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Characterization and Spatial Distribution of Quartz Reefs in Archean Bundelkhand Craton Based on Remote Sensing Data and their Implications

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Abstract
The quartz veins intruded through the host granitoids spread over 29,000 sq km area of the Achaean Bundelkhand craton, represent a massive Precambrian (2.15 Ga) silica-rich fluid activity in the central Indian shield.. These pervasively disposed quartz veins with variable orientations (NE-SW, NW-SE, ENE- WSW and E-W) represent the regional tectono-hydrothermal activity in the Bundelkhand craton. The quartz veins have characteristic signature in remote sensing data. They show white tone by which they distinguished from the other litho-units, mostly linear body having a perfect orientation, clear cross cutting relationship with mafic dykes show high vegetation along the flanks of the quartz veins. These veins form a striking curvilinear feature with positive relief having a preferred orientation NE–SW to NNE–SSW in the Bundelkhand Craton. Their outcrop widths vary from ≤1 to 70m and pervasively extend over tens of kilometres along the strike over the entire craton. The majority of the post-plutonic quart veins of the Bundelkhand Craton show a preferred orientation (NE-SW trend) indicating a strong tectonic control for their emplacement along the tensile fractures within the solidified granitoid host with sharp contact.

Key Words: *Archean Bundelkhand Craton, Quartz Reefs, Central India*

Introduction

High resolution imageries produced from different satellite can be effectively used to support the mapping and exploration programs of different natural resources. Good spectral resolution of the imagery also provides supportive information about mineral composition. In the multispectral image the silica and silicate minerals, the major components of the Earth's crust, show strong fundamental spectral bands corresponding to the Si–O bond length in the visible to shortwave infrared region of the spectrum atmospheric window (0.4–2.5 Am), Lyon (1965). LANDSAT (MSS) data provides measurements relating to surface reflectance and emissive properties of scene objects. MSS data has been used widely in the geological field for mapping of different surface features. Usefulness of remote-sensing for lithologic mapping in multi spectral signatures was demonstrated by many workers (Kahle & Goetz, 1983; Kahle et al., 1980; Kahle & Rowan, 1980).

The giant quartz veins in the Bundelkhand Craton, central India, spread over nearly 29, 000 km^2 constitute extravagant landforms in a regional scale because of their high resistance to erosion, unique spatial disposition and homogeneous distribution with a preferred orientation. There are more than 1540 mappable quartz veins, presently exposed in the Bundelkhand Craton. Such veins are found in different parts of the world in similar settings (Kerrich and Feng 1992). The present study is mainly focused on spatial distribution and their relationship with host granitoids and other rock types in the Bundelkhand craton with help of LANDSAT (ETM+) data and digital image processing techniques.

Geology of the Bundelkhand Craton

The Bundelkhand Craton is bound on its east, west and south by the Vindhyan Supergroup of rocks (Fig.1). Its south-western fringe is marked by a relatively small outcrop of the Deccan basalt and the northern part is hidden under the Indo-Gangetic alluvium. In addition to the granitoids (2.2-2.5 Ga), syenites, metasupracrustals (amphibolites, BIF, tonalite-trondhjemite- granodiorite (TTG up to 3.3 Ga; Mondal et al., 2002) gneisses, calc-silicate rocks, quartzites, pillow lavas-basaltic komatiites of boninitic affinity-volcaniclastic metasediments (Malviya et al., 2004 and 2006), GQVs (Pati et al., 2007, 2008, 2009, 2010) and volcanics (rhyolites) occur in the ABC. Mafic-ultramafic rocks are also exposed in Kurrat area, Lalitpur district, U.P. (pillowed metabasalt; Pati and Raju, 2001) and between Madaura and Purani Pindar, Lalitpur district (PGE-bearing mafic-ultramafic rocks; Pati et al., 2005) of the Bundelkhand Craton.

The giant quartz veins were probably emplaced due to ongoing crustal movements subsequent to the stabilization of the cratonic segment at about 2.5 Ga. Thousands of quartz veins of varied size and shape (sygmoidal) are observed in parts of the Bundelkhand

Craton representing an episodic tectonic-controlled hydrothermal activity (Pati et al., 1997; Pati et al., 2007) which are intruded by mafic dykes in places. Mafic dykes represent the youngest intrusive phase (2.0-2.15 Ga; Rao et al., 2005).

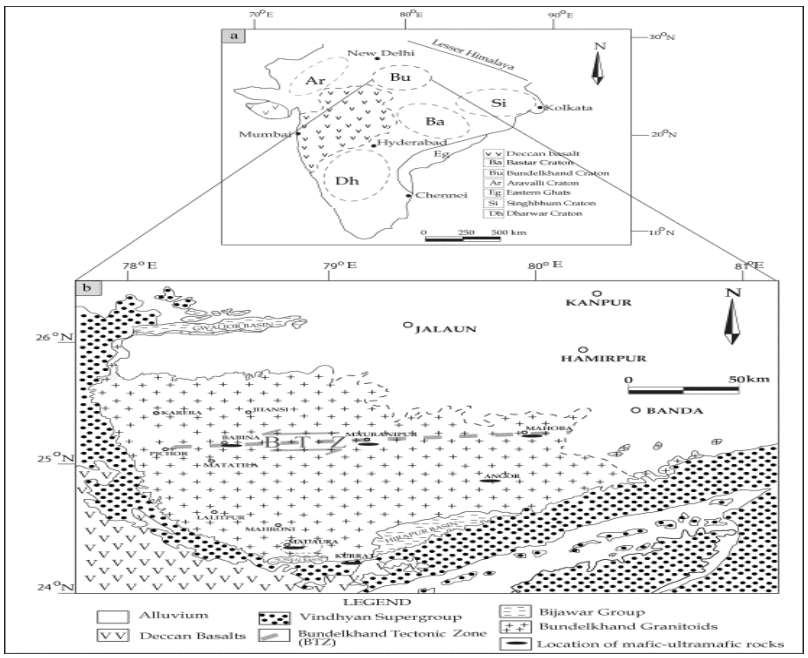

Figure1: **(a)** Map of India showing the different cratonic blocks and Bundelkhand in central India.
(b) Diagram showing the Bundelkhand Craton, which is bounded on its east, west and south by the Vindhyan Supergroup of rocks

Methodology

Enhanced Thematic Mapper (ETM+) and Shuttel Radar Topographic Mission (SRTM) data (date of acquisition - 2006-09-30) are used for delineation of the mafic dykes from other lthounits. The ETM+ data was obtained from Global Land Cover Facility. The ETM+ is a cross-track scanner providing seven multispectral channels (3 visible, 1 near-infrared, 2 mid-infrared, 1 thermal-infrared) at 30-meter resolution while 15 meter spatial resolution in panchromatic mode (120-meter resolution for the thermal-infrared band) and orthorectified data with moderate resolution 30-90 meter of Date 2000/11/20.

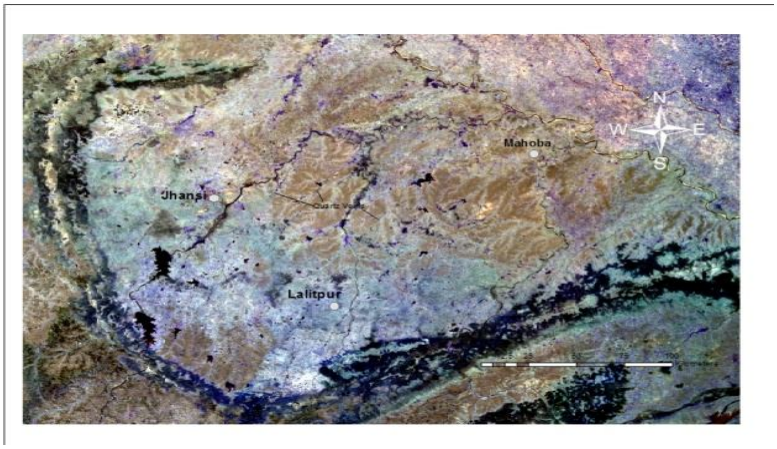

Figure2: FCC of LANDSAT (ETM+, bands 2:5:7: R:G:B) image showing Vindhyan Supergroup bounding the Bundelkhand .

The LANDSAT ETM+ data is being used primarily to provide the regional overview of the area. Four ETM+ scenes have been calibrated and mosaicked together to furnish entire site coverage. This mosaic data is being digitally analyzed by different image processing techniques to provide better regional spectral information. Color-ratio-composite images using the 5/7, 3/1, and 3/4 ratios (RGB) allow discrimination of areas with clay/carbonates, iron oxides, and mixtures of these two groups. The 3/4 ratio is useful for mapping vegetation distribution. Additionally, standard photo interpretation is being used on the ETM+ scenes to add regional structural and lithological information.

Results and Discussion

The quartz veins occur as cuesta-like features cropping out over the surrounding plain and are easily identified in LANDSAT ETM+ imageries due to their lighter tone and long linear-to curvilinear disposition. Vegetation on their flanks gives the veins a darker tone and provides further contrast. The outcrop pattern of giant quartz veins is variable but most veins are linear with very high aspect ratio and local sigmoidal geometry (Fig. 3). Such geometry suggests that the veins are emplaced along regional fault planes. Some of the veins occur as lenticular bodies, and at places, anastomosing types are also found.

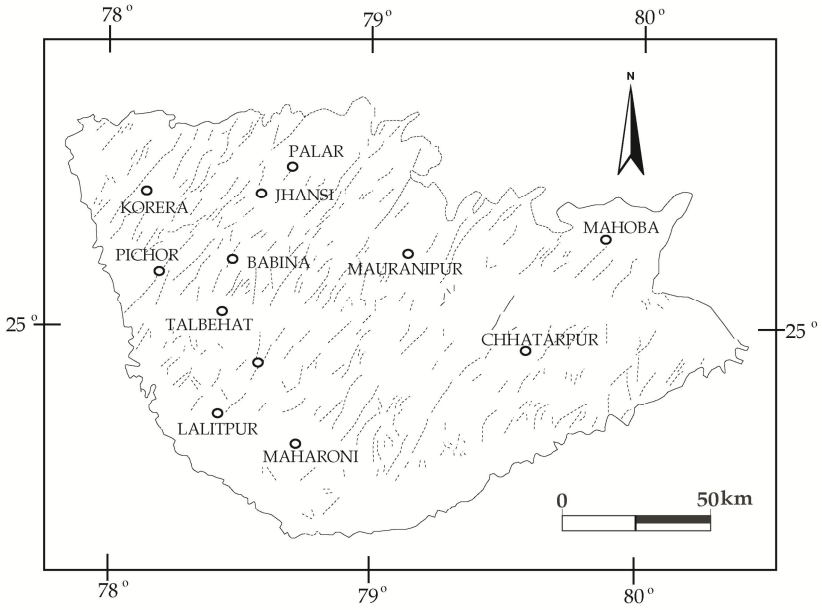

Figure 3: Sketched out diagram of the quartz reefs (1540) intruded in granitic rocks of the Bundelkhand Craton.

The maximum outcrop length of the giant quartz veins is more than 60 km (Basu 1986). However, they can be traced along the strike for over 100 km as discontinuous pinch and swell type outcrops with the average length of individual outcrops exceeding 1 km.

The GQVs, in general, trend NNE–SSW with sub-vertical dips. Lateral veering of these veins is quite common and a few of them exhibit an EW orientation, some even showing NS to NNW–SSE trends (Fig.4). The prominent ones occur between Birdha and Bhuchera, to the NW of Bansi and north of Jamalpur, east of Rampur, and SE of Kotra (Lalitpur district).

The EW trending GQVs occurring to the east of Bhainsai in the Mahoba district is an exception. In places, some of the veins are found to coalesce with or intersect each other, e.g., Jiraun Kasba of Jhansi district, Kandhari Kalan, Khariadhana, Bar and Patori of Lalitpur district and around Garhmau of Jhansi district. Interestingly, pyrophyllite-diaspore (Palar-Garhmau, Jhansi district; Larwari-Bar, Lalitpur district) and sporadic Cu mineralization (Karesara Kalan, Lalitpur district) are largely confined to intersecting GQVs (Pati, 1998).

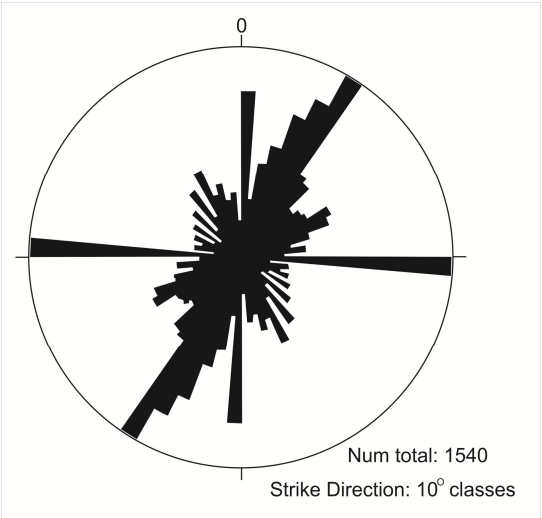

Figure 5: Rose diagram showing the orientation of the quartz reefs.

Conclusions

The general trend of the quartz veins is NE-SW and spread over 29000 km^2 area of Bundelkhand craton. However some of the quartz veins have NW-SE and ~E-W trend. Maximum concentrations of the quartz veins are observed in NW and SE part of the Bundelkhand craton. One immensity is seen near the Khajuroho, district, Madhya Pradesh, where maximum concentration of dykes are observed and other bulk is seen near Lalitpur, district, Uttar Pradesh. The majority of the post-plutonic quart veins of the Bundelkhand Craton show a preferred orientation (NE-SW trend) indicating a strong tectonic control for their emplacement along the tensile fractures within the solidified granitoid host with sharp contact.

Numerous younger thin quartz veins with somewhat similar orientation cut across the giant quartz veins. They show imprints of strong brittle to ductile–brittle deformation, and in places are associated with base metal and gold incidences, and pyrophyllite-diaspore mineralization. The Quartz reefs are genetically related to the development of ductile shear zones within the granitic rocks and brittle–ductile shears in the intervening wall rocks and these quartz veins are basically co-genetic melt secreted product of microgranites (Roday, 1995).

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