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Geological and Structural Inferences from Satellite Image in Parts of the Eastern Dharwar Craton, India.

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ABSTRACT

The geological interest of the Precambrian Dharwar craton in the Indian peninsular shield stems from its complexity. An IRS-ID LISS-III satellite image covering an area of approximately 18,900 sq. km corresponding to the region in and around Maddur, Narayanpet and Makthal in the eastern Dharwar craton was digitally processed and visually interpreted to present a schematic map of the geology and elucidate the structural fabric of the region. The disposition of the schist belts, shear zones and various faults and other lineaments in the region are delineated. The findings are significant in relation to structural data in the region and form a part of the geo-structural database for ground surveys.

INTRODUCTION

It is known that remote sensing is a useful aid to geological mapping and has been in practice for the last several decades (Griffiths et al. 1987; Abdelhamid & Rabba 1994). Computer enhanced multi-spectral digital images provide an excellent means for mapping the distribution and geometrical patterns of lithologic units that commonly reveal the tectonic setting and local fold and fault structures (Watson & Knepper 1994), which often constitute the structural controls of mineralization and also possible emplacement of kimberlites/lamproites. Thus knowledge of the structural fabric of a region is a prerequisite for exploratory geophysical surveys.

The Archaean to Proterozoic Dharwar craton is interesting both from the economic – it comprises a vast storehouse of minerals - as well as the geologic points of view. The three major geological constituents of the craton in order of decreasing age are the Peninsular gneisses, the schists and younger granites (Ramam & Murty 1997). Though the craton has been extensively studied (Naqvi & Rogers 1987, Rajamani 1990) much still remains to be known. Interestingly, semi-regional to detailed structural investigations in parts of the eastern Dharwar craton (unpublished report of GSI 1994; Nayak et al. 1999) have been very informative and promising in terms of potential for mineralization.

The present study is in continuation of structural studies in the Dharwar craton and attempts to provide a structural map from interpretation of a satellite image of the region extending from the Narayanpet kimberlite field in the north to river Krishna in the south. This region forms a type area for the study of the eastern Dharwar craton.

DATA PROCESSING AND IMAGE ENHANCEMENT

An IRS-ID LISS-III image covering an area of approximately 18,900 sq. km (latitude 16°00′ to 17°5′ N and longitude 77° to 78° 15′ E) in and around Maddur, Narayanpet and Makthal in the eastern Dharwar craton was procured from NRSA, Hyderabad, for analysis. The date of satellite pass over the area is 2nd February 1999 and the standard data product corresponds to a scene with path/row numbers 99/61. This image was processed (Jensen 1986) and analyzed using 'Image Analyst' (Intergraph Corporation) software. From visual examination of the different false color coded (FCC) image combinations, as well as statistical analysis (Short 1982, Hammond & McCullagh 1980, Castleman 1978) of the brightness values of the scene in each band (B2: 0.52 – 0.59 μm, B3: 0.62 – 0.68 μm, B4: 0.77 – 0.86 μm and B5: 1.55 – 1.70 μm) the FCC composite of bands B5, B4 and B3 was found to be optimal for geomorphologic and geological interpretation. While B2 and B3 correspond to the visible region, B4 and B5 correspond to the near infra red and short wave infrared regions of the electromagnetic spectrum. The ground resolution and swath for the B2 and B3 bands are 23.5 m and 141

Km respectively while the corresponding figures for the B4 and B5 bands are 70.5 m and 148 Km respectively.

The extracted FCC was subsequently enhanced. A weighted high pass filter with maximum available center weight setting and kernel size was found to enhance the distinction between different rock types as well as bring into focus the smaller details of geological variation. This was followed by the application of logarithmic /exponential stretch, which had the effect of selectively highlighting different features of interest in the image. Finally, the image was geo referenced for further analysis (Figure 1).

ANALYSIS AND RESULTS

Type and composition of minerals determine the spectral response of the rock type (Singer 1980; Miller & Pearson 1971; Price 1995). Pandey (1987) summarized the signatures of various rock types on remotely sensed images, which can be used as a guide to geological interpretation. Broadly, acidic rocks give a lighter tone on the images obtained in the visible and reflected infrared region as compared to basic rocks, which give a darker tone. Similarly, coarse-grained rocks appear brighter as compared to fine-grained rocks. Generally, rocks have low reflectance at shorter wavelengths with increasing reflectance towards longer wavelengths, reaching a maximum reflectance between 1 and 3 µm (Hunt 1977).

However, it must be borne in mind that though the composition of a rock determines its spectral response, the latter is not always diagnostic because of various reasons. Firstly, several factors including the crystal lattice, the surface of the rocks and the atmospheric conditions have to be taken into account (Szekielda 1988). Secondly, mineral constituents rarely display conspicuous spectral features at a particular wavelength or do so in a very narrow wavelength band of the order of about 10 nm. As current sensors aboard the IRS satellites do not provide data in such small wavelength bands, direct unambiguous, identification of rocks with varying mineral compositions is not possible (Rao 1995). This implies that while the schistose regions can be clearly delineated, finer compositional variations cannot be as easily recognized. Therefore, it has to be kept in mind that only an indirect, deductive approach, through the study of various interpretation elements combined with ground checks where necessary, can be used to identify the rocks on the remotely sensed image.

GEOLOGY

Figure 2 shows the geology map of the region as inferred from the image. As has already been discussed earlier the three major rock constituents of the region are Peninsular (migmatite) gneisses, schists (enclaves of meta supracrustal rocks comprising ultramafics, amphibolites and meta-basalts) and Younger (biotite) granites, with respective ages of 3400-3000 million years (Ma), 2900-2600 Ma and 2600-2500 Ma (Beckinsale, Drury & Holt 1980, Taylor et al. 1984 and Bhaskar Rao et al. 1991). The area is intruded by heterogeneous mafic intrusives like gabbro, pyroxenite and dolerite dykes and basic intrusives of kimberlitic affinity in the central portion. The spectral signatures (Pandey 1987) of these rocks in the image are characterized by dark tones, exhibiting linear to curvilinear ridge like topography with discordant relationship with country rocks. In addition, small occurrences of the Deccan traps are seen in the northern and northwestern part of the image. These traps are associated with a plateau like topography and development of black soil and thick vegetation in areas where weathering has taken place to an appreciable degree. In the southwestern part of the image are seen the Diorites, Granodiorites and Kallur Diorites. It is evident that the predominant trend for all the formations is NW-SE (Naha, Srinivasan & Mukhopadhyay 1996).

The Peninsular Gneisses form the Archaean basement of the area and represent a set of formations of varying composition. Their nomenclature varies: migmatitic tonalitic gneiss (GSI 1981), Peninsular gneiss (Project Vasundhara 1994), plutonic rocks of the Dharwar batholith (Chadwick, Vasudev & Hegde 2000). These rocks are seen as small exposures in the central part of the image.

The two schist belts exposed in the region are the NW-SE trending Gadwal and Raichur schist belts (fine textured green tones). While the former is relatively narrow and occurs discontinuously, the latter has a greater areal extent. The Narayanpet schist belt forms the northwestern extension of the Gadwal schist belt (Ramam & Murty, 1997). The shearing associated with these belts is barely visible, apparent more as a minor textural characteristic than any tonal change.

The high-density granodiorite (Chadwick, Vasudev & Hegde 2000, Ramadass, Ramaprasada Rao & Srinivasulu 2001) is seen in dark green, fine textural tones and lies in between the diffused banded granites and the Raichur schist belt. The Kallur diorites are seen in the extreme southwest corner of the image.

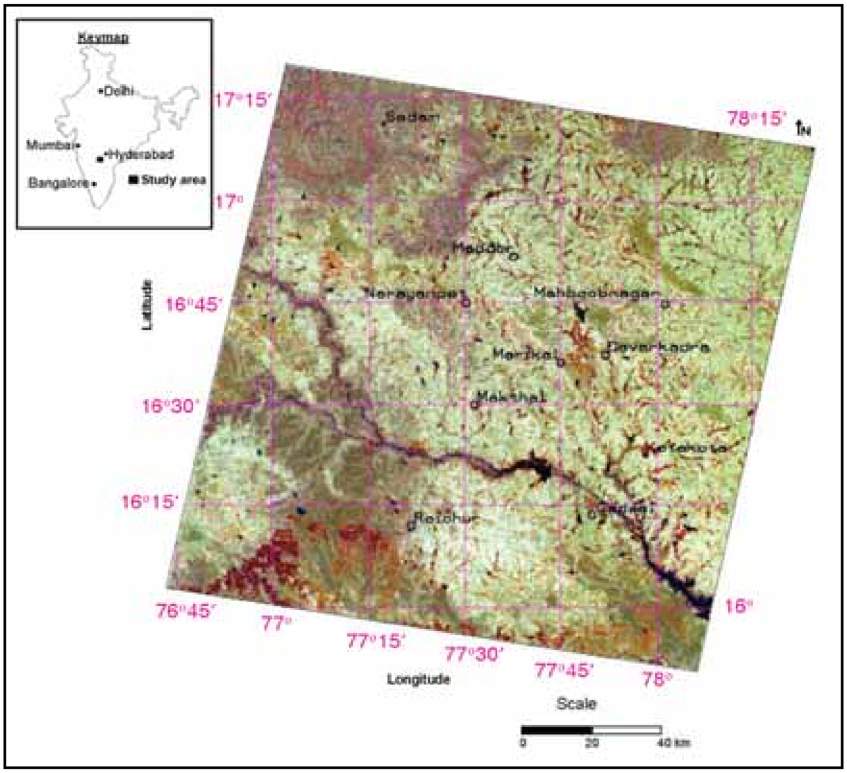

Figure 1. IRS ID LISS-III satellite image of the region in and around Makthal-Maddur-Narayanpet in the eastern Dharwar Craton, India.

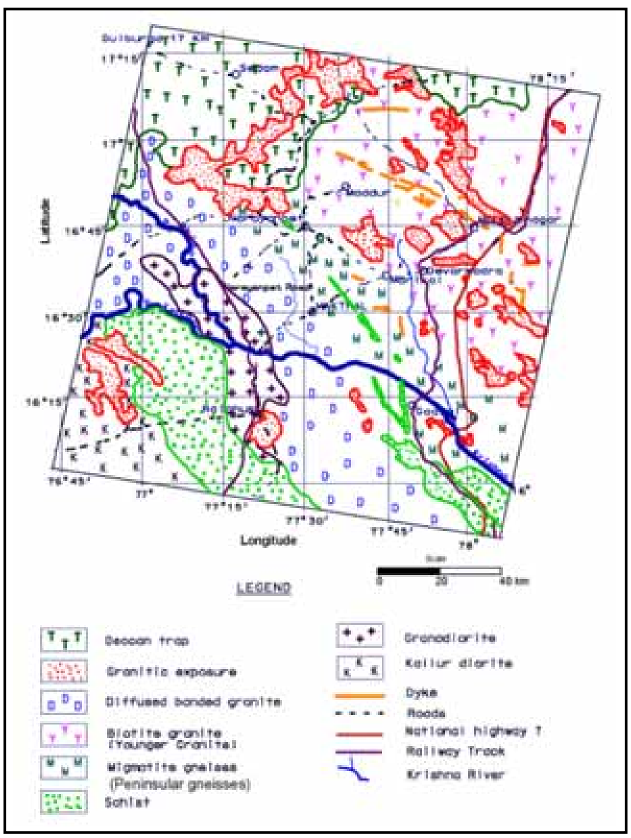

Figure 2. Geological map of the Makthal-Maddur-Narayanpet region as inferred from satellite image of the area.

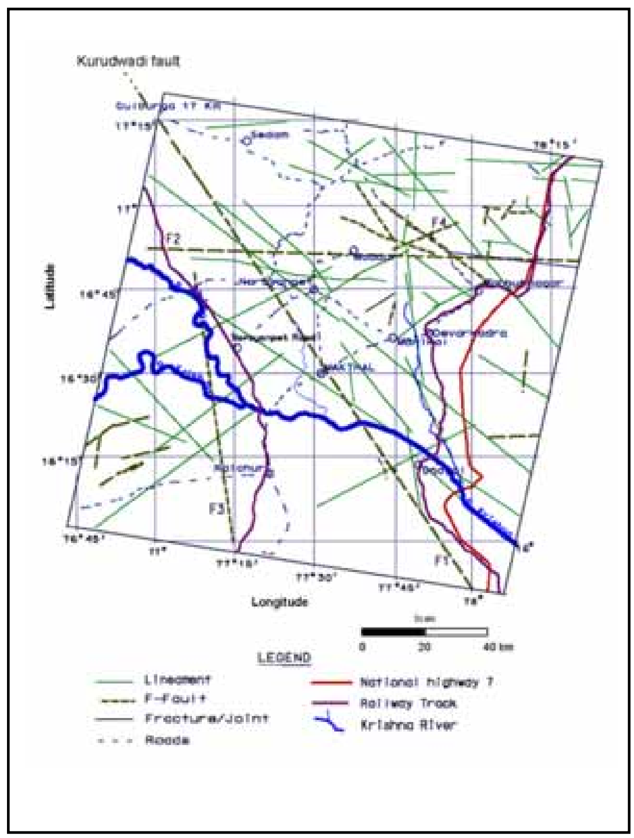

Figure 3. Structural map of Makthal-Maddur-Narayanpet region as inferred from satellite image of the area.

Most of the granitic exposures are seen to the northeast of the migmatite gneisses.

Within the gneisses are seen exposures of banded diffuse granites (dark green to brown tones) and biotite granites (light green to green tones), characteristically exposed as boulders (dark green tones). The migmatite gneisses lie between the biotite granites on the northeast and the diffused banded granites in the southwest.

The youngest geological members in the region are the Deccan Traps, seen as small exposures (dark brown tones, with evidences of vegetation) in the northwest and northern part of the image.

The tonal characteristic of the image is a little ambiguous. From known geology (Chadwick, Vasudev & Hegde 2000; Nayak et al. 1999) it is seen that different geological formations have almost the same tonal signatures, such as the Deccan Traps in the northwestern parts, mafic and ultrabasic intrusives in the central part and as also the schist belt in the southern part (Chadwick, Vasudev & Hegde 2000, Ramadass, Ramaprasada Rao & Srinivasulu 2001) - all are identifiable as dark green to brown tones. Also, the variation from Peninsular Gneiss to granite is gradational. Further, while the Younger granites and schists, later members in the geologic evolution of the area, in general overlie the gneissic complex, no conclusive inference about the relative topography can be made as the region has undergone various phases of deformation (Chadwick, Vasudev & Hegde 2000).

STRUCTURE

Apart from the lithological composition of rocks, the other major element of geological interpretation is structural study. However, though subjective (Moore & Waltz 1983), a manual procedure is sometimes more reliable than their detection in the field (Drury 1987). Structural interpretation in the present work has been limited to lineament mapping and analysis. A preliminary examination of the image reveals several instances of tonal variation along a linear feature suggesting the presence of various lineaments (Figure 3). Thus lineaments that fall within the migmatite gneisses show a concordant relation with the regional Dharwarian trend, i.e., NW-SE, where as lineaments that fall over the biotite granites show both parallel as well as transverse relation, i.e., NW-SE, WNW-ESE, E-W, ENE-WSW and N-S trends. Intersecting lineaments form structural locales conducive for emplacement of kimberlites. The region around Maddur, a rich kimberlite field (Nayak et al. 1988, Babu Rao, Bijendra Singh & Jain 1992; Sreerama Murty et al. 1997, 1999) is characterized by intersection of a few major and several minor tectonic elements.

The observed lineaments have been classified into faults, fractures/joints, and lineaments. This classification was guided by the following considerations: While tonal variation along a linear feature constitutes a lineament, a lineament with discordant relationships (as for e.g., the displacement or offset of part of a dyke from its main trend) between geological members on either side of it is inferred to be a fault. Relatively smaller lineaments exhibiting high frequency of occurrence in varied azimuths within a geological type are inferred as fractures and joints. Features exhibiting a linear trend but additionally marked by discontinuous exposure, dark tones, fine texture, elevated topography (at places), and an intrusive relationship with the country rocks are identified as dykes. Linear features that could not be conclusively identified as either fault or joint/fracture or dyke have been simply classed as 'lineaments'.

Faults and joints in rocks are important features in geologic and hydrologic studies. Four major faults, marked F1, F2, F3 and F4 are seen. F1 corresponds to a major fault, which was earlier delineated from controlled source audio frequency magneto-tellurics (CSAMT) by Ramaprasada Rao, Venkata Chary & Ram Raj Mathur (2003). Forming the southern extension of the Kurudwadi fault that runs through Yadgir (west of Narayanpet) to Cuddapah basin further southeast this fault is associated with seismic activity (Peshwa, Kale & Gouri Dole 2001). The E-W trending fault F2 was earlier commented upon by Nayak et al. (1999), F3 appears to represent the faulted contact between diorite and the Raichur schist belt; support for this inference comes from magnetic investigations carried out by Ramadass, Himabindu & Ramaprasada Rao (2004) who reported a fault west of Raichur. Within the Younger granites are seen several fractures and a small fault, the NE-SW trending F4. No ground surveys confirming presence of this fault have been reported yet.

The lineaments in the area as inferred from tonal variation are seen to trend in NW-SE, NE-SW, ENE-WSW, E-W and WNW-ESE directions. The geometry of contacts depends upon the processes of evolution of the corresponding rocks. Some of the lineaments can be attributed to geological contacts. Metamorphism at contacts has resulted in alteration of the rocks as can be seen in the deepening of tone at the edges.

Apart from the above some gabbro, pyroxenite and doleritic dykes (expressed in narrow linear dark green to brown tones and marked in orange in the geology map) are seen in profusion mainly in the migmatitic gneisses, and to a lesser extent in the Younger granites.

CONCLUSIONS

An IRS-ID LISS-III satellite image covering an area of approximately 1.25° X 1.25° in the eastern Dharwar craton (latitude 16° to 17°15′ N and longitude 77° to 78° 15′ E) in the region in and around Makthal was digitally processed and visually interpreted to elucidate the structural fabric of the region comprising the geology and lineaments. Geological elucidation consisted of tonal demarcation of the various geological members of the region, mainly Peninsular gneisses, schists and Younger granites. Observed linear features were classified into four categories – faults, fractures/joints, lineaments and dykes. Four major faults trending NW-SE, E-W and NE-SW and several lineaments trending mainly NW-SE were found to criss-cross the entire area. The Maddur area, known for kimberlite occurrences, is characterized by several intersecting faults and lineaments. The southern extension of the Kurudwadi fault finds expression in the image as one of the major faults identified - the NW-SE trending F1.

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