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Potentials of Alternate Polarization of Envisat ASAR Data in Geological Mapping – A Case Study in Kurnool Group of Rocks, Andhra Pradesh

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Abstract: The application of SAR data is a proven technology in geological studies but very few accounts are available in India, which can evaluate and demonstrate the utility of microwave signatures as an important tool for geological mapping. In this connection, the significance of polarization is an important parameter in enhancing geological elements. Present study reveals that the simple polarization composite prepared from different polarization channels can significantly aid the delineation of geological features as demonstrated from the Proterozoic metasedimentary sequences of Kurnool Group. The polarization colour composites reveal that different sedimentary units can be differentiated on the basis of variable back scattering return in different polarization channel. Further geological structures of regional importance can also be delineated in these colour composite images. Comparative analysis of different composite images with published geological maps, illustrates the capabilities of the microwave polarization in enhancing geological elements and how they can be used in updating geological data.

Keywords: Microwave Remote Sensing, Geological mapping, Kurnool Group, Andhra Pradesh.

INTRODUCTION

Imaging radars are operated in the microwave range of the electromagnetic spectrum at wavelengths from 1 cm to 1 m (Ford, 1998). Polarization of microwave signal provides valuable information related to the scattering behaviour of earth surface features and an insight related to the dielectric properties of materials. Many radar systems are designed to transmit microwave radiation with either horizontal polarization (H) or vertical polarization (V). A transmitted wave of either polarization can generate a backscattered wave with a variety of polarizations after the transmitted wave interacts with the terrain. It is the analysis of these transmitted and received polarization combinations, that constitute the science of radar polarimetry. Radar imaging systems commonly transmit plane polarized electromagnetic radiation (EMR) horizontally. When this EMR interacts with the earth surface features, it is depolarized and rotated to varying degrees depending upon the mode of scattering. Present SAR systems can transmit both horizontal and vertical polarized electromagnetic radiation. Therefore, the transmitted and received signal is of the same polarization or can be depolarized. Thus, there are four combinations:

1. Horizontally polarized transmitted energy (H) and received horizontally H (HH)
2. Horizontally polarized transmitted energy (H) and vertically polarized (HV)
3. Vertically polarized transmitted energy (V) and received horizontally H (VH)
4. Vertically polarized transmitted energy (V) and received vertically V (VV)

The first and last combinations are referred to as "copolarised" because the transmitted and received polarizations are the same. The other two combinations are referred to as "cross-polarized" because transmitted and received polarizations are orthogonal to each another. Co-polarized signals give more information on surface scattering; which is guided by the surface roughness and dielectric property of the surface element. On the other hand, volume scattering of the microwave energy from the surface features causes depolarization. Volume scattering is a type of scattering where electromagnetic

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energy penetrates through the surface feature and gets repetitively scattered throughout the volume of that surface features and therefore causes change in polarization of electric field of microwave signal. Multiple scattering across the planes oriented in different direction to the incident microwave signal also can create significant amount of depolarized signal. Forest cover is an important features; which causes significant amount of depolarization.

Experimental evidences suggest that depolarized back scatter is much less dependant on surface roughness and incident angle of microwave signal than co-polarized back scatter (Blanchard et al. 1980).

Sedimentary rocks are of different mechanical strength and chemical competence and susceptible to chemical and mechanical weathering to different degree. Therefore they support varied land covers and hold surface moisture in varied degree distinctive to each rock type. These elements parameter influences the scattering of microwave signal. Therefore there is always a possibility of distinguishing between various lithologies by using multi-channel, cross and like polarized radar images (Daily, 1978; Bloom et al. 1987).

Objectives

The main focus of present work is to identify the utilities of C-band ENVISAT ASAR data of particular beam (IS2) HH, HV polarization for studying the regional geological elements of Kurnool Group of rocks.

Study Area

Study area is located at northwestern part of Andhra Pradesh. The area falls in north latitudes from 15°05'00" to 15°25'00" and east longitudes from 77°50'00" to 78°15'00" and covered in the parts of toposheet 57I/3, 57I/4, 57 I/6, 57I/7 and 57I/8. This area is well connected to the state capital.

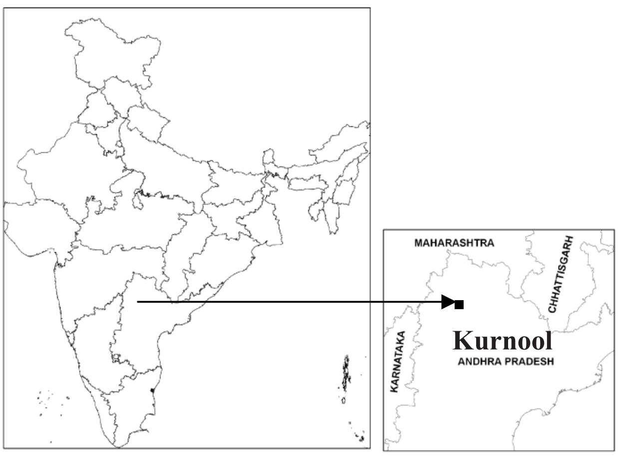

Fig.1. Location map.

GENERAL GEOLOGY

The major part of study area is occupied by Kurnool Group of rocks; which overlies the Cuddapah Supergroup and separated by an unconformity. Kurnool Group of rocks are found in two major basins namely Kurnool sub basin and Palnad sub basin (Nagaraja et al. 1987) and present study area falls in parts of Kurnool sub basin. At the western most flank, rocks belonging to peninsular gneissic complex are exposed and these are separated from Cuddapah rocks by Eparchean unconformity. Dharwar rocks occur in patches within the granite-gneissic complex along with dolerite dykes and they are faulted by younger faults occurring within Archaean rocks. NW trending regional foliation; is the major regional structural trend in the gneissic complex.

Several intraformational faults are exposed within the area. General trend of major fault is WNW in the Kurnool sub basin. Another trend of faulting is along NNE. Faults reveal characteristic geomorphic signature; viz. presence of scrap face truncating with particular litho unit abruptly, linear juxtaposition of natural ponds/reservoirs, sudden discontinuity or change in direction in natural drainage, variation in drainage density, geomorphology, soil type etc. Master joints are natural lineament present in the Kurnool sub basin.

MATERIALS AND METHODS

Envisat satellite launched in March 2002, by European Space Agency was largest single instrument called Advanced Synthetic Aperture Radar (ASAR) operated at band (5.331 Ghz). In the alternating polarization mode PP), ASAR can acquire two images in two-polarization ›de (HH and VV or HH and HV or VV and VH) with ›und resolution of 30 meter sampled at 12.5 m. For the rpose of present study, C Band APP Data (HH and HV larization) with specific incident angle (IS2 beam (18°- °)) was used. The data was collected by the satellite in : month of September, 2005. In this work, major emphasis is given to understand how much geological information n be extracted from SAR polarization composites in rms of delineating the structures and lithologies and sociated lithological and the structural variants in ırnool Group.

With this objective, Envisat ASAR data set was retrieved from original raw data format to software compatible format, with the help of available image processing software (ERDAS Imagine 9.1 software). The image had two channels related to specific combination of polarization of transmitted and received microwave signal (HH & HV).The data was co-registered with the help of georectified Landsat ETM data before it was used to interpret the geological informations. For better interpretability, Envisat ASAR data was subjected to Lee- Sigma filter to reduce the speckle from the image. Lee-Sigma filter shows very good edge preserving capability and it is very effective speckle removal filter (Rivera Rio et al. 2000).

Colour composite images were generated with the combination of dataset representing different polarization combinations of transmitted and received microwave signal. In this composite HV channel is represented by red channel and HH channel is represented by green and blue channels of RGB colour space. Such colour composite data was interpreted for delineating various geological features.

RESULTS AND DISCUSSION

In the present study, various geological features are delineated and compared with regional geological map of GSI to validate the information analyzed from SAR data. The aim of the analysis is to evaluate the role of polarization in delineating different litho units.

Microwave signal once incident on a surface, it gets scattered from the natural surface in different direction and part of the scattered signal (also called backscattered energy) is only received by the sensor. The amount of backscattered signal received by sensor is dependent on the type of scattering process took place on surface. The type of surface determines the scattering process. Specular surface reflects the incident energy towards the opposite direction of incidence and therefore hardly minimum energy is received by the microwave sensor. This is why the specular surface or smooth surface (e.g. water body) appear darker in microwave image. On the other hand, rough surface scatters the incident energy in all direction. This type of scattering is known as diffuse scattering. Diffuse scattering allows considerable energy to return back to microwave sensor.

There are other types of scattering takes place on natural surface. One of such scattering is multiple scattering. Multiple scattering takes place from multiple irregular surface planes existing within rough surface. Volume scattering is another scattering process in which scattering takes place through entire volume of the surface material. Vegetation is one kind of surface; which volume scatters incident microwave energy. Volume scattering and multiple scattering allow incident microwave energy to backscatter to microwave sensor. Moreover; these type of scattering processes also responsible for changing the polarization of electric field of incident microwave energy.

Rough surface has the potential to create more depolarized signal compared to smooth surface if surface is dielectrically homogeneous and allow microwave signal to penetrate through it and thereby allow volume scattering of the incoming signal. Vegetation and forest covers are such type of surface. Even if the surface does not allow the microwave signal to penetrate; multiple scattering from very rough surface also can create some amount of depolarization. But volume scattering causes more depolarization in comparison to multiple scattering. As depolarization causes shifting of transmitted horizontal polarization (H) to generate a vertical component (V); therefore wherever depolarization effect is more we get more return in HV channel. This generally takes place in forest areas; where twigs, stems preferentially grow over particular lithounit can scatter the incident microwave energy in multiple directions and depolarize the H (horizontal) signal to V (vertical). Jointed quartzite also can depolarize the H signal but co-polarized component (HH) of incident energy would be more in quartzite than depolarized component (HV). On the other hand, co-polarized component (HH) is higher for the surface element with lower order roughness (which can cause diffuse scattering without depolarizing the electric vector of microwave signal) and high moisture content. Low return in HH and HV can be expected over a terrain with fine grained, smooth waterlogged or oversaturated soil developed over shaly limestone.

The difference in polarization signatures between quartzite and limestone helps in differentiating them from each other. Quartzite backscatters more energy in co-polarization signatures compared to shaly limestone as diffuse scattering is more over quartzite. Moreover, cross polarization return is also more for quartzite; wherever forest cover is present. Limestone valley is smooth and also remains waterlogged during September and at places limestone behaves as specular surface to C-band microwave signal. Therefore, limestone valley is characterized by low co- and cross-polarization signature (Fig.2).

On the other hand, polarization composites also give very good informations on structures especially high angle faults and joints. WNW trending Tuppadulore (Fig.3) fault is clearly visible cutting the Kurnool and Cuddapah rocks and produce displacement along the strike of the fault. Joints are also delineated due to depolarization caused by vegetation which are aligned along joint.

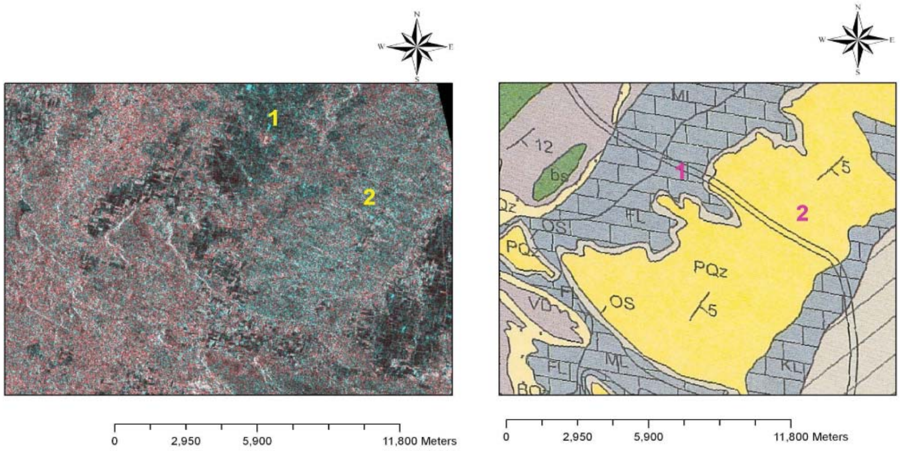

Fig.2. Polarization composite (Left figure) delineates Narji limestone, and Panium quartzite (both belong to Kurnool Group). Corresponding geological map is shown in right figure. 1= Limestone; 2 = Quartzites. In RGB polarization R = HV; G= HH; B = HH.

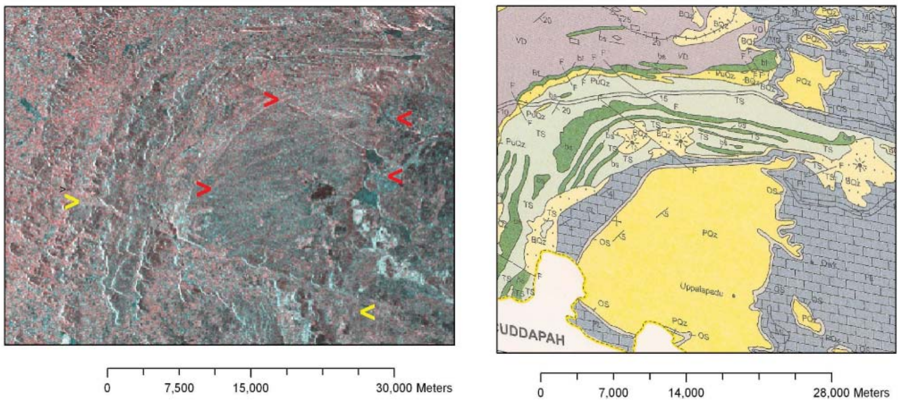

Fig.3. Polarization composite (Left figure) is also helpful in delineating high angle linear structures. Fault trending WNW-ESE is shown at the lower part of the image. Two linear structures perpendicular to each other are also enhanced. Corresponding geological map is shown in right figure. In RGB polarization R = HV; G = HH; B = HH.

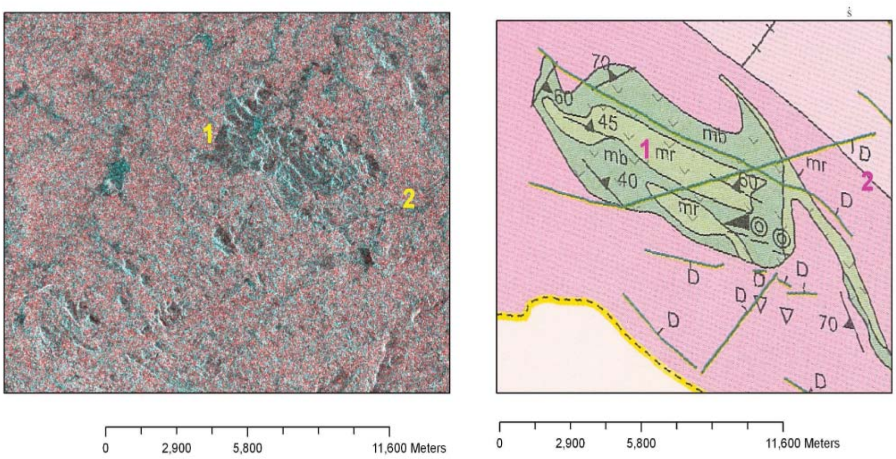

Fig.4. Polarization composite delineates Dharwar rocks from granite gneiss. Soil developed over Dharwar rocks and rocks itself is giving high return in co-polarization channel while depolarization is more in granite. Corresponding geological map is shown in right figure. 1 = Dharwar rocks; 2 = Gneissic complex.

Dharwar rocks (meta basalts) give higher return in co-polarized channel compared to basement granite gneissic complex where back scattering return in cross polarization channel is more than the co-polarization channel (Fig.4). Dharwar rocks cause diffuse scattering; which results high co-polarization (HH) return. Moreover, Dharwar rocks weather to fine grained moisture saturated smooth soil cover; which remain moisture saturated and therefore give high HH return. On the other hand, bushs, hurbs etc developed over granite gneiss cause depolarization and therefore give more HV return.

The present study highlights the capability of polarization composites of SAR data and how they can be useful in geological mapping especially in sedimentary terrain. The study concludes with following points:

1. Variation in polarization signatures of different sedimentary rock are due to the variation in surface roughness, moisture content of surface elements distinctively developed over each rock type. These signatures can be used to delineate the rock types from each other.
2. Geological lineaments are also enhanced and therefore can be delineated in the polarization composites.

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