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Lithological Discrimination by Selective Image Processing Techniques

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Abstract

Exploration geology involves mapping of rocks that includes delineation of different rock types known as lithological maps. Such maps provide primary information about the mineralogical and hydrological occurrences beneath the surface of the earth. Remote Sensing by satellites and their study through GIS are sophisticated techniques available today for lithological discrimination and mineralogical and hydrological exploration. Spatial technology through satellite data has become an excellent technology not only for lithological mapping, but lineament extraction, structural mapping etc. In the present study image processing techniques have been applied to IRS P6 LISS III image of 57j/7 scene covering Vempelli, Vemula and Velpula villages of 720 sq.km area. It is composed of all three varieties of rock types *viz.*, igneous, metamorphic and sedimentary rocks. Peninsular Gneissic Complex (PGC) is the basement rock consisting of granites, granodiorites, schists and gneisses forms the basement of the area, over which Cuddapah Supergroup rocks are present. Gulcheru quartzites, Vempalli dolomites, of Papaghni group, Pulivendla quartzites, Tadipatri shales of Chitravati group are the Cuddapah Supergroup rocks occurring in the study area. Igneous activity is seen between Vempalli dolomites, Pulivendla quartzites and within Tadipatri shales in the form of sills.

Keywords: Lithology; Exploration; Mapping; Quartzites; Limestones; Dolomite; PGC

Introduction

Image Processing Techniques key elements in the interpretation of satellite image for various studies like land use land cover, mineral exploration, groundwater exploration, lithological discrimination, forest cover studies etc. Satellite image of 57j/7 (Figure 1) has been taken for lithological discrimination by the application of selective image processing technique. The advanced software ERDAS Imagine provides various image processing techniques such as radiometric correction, filtering, classification and PCA techniques. In the present study filtering techniques like High pass and Low pass in 3 × 3, 5 × 5 and 7 × 7 and PCA analysis technique are applied for delineation of lithological units of the study area. These maps provide primary information about the lithological distribution over the surface of the earth which is used to infer mineralogical and hydrological distribution beneath the surface of the earth [1]. The study area exists between 14°15`N, 14°30`N latitudes and 78°00`E, 78°15`E longitudes. It consists of all types of rocks *viz.*, igneous, sedimentary and metamorphic rocks. Granites and granioids, schists and gneisses are the igneous and metamorphic rocks belonging to the Archaean basement known as Peninsular Gneissic Complex (PGC) which is separated from the overlying Cuddapah Supergroup meta sediments by an unconformity. Sedimentary rocks comprises of quartzites of Gulcheru formation, dolomites, shales of Vempalli formation of Papaghni group, quartzites of Pulivendla formation of Chitravati group and shales of Tadpatri formation of lower Cuddapah Supergroup of rocks. Igneous intrusions occur in the form of sills [2]. Present study reveals the impression of these rocks in satellite image and properties exerted through various image processing techniques.

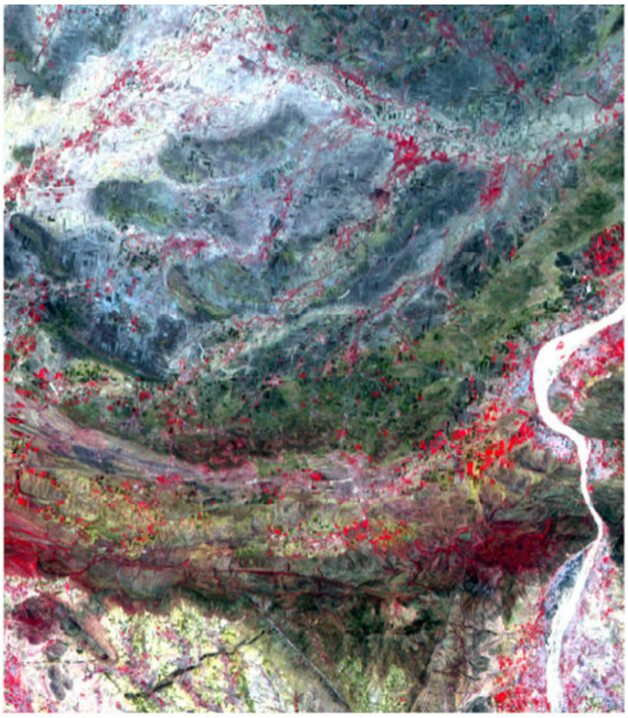

Figure 1: Satellite image of the Study area 57j/7.

The main objective of the present study is to differentiate various rock types of the study area. In general basement granites and

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ganodiorites are rich in quartz and feldspars, hence they show lighter tonte and rough texture, qurtzites which are ferrugenous show darker tone. Calcium rich limestones and dolomites show lighter tone and smooth texture. Shales show lighter tone and smooth texture, Basaltic sill bodies occurring in the study area rich in magnesium and iron are showing dark tone and rough texture and enriched in vegetation. When the image is subjected to digital image processing techniques, these rocks show varied diagnostic properties.

Methodology and Materials

Georeferenced IRS P6 LISS III image of Vempalli, Vemula, Velpula area corresponding to 57j/7 at 1:50,000 scale is used in the present study. Primarily all the rock types of study area are delineated using Geographic Information System (GIS) 9.1 software and thematic map of geology of the area has been prepared (Figure 2). Image processing techniques of ERADAS Imagine 9.1 software such as histogram equalization, 3 × 3, 5 × 5, 7 × 7 Lowpass filtering, 3 × 3, 5 × 5, 7 × 7 High pass filtering and Principal Component Analysis (PCA) techniques are applied to study the characteristics of different rocks type of the study area during application of different techniques.

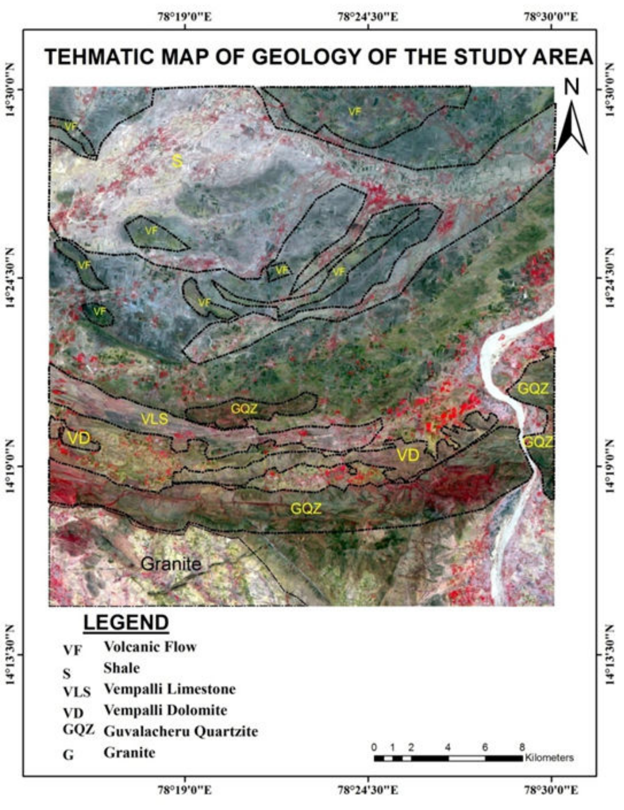

Figure 2: Thematic map showing the Geology of the Study area.

Principal Component Analysis (PCA)

Images generated by digital data from various wavelength bands often results an image difficult to interpret due to redundancy of multispectral band data. Principal Component Analysis is the technique designed to reduce such redundancy. This technique is applied prior to visual or digital interpretation of data [3].

Enhancement techniques

Image enhancement techniques improve the quality of an image as perceived by a human. These techniques are most useful because many satellite images when examined on a colour display give inadequate information for image interpretation. There exists a wide variety of techniques for improving image quality. The contrast stretch, density slicing, edge enhancement, and spatial filtering are the more commonly used techniques. Image enhancement is attempted after the image is corrected for geometric and radiometric distortions. Image enhancement methods are applied separately to each band of a multispectral image. In the present study spatial filtering is used to delineate the lithology.

Spatial filtering

A parameter of Remotely Sensed images is spatial frequency defined as number of changes in Brightness Value per unit distance for any particular part of an image. In other words filtering is the process by which the tonal variations in an image in selected ranges or frequencies of the pixel values, are enhanced or suppressed. This process selectively enhances or suppresses particular wavelengths or DN values with an image. If there are very few changes in Brightness Value once a given area in an image, this is referred to as low frequency area. Conversely, if the brightness value changes dramatically over short distances, this is an area of high frequency. Spatial filtering is the process of dividing the image into its constituent spatial frequencies, and selectively altering certain spatial frequencies to emphasize some image features. This technique increases the analyst's ability to discriminate detail. The three types of spatial filters used in remote sensor data processing are Low pass filters, Band pass filters and High pass filters. The mechanics of the spatial filtering involves the movement of the filter mask over the image. Convolution filter is most commonly used filters in image enhancement. In this method the filter mask is called convolution mask or convolution kernel. These kernels are generally square in shape and are of odd number of pixels in size like 3 × 3, 5 × 5, 7 × 7 etc. The high pass and low pass convolution filters emphasize the high frequency and low frequency features respectively.

Results and Discussion

DN Values of rocks of study area

Digtal Numbers (DN values) are intensity values representing the solar radiance in a given wave length band reflected from the ground. In an image the actual intensity of reflected light can be derived from the pixel digital number. The DN values exerted various rock units in the present study area are given in the Table 1 [14].

Principal component analysis

The multispectral image data is usually strongly correlated from one band to the other. The level of a given picture element on one band can to some extent be predicted to some extent from the level of the same pixel in another band. Principal component analysis is a pre-processing transformation that creates new images from the uncorrelated values of different images.

Sl. No	Name of the Rock	Band 1			Band 2			Band 3			Band 4		
		Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean
1	PGC	61	149	94	46	156	95	42	150	90	45	128	89
2	Gulcheru Quartzites	61	123	80	44	124	76	48	145	75	43	105	70
3	Vempalli Dolomite	64	141	87	46	149	90	49	140	86	47	113	84
4	Vempalli Limestone	64	124	89	44	133	87	50	164	84	47	105	80
5	Tadipatri Shale	65	147	104	47	163	102	48	151	91	40	235	82
6	Volcanic Flow	65	132	91	52	131	85	47	135	73	48	122	74

Table 1: DN Values shown by various rock types of study area.

This is accomplished by a linear transformation of variables that corresponds to a rotation and translation of the original coordinate system. Principal component analysis operates on all bands together. In the present context, the study area composed several rock types among which quartzite, limestone, dolomite, shale and granite are light coloured and thus there is plausible correlation of bands of image data. PCA technique is applied to reduce the number of collelated band of the image to few uncorrelated bands and the visual interpretation for ground features is highly enhanced. The enhanced image is effectively used as a base for ground truth collection during the classification of various geological features of the study area (Figure 3).

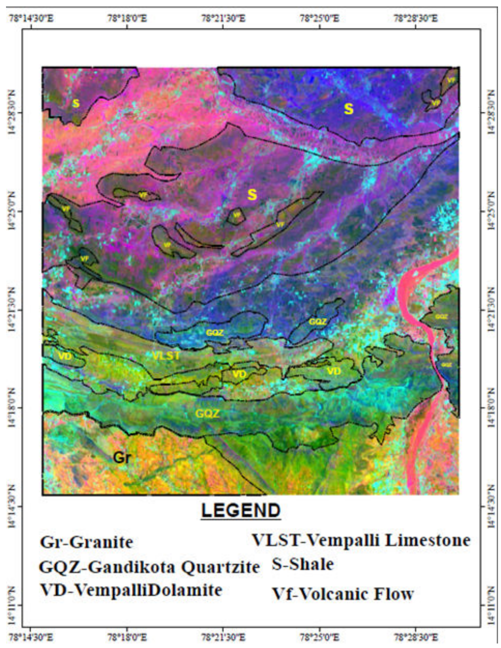

Figure 3: Principal Component Analysis.

Low pass filtering in the spatial domain

Image enhancements that de-emphasize or block the high spatial frequency are low-frequency or low-pass filters. The simplest low-frequency filter evaluates a particular input pixel brightness value, BVin, are the pixels surrounding the input pixel, and outputs a new brightness value, BVout, is the mean of this convolution. The size of the neighbourhood convolution mask or kernel (n) is usually 3 × 3, 5 × 5, 7 × 7, or 9 × 9 (Figures 4-6).

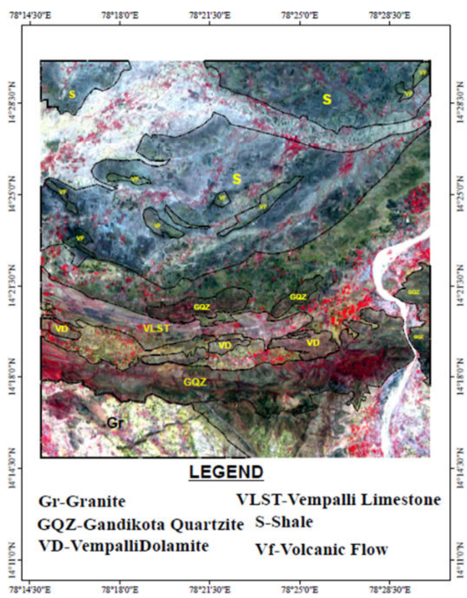

Figure 4: 3 × 3 Low pass filtering.

The simple smoothing operation will, however, blur the image, especially at the edges of objects. Blurring becomes more severe as the size of the kernel increases. Using a 3 × 3 kernel can result in the low-pass image being two lines and two columns smaller than the original image. Techniques that can be applied to deal with this problem include (1) artificially extending the original image beyond its border by repeating the original border pixel brightness values or (2)

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replicating the averaged brightness values near the borders, based on the image behaviour within a view pixel of the border. The most commonly used low pass filters are mean, median and mode filters.

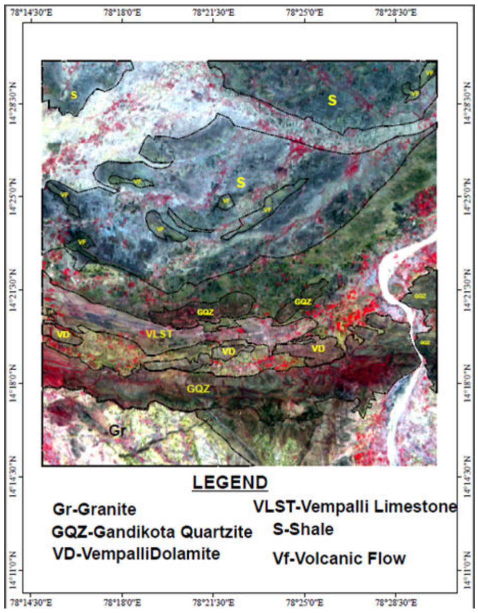

Figure 5: 5 × 5 Low pass filtering.

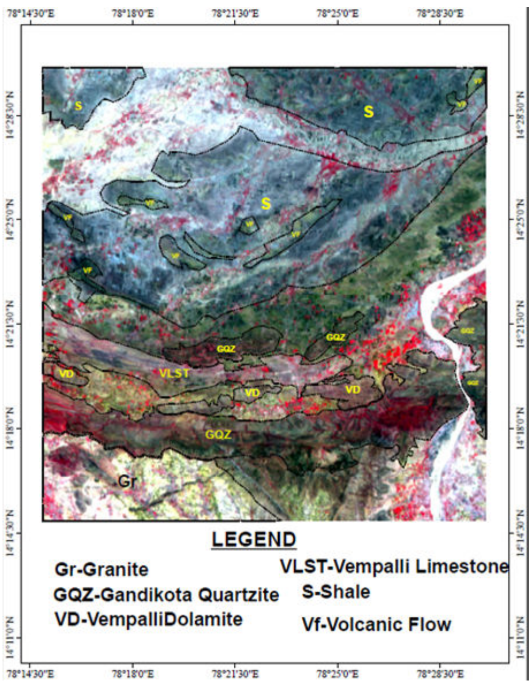

Figure 6: 7 × 7 Low pass filtering.

High pass filtering in the spatial domain

High-pass filtering is applied to imagery to remove the slowly varying components and enhance the high-frequency local variations. Brightness values tend to be highly correlated in a nine-element window. Thus, the high frequency filtered image will have a relatively narrow intensity histogram. This suggests that the output from most high-frequency filtered images must be contrast stretched prior to visual analysis (Figures 7-9).

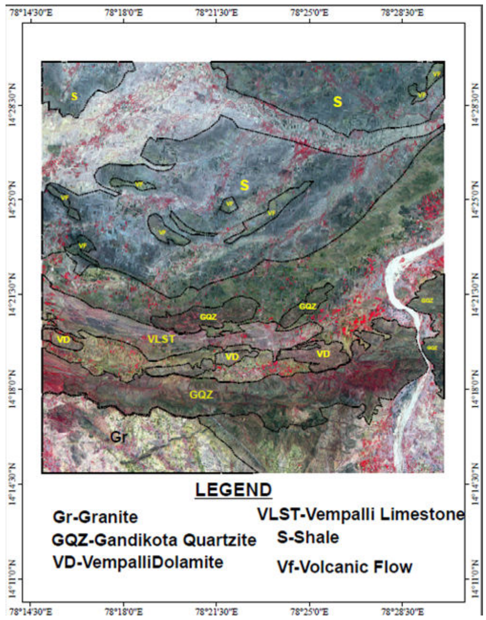

Figure 7: 3 × 3 High pass filtering.

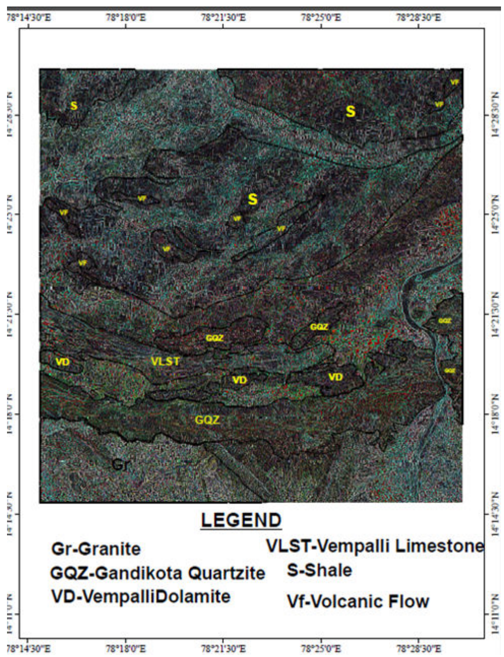

Figure 8: 5 × 5 High pass filtering.

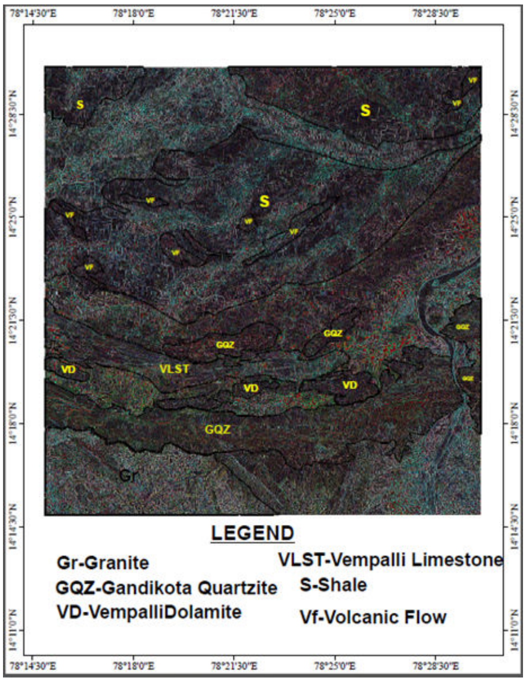

Figure 9: 7 × 7 High pass filtering.

Conclusions

Digital image processing's of satellite data can be primarily grouped into three categories: Image Rectification and Restoration, Enhancement and Information extraction. Image rectification is the pre-processing of satellite data for geometric and radiometric connections. Enhancement is applied to image data in order to effectively display data for subsequent visual interpretation. Information extraction is based on digital classification and is used for generating digital thematic map.

DN values

The study of DN values of the IRS P6 LISS III image reveals that mean DN values between 89 and 95 denote granitic rocks, mean DN values between 70 and 80 indicate quartzites, mean DN values between 84 and 90 corresponds to dolomites, mean DN values between 80 and 89 denote limestones, mean DN values between 82 and 104 represent shale and mean DN values between 73 and 91 indicates volcanic flows (Table 1).

PCA of image of study area

Principal Component Analysis of the image of the study area has shown a clear variation between rocks like quartzites, limestone, dolomite, shale and granite, composed of lighter minerals and also those of volcanic flows composed of darker minerals. Quartz and feldspar rich granites and granodiorites have shown very lighter tone and mafic mineral bearing rocks such as dykes and volcanic flows have shown very darker tone. Ferrugenous quartzites have shown moderately darker tone.

Low pass filtering techniques

Low pass filtering technique of the order of 3 × 3, 5 × 5 and 7 × 7 is applied to the image of the study area, the enhanced image has shown specific demarcation between varied rock types (Figures 4-6). Darker tone has shown much darker and lighter appeared still lighter than the original image. Litho units such as granites, granitoids, gneisses and schists of PGC, dolomites, limestones, shales and basic intrusives appeared with sharp edges. More sharpened edges have been observed in 5 × 5 low pass filtering and 7 × 7 low pass filtering. Lineaments like faults planes, dyke intrusions are seen more clearly.

High pass filtering techniques

High pass filtering techniques of the order 3 × 3, 5 × 5 and 7 × 7 when applied the image has shown much variations in relation to the Low pass filtering. In 3 × 3 High pass filtering, the image has shown highly sharpened edges for PGC, quartzites, dolomites, limestones, shales and volcanic flows. Lineaments like faults and dykes are elevated very clearly (Figure 7). In 5 × 5 and 7 × 7 High pass filtering, rocks composed of dark coloured minerals like mafic dykes intruded in the PGC and volcanic flows between Vempalli formation and Pulivendla formation, ferruginous quartzites of Gulcheru formation appeared with more darker tone, while other rocks like PGC, Vempalli dolomites and Tadipatri shales appeared with very lighter tone.

The selective Digital Image Processing techniques like special filtering through low pass filtering and high pass filtering in the order of 3 × 3, 5 × 5 and 7 × 7, PCA can be applied for the identification of various rock types in a satellite image. This kind study is useful in mapping, mineral exploration and ground water explorations.

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