In southern Rajasthan, unfortunately, these rocks are totally devoid of metallic deposits but they host large deposits of talc[1] and world's largest deposits of amphibole asbestos[2,3]. Moreover, since the last decade, one of their metamorphosed derivatives, the massive and green serpentinite has acquired a significant recognition as a

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decorative and dimensional stone (DDS) all over the world and is utilized as 'green marble', popularly known as 'Kesariaji green marble'. Geologically, it is serpentinite but has acquired a name in the marble industry due to its easy blockability, ability to take excellent polish and low hardness. Some of the other derivatives like highly fractured green serpentinites; the massive, non-foliated and compact talc schist (steatite) and chlorite schist have also found a place in the field of architecture.

Geological setting and metamorphism

In southern Rajasthan, the UM rocks occurring within the metasediments (phyllite, quartz–mica schist and quartzite) of Aravalli Supergroup (2500 to 2000 m.y.)[4] are exposed mainly as lenticular bodies or sheet-like masses of varying dimensions and exhibit concordant relationship with them[4–7] (Figure 1). UM rocks of this area are considered to be emplaced within the Aravalli rocks at the end stages of sedimentation but prior to their deformation[8] and are represented as ophiolite[9–11] (obducted oceanic crust). They are also considered as derivatives of lherzolite subtype[12] (orogenic 'root-zone' peridotite). In this region, they constitute three well-defined belts, namely Rikhabdev UM belt, Jharol-East UM belt and Jharol-West UM belt[12]. The original UM rocks have undergone a varying degree of metamorphism in different areas[13]. They are now represented by varied lithologies, viz. antigorite schist, antigorite–talc–chlorite schist, serpentine–carbonate rock, talc–chlorite–antigorite schist and talc–antigorite–tremolite–actinolite schist in the former two belts and anthophyllite–talc schist[12] in the latter one. On the basis of mineral assemblages present in these rocks, the following successive stages of metamorphism have been deduced. (i) Formation of antigorite schist (serpentinization); (ii) Formation of talc and talc–chlorite schist (steatitization); (iii) Formation of tremolite–actinolite schist (tremolitization); (iv) Formation of anthophyllite schist (anthophyllitization[12]).

The present study reveals that in the Rikhabdev and Jharol-East belts, UM bodies have undergone changes up to the third stage of alteration. But in the central part where these rocks occur as comparatively large bodies, they have suffered changes only up to the stage of serpentinization. The UM bodies of the Jharol-West belt are highly altered and have undergone all the four stages of alteration followed by retrograde metamorphism[12].

UM rocks as DDS

Serpentinites as 'green marble'

The UM bodies which have undergone metamorphic changes only up to the stage of serpentinization and occur as deep green, massive serpentinite are suitable for use as DDS. They occur at a number of localities (Figure 1), but the richest and best quality of deposits occur at Odwas and Masaron-ki-Obri near Rikhabdev, hence they can be defined as type areas of 'green marble'. Mining activity in the state started about a decade and half back but a significant increase in production in the form of well-dressed

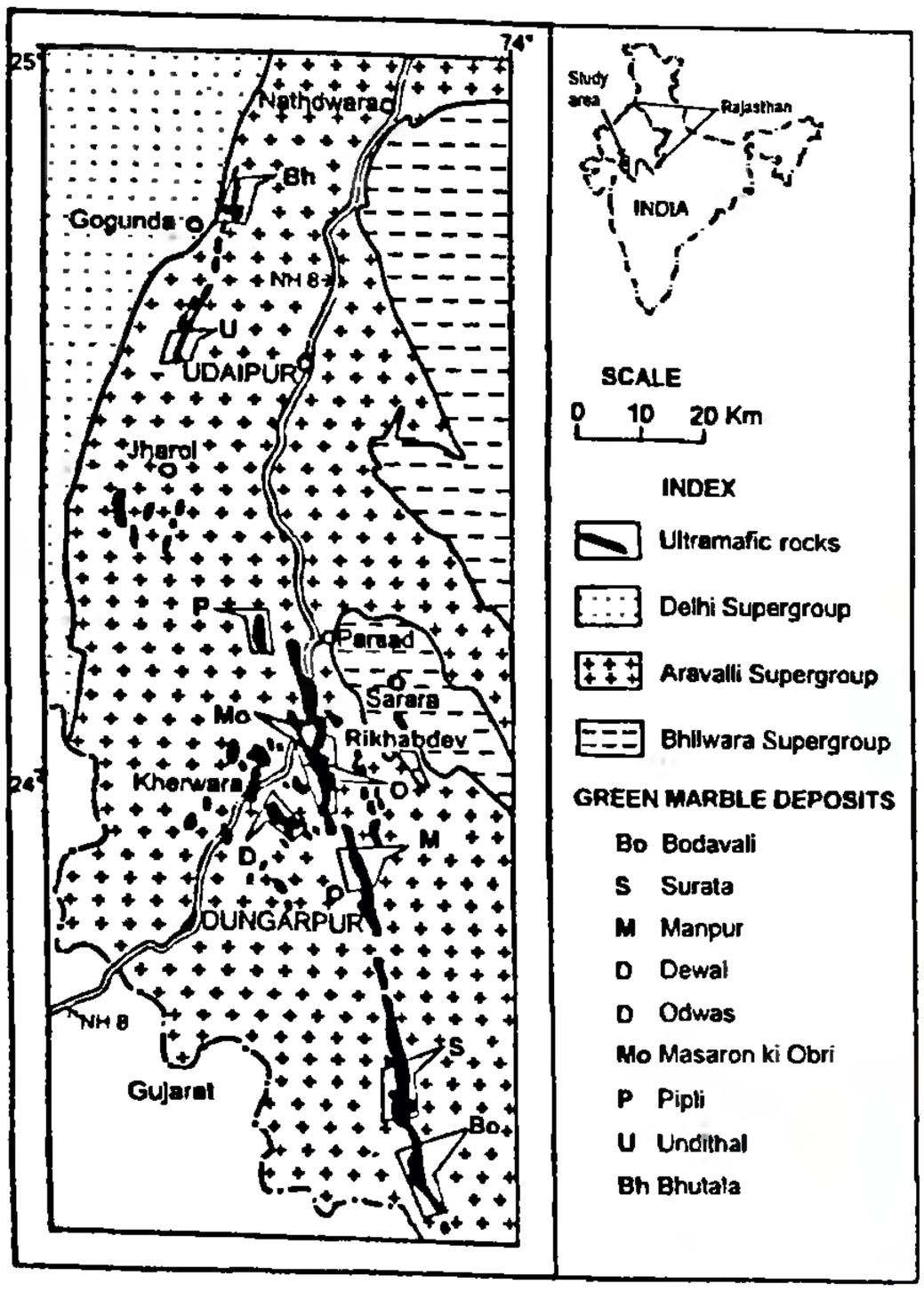

Figure 1. Geological map of the study area showing the location of 'green marble' deposits (modified after ref. 4).

Figure 2. Field photograph showing diamond wire-sawed blocks at a 'green marble' mine.

blocks (Figure 2) has been achieved since 1990 with the introduction of diamond wire-saws. In addition to its domestic consumption, a major proportion is being exported for use as dimensional stone. The 'green marble' is also extensively used for manufacturing a large variety of decorative items and idols (Figure 3) which take an attractive black colour on being smeared with oil. Incidentally, the famous black idols of 'Shri Eklingji' and 'Rikhabdev' are also made of this rock.

Varieties and industrial characteristics of 'green marble'

On the basis of texture and colour, four varieties of 'green marble' have been identified. These are: (i) plain deep green (without a white network structure), (ii) deep green with white network structure, (iii) parrot green (also known as apple green) and (iv) greyish-green with a white network structure. The characteristic features that make the UM rocks globally popular as DDS are: (i) their occurrence as massive and compact bodies which can easily be quarried and cut into blocks, (ii) their favourable hardness (about 4 on Mohs' scale of hardness), (iii) their ability to take excellent mirror-polish, and (iv) their attractive colour and beautiful designs (green with white network structure and plain deep green colour).

Mineralogic and petrographic characters

Petrographic study reveals that these rocks mainly consist of variable amounts of antigorite, relict olivine, iron oxides, carbonates, chrysotile and chlorite. Antigorite, a variety of serpentine, is the chief constituent of these rocks and is formed by alteration of olivine as evidenced by the development of antigorite along the boundaries of relict olivine and also within the irregular fractures of polygonal olivine grains. The relicts of olivine are also present in variable amounts within the groundmass of antigorite and the size of its grains vary from microscopic to macroscopic (1 to 5 cm). Unaltered grains of olivine are not present but altered pseudomorphic grains are commonly observed. Other important constituents of the 'green marble' are carbonates (dolomite and magnesite) found in recrystallized form along the fractures developed within these rocks by shearing effects. The carbonates act as a cementing medium and impart an attractive network structure. At a few places, white to smoky coloured crystals of calcite have also been noticed along the former fractures. The iron oxides (magnetite and ilmenite) are present in considerable amounts mostly as andedral to euhedral grains. Chrysotile frequently occurs in the form of cross-fibered, irregularly oriented, thin and long ribbon-shaped veins which vary in width from 1 to 10 mm.

Guide for locating 'green marble' deposits

In greater parts of the area, the serpentinites are highly altered, intensively fractured and majority of outcrops are also capped by thin soil cover and hence are a hindrance in localizing the underlying deposits of commercial importance. By field study, spheroidal dark green boulders lying partially or fully detached with the underlying outcrops of serpentinites (Figure 4) have been deduced for localizing the potential deposits of 'green marble' in the

Figure 3. Photograph of a statue of Lord Buddha carved from serpentinite.

Figure 4. Field photograph showing a well developed, fully mechanized 'green marble' quarry with diamond wire-sawed vertical faces and spheroidal boulders (a significant guide for massive serpentinite) at the top of the hill.

area. These boulders ranging in diameter from 1 to 10 m generally rest on the topmost part of the hill/outcrop. They exhibit massive form (non-fracturing nature) and have the same mineralogical composition as that of the underlying outcrops of serpentinite.

Steatite and chlorite schist as decorative stone

Steatitized UM rocks occurring in the area host potential deposits of steatite (a compact rock rich in talc, also known as 'soapstone' as it is soapy to touch). These deposits are being extensively quarried for various industrial uses. However, a small quantity of massive and non-foliated steatite recovered in the form of large-sized lumps find its use in the manufacturing of various types of decorative items and statues due to ease of sculpting. Similarly, the massive, non-foliated and fine grained variety of chlorite schist, occurring in association with serpentinites, has also been used for making various types of carved items and idols.

Conclusions

Deep green, massive serpentinites occurring in southern Rajasthan are composed mainly of antigorite with subordinate amount of carbonate minerals. Their massive nature, appealing deep green colour, white network structure of carbonates, desirable hardness and ability to take excellent polish make them suitable for use as DDS green marble all over the world. Occurrence of dark green spheroidal boulders at the topmost part of the hill/outcrop is the key guide for locating its deposits in this area. On the other hand, the highly fractured deep green serpentinite has established itself in the domestic market as flooring mosaic chips. Steatite and massive, fine grained, chlorite schist are used for carving decorative items.

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