Litho-Structural Mapping of Sind Catchment (Kashmir Basin), NW Himalaya, using Remote Sensing & GIS Techniques

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Abstract: ***Litho-structural mapping in an inaccessible rugged and mountainous region like the Himalaya has frequently been a great challenge for geologists. In the present study, litho-structural mapping was carried out based on enhancement and interpretation of IRS LISS-III data by the application of remote sensing and GIS technology. Different band combinations (421, 432 etc) of the image are applied for visual image interpretation to digitize the rock boundaries while as Sobel and Laplacian filtering techniques are utilized for lineament mapping. The results of this study demonstrate that the processing and interpretation of IRS LISS III data set can be employed as a powerful tool to improve lithological discrimination, highlight the lineaments and enhance the overall mapping performance in the rugged and hilly terrain like Himalaya.***

Keywords: Remote sensing, GIS, Lithology, Structure, Lineament, FCC, Laplacian, Sobel

1. Introduction

A significant component of geology involves mapping rocks called lithological maps. Lithological map shows the distribution of different rock types over the surface of the earth. Since lithological maps were first constructed in the late 18th & 19th centuries, they have played a fundamental role in understanding the history of the earth & provided the information needed to solve practical land use problems, such as ground water quality, earthquake, volcano, landslide & flooding hazards etc. Litho-structural mapping was once based entirely on the work of geologists who would traverse an area on foot or horse, recording on maps the character of rocks and structures exposed at the surface. This information was compiled to form geological maps representative of the region under study. A general lithological map by itself provides an extraordinary amount of information. The color patterns on lithological maps show the distribution of various geologic materials at the surface of the Earth. Today, many more techniques are available, from the sophisticated interpretation of aerial photographs to remote sensing by satellites. With the advent of remote sensing and GIS, the research has been carried out and is going on in different fields of geological sciences with ease and accuracy [1-16]**.** GIS has become a common place technique for geological mapping [13].

Researchers from all over the world have used satellite data and remote sensing for the discriminating the lithology. Many previous studies have proposed various approaches for discrimination and mapping of surface rock types by using multispectral data; for instance, band ratio, principal component analysis (PCA), multiband classification, etc. [17-19]. So in the last few decades, satellite data have been used extensively for lithological mapping and mineral exploration [17, 20-22].

Not only lithology but lineament (structures) extraction can be performed betterly using spatial technology than field work in the highly rugged terrain like Himalaya. Many workers [23-25] have shown that lineaments can be delineated and interpreted from remote sensing imageries. For example, tectonic structures have been delineated through contrast stretching of satellite imagery in combination to the application of directional filters and the generation of different combinations of False Color Composites (FCC) in south-west Iran[1]. Accordingly, in different parts of the world, photogeological techniques have been applied to perform structural studies [7, 17, 23, 25, 26].

Lineament is an extended mappable linear or curvilinear feature of a surface whose parts align in straight or nearly straight relationships that may be the expression of folds, fractures, or faults in the subsurface[27]. Geomorphologically, lineaments are defined as mappable simple or composite linear features whose parts are aligned in a rectilinear or slightly curvilinear and linear surface features such as valleys, ridges and boundaries of elevated areas, coastlines, boundaries of formation, fractures, faults, and joints [11, 28].

However, due to complex and rugged terrain of Himalayas, conventional field based lineament mapping is a difficult task but it is well-known that, these linear geological features can be seen easily by using ordinary satellite's black-white or colored composites. So, now a day's multispectral satellite remote sensing technology provides a relatively efficient and low cost method for the lithological and lineament mapping of areas having rugged terrain and geological complexity as found in the Himalaya. However, the results obtained from digital image processing and analysis requires a field support in some selected areas in order to confirm the precision results. In the present study, lithological and lineament mapping of Sind catchment (Ganderbal district) of Jammu and Kashmir was done with a view to enhance and modernize the geological prospective of the area.

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2. Study Area

2.1 Location Setting of Sind Catchment

The Kashmir valley is comprised of a number of micro & macro watersheds. These watersheds form the part of main drainage system of the valley, which is constituted by the river Jhelum & its seventeen tributaries. These tributaries could be treated as the macro watersheds. The Sind catchment one of the major right bank tributary of the river Jhelum has been selected as the study area for the present work. Sind Catchment is falling in Ganderbal district. Ganderbal is located at 34.23° N and 74.78° E. It has an average elevation of 1619 M (5312 feet).

The area gradually rises in elevation from south to north. The Sind river valley is girdled on three sides by lofty ridges. Sind nallah has its source in the inner Himalayas at drass and after it is fed by the Gangbal Lake lying at Harmukh Mountain (5150 meters), it joins the 2ander at shadipur and it is 96 km in length. The famous health resorts of Sonamarg and 2anderbal are situated on its banks. Its water is used for irrigational purpose and the Sind valley hydroelectric power project uses its water at Ganderbal to produce electric power.

3. Data Sets

The different datasets were used:

- IRS LISS III satellite Image and ASTER DEM
- Survey of Indian Topographic Sheets (1:50,000)
- Geological Map [22].
- Field data of the study area.

Satellite Data is the main input for preparing the geological maps. It is to be used mainly for preparing the lithology, geomorphology and structural layers which in turn are integrated to generate the geological map. The Indian Remote Sensing satellites (IRS-IA,-IB, and -IC) launched in 1988 through 1995, contain several sensors; the LISS-I, LISS-II, and LISS-III. The satellites are in 900-904km (sun synchronous orbit with 22 day repeat coverage. LISS-I has a ground swath of 144km (98mi) with 72x72m (234x234ft) resolution. The LISS-II has a 74 km (44mi) swath and 36x36m (117ft) ground resolution. Each has four spectral bands in the range 0.45 to 0.86 microns. LISS-III, launched on IRS-IC satellite in 1995, has a 24 day repeat cycle with 23.5m resolution in the VNIR range and 70.5 m resolution in the SWIR region. Indian Remote sensing satellite (IRS) was a step towards the national operational satellites, which directly generates resource information in a variety of application areas such as forestry, geology, agriculture and hydrology. A series of IRS satellites has been launched. In the present research, IRS LISS-III data has been used. Existing geological map (**Fig. 1**) of Kashmir valley was also utilized as a guide for reaching to the best results in this research.

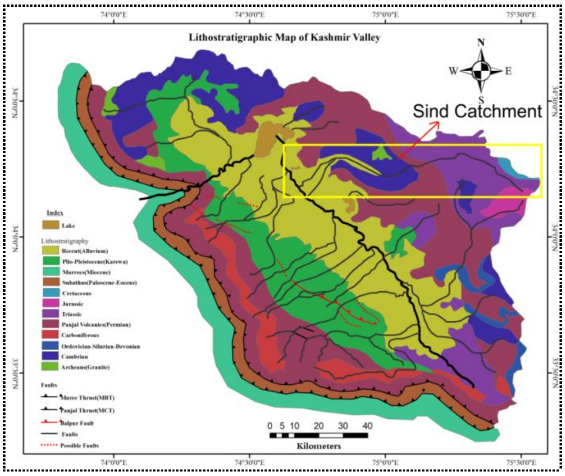

Figure 1: Geological map of Kashmir Valley and Sind catchment (yellow box) and surrounding area[22].

Survey of India topographic maps were also used to locate the villages and for preparation of road map which was necessary for the field work and comparisons with lineaments in the area.

4. Methodology

To achieve the Objectives of the present work, the methodology adopted is as fallows:

4.1 Image data

In this study the basic data was satellite imagery and ASTER DEM, which was employed to achieve the above mentioned objectives. In order to achieve the objective, an integrated approach involving remote sensing, GIS and field surveys were employed. For the Digital image processing, ERDAS IMAGINE software was employed in order to process the LISS-III satellite image. The false color composite images (FCC) (**Fig**. **2**), edge enhancement images [Laplacian (**Fig. 3**) and Sobel filtering (**Fig. 4**)], aspect map and shaded relief map were applied for the visual examination and interpretation of lithology and lineament. For carrying out the analysis and database generation Arc GIS 9.3 and Global Mapper software were used.

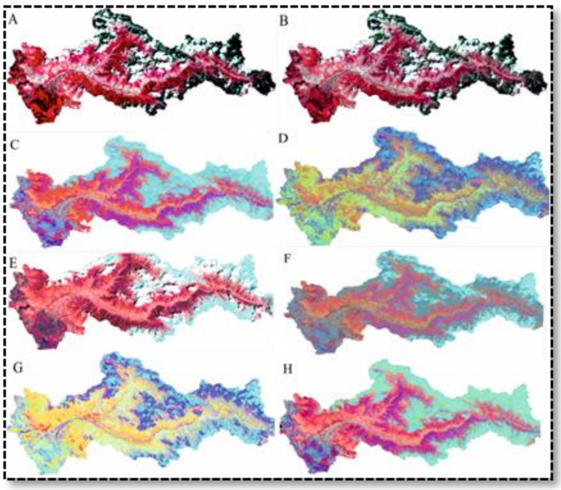

Figure 2: A) FCC 421 band combination with more contrast, B) Band 421 image with little contrast, C) Band 431 image, D) analog 421 band combination with little contrast E) 431

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band combination with little contrast F) Band 421 with low contrast G) analog 421 band combination with more contrast, H) Band 421 with low contrast/

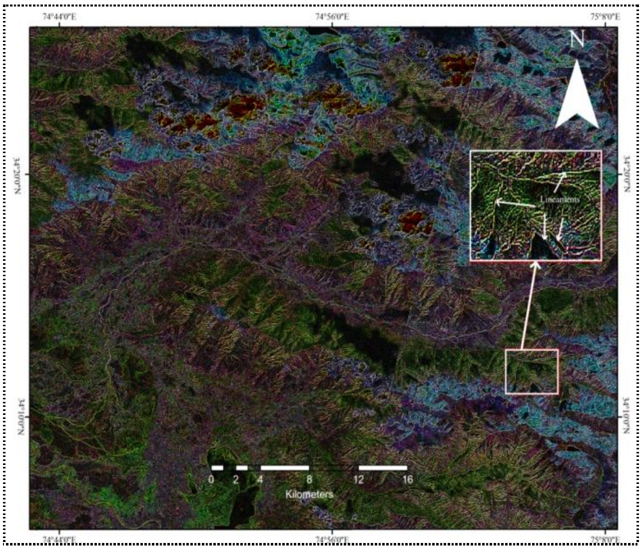

Figure 3: Laplacian image which is used to enhance edges regardless of edge direction.

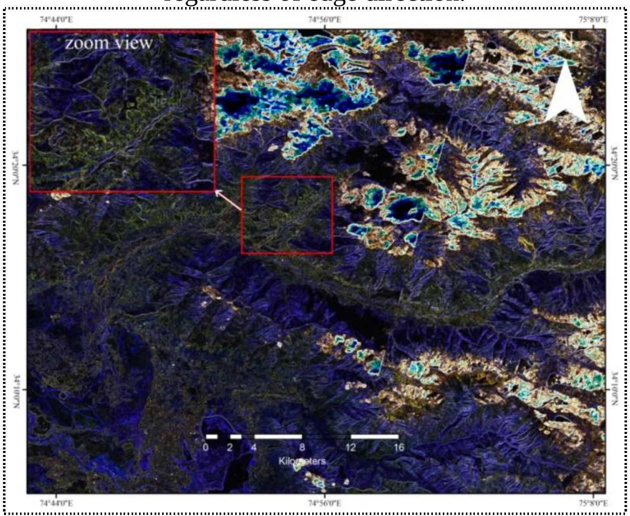

Figure 4: Sobal operation which is made up of 3x3 convolution kernels

4.2. Existing Data

Existing geological map of Kashmir valley was also used which provided information related to rock formations like Archean (granite), Cambrian, Permian (Panjal Volcanic), Triassic, Jurassic, Cretaceous, Recent (Alluvium) present in the area. So this information from Geological map[29] was applied to obtain and give the direction towards the best results. The layer of information obtained from the existing data was integrated with the layer of information obtained from the enhancement of LISS-III image and the resultant layer was obtained related to presence of lithology.

4.3. Field Data

Before proceeding to the field for ground checks, proper planning has to be made regarding the type of data to be collected and the locations to be selected for this purpose based on the road network. By using Toposheets (SOI) of the study area, road map of the study area was prepared in order to reach the places to cross check the lithology and lineaments on image with lithology and structural features in the field. Almost ten sites were chosen for the verification of digitized lithology from LISS-III image.

After doing all in the lab, results obtained were checked in the field. For the field work, we have taken with us the digitized map of lithology and lineament of Sind Catchment and the also the map showing the places where we have to collect data related to different rock types and structures. So ground data form an important source of information for mapping and accuracy estimation.

4.5 Digitization of lithological units and lineaments

Digitization is an art/technique using specific software to delineate the spatial extent of a feature under investigation. Digitization was performed to convert all contacts of litho-units and highlighted lineaments on the imagery (on the basis of tone & color, texture, shape, pattern) and on existing geological map into digital format with the help of Arc GIS 9.3. Enhance image of 421 band combination with more contrast is best for lithological mapping. The lithology shown on the existing geological map was also related with the rock types identified on the LISS-III image. The lineaments were identified and digitized from Laplacian and Sobel filtered images and were correlated with the drainage and roads present in the area. The field verification of these digitized rock types on the LISS-III image is also carried. During the field work the different rock types of the image under suspension are verified in the field. After the field checks, the final lithological map of the Sind Catchment was prepared and is shown in the result section (**Fig. 5**).

5. Results and Discussions

Various image enhancement techniques were applied to LISS-III image and all the lithological contacts were digitized and converted into digital format by means of digitization. There was little difficulty in the identification of lithology where the rocks are covered with vegetation. Soil or vegetation in most of the study area covers bedrock. Therefore, the cover material masks the reflectance from rock leading to difficulties in capturing direct radiation essential for geological interpretation.

When displaying a multi-spectral image in color (Red, Green, and Blue) different color composites (cc) were created each having its own characteristics. Color combinations 432 and 421 were found to be valuable to distinguish the different lithological boundaries and were chosen for the digitization of the various lithological units by the visual image interpretation. Different rock types identified on satellite data from one another by their tone, texture, drainage pattern, drainage system, and by having priory knowledge are confirmed in the field (**Fig. 5**) and their description in **Table 3**.

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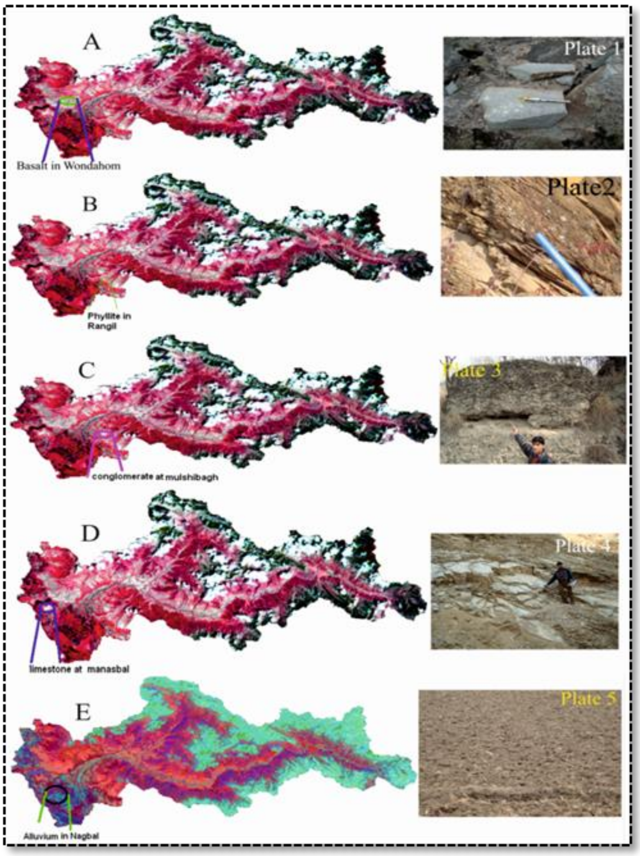

Figure 5: Field validation of basalt, phyllite, conglomerate, limestone and alluvium interpreted from respective images.

Another approach that was adopted to complete the study involves the drainage pattern as an aid in lithological mapping. Examination of drainage pattern or drainage density provides clues to the lithology even when the rocks are not directly exposed. This is because, the drainage density is more in the hard rock's (basalts) where infiltration of water downwards is less as compared to loss rocks (alluvium) where water easily percolates downward and gives rise to low drainage density. The final lithological map (**Fig. 6**) of the Sind catchment was prepared after doing all the lab and field studies.

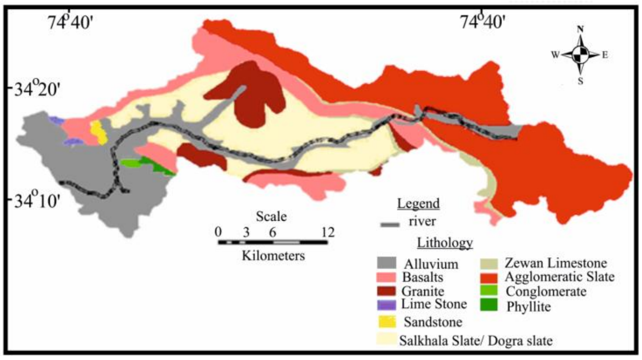

Figure 6: The final lithological map of the area.

Satellite data has provided an advantage in lineament identification and mapping. The best enhanced satellite images which highlighted the lineaments were laplacian and Sobel edge filtered images. These edge enhancement techniques have an advantage to enhance edges regardless to edge direction and were mapped by screen digitization (**Fig.7**).

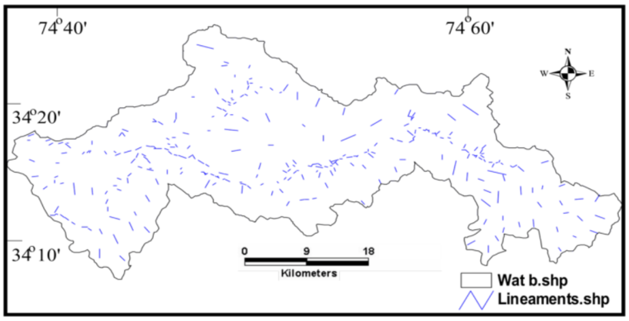

Figure 7: The lineaments present in the area

Table 3: Description of rocks

Nature	**Volcanic rock**	**Metamorphic**	**Sedimentary**	**Sedimentary**	**Sedimentary**
Colour	Light green	Light Yellow	Gray	Light Yellow	Light brown.
Texture	Fine grained	Fine grained	Coarse Grained	Fine to medium Grained	Fine to medium Grained
Dominent minerals	Feldspars, pyroxene, Olivine	Mica, Chlorite, Quartz	Quartz, few green and micaceous minerals.	Calcium Carbonate	Clay minerals
Inference	Basalt	Phyllite	Conglomerate	limestone	Alluvium
Plate	Plate 1 (Fig. 9)	Plate 2 (Fig. 9)	Plate 3 (Fig. 9)	Plate 4 (Fig. 9)	Plate 5 (Fig. 9)

The lineaments delineated were compared with the road map to exclude false lineaments in the lab and were confirmed in the field (**Fig. 8**). The output linear feature map contains a total number of 244 linear features.

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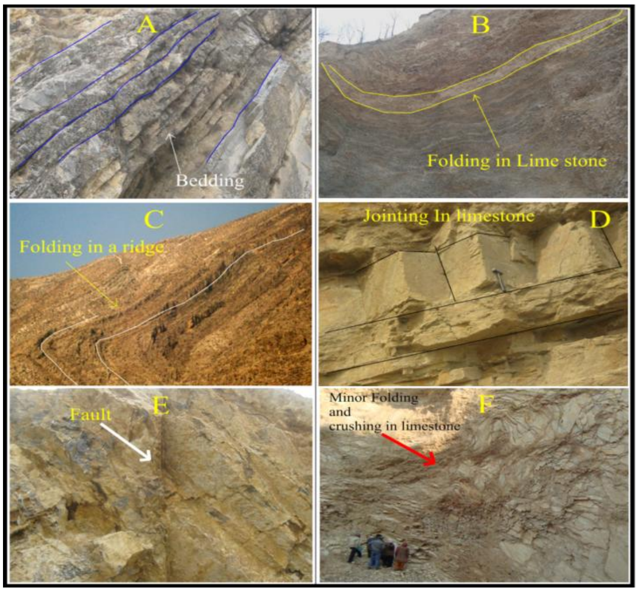

Figure 8: Some of the field photos in which A) bedding in limestone, B) folding in limestone, C) ridge with evident folding, D) jointing in limestone, E) fault in limestone, F) minor folds and crushing in limestone

The mapping of the lineaments, drainage networks and lithology present in the area has leaded us to know that the area has gone through intensive deformation which confirmed that the area is under the influence of major structure surrounding the Kashmir Basin. So the present work demonstrated remote sensing and GIS plays a great role in identifying lithology and lineaments in the highly rugged terrain like Himalaya.

6. Conclusion

Remote Sensing and GIS techniques can be integrated to distinguish rock types and lineaments. GIS spatial analysis functions have permitted us to develop a lithological and lineament map by means of overlaying different layers of information that were generated, using image processing techniques like visual image interpretation, principle component analysis, FCC and filtering techniques etc. The rock types which were identified from the satellite data shows close resemblance with rock types present in the existing map include basalt, limestone, phyllite, granites, conglomerate and alluvium, etc. Consequently, edge enhancement (Laplacian and Sobel filtering) techniques have proven best for recognition of lineaments which are hard to trace by field based mapping.

Although lithological mapping using the satellite remote sensing technique is somewhat hindered by the presence spectral similarities between some of the lithological units caused by the similar vegetation cover but we cannot neglect the role of satellite data playing in the hilly terrain like Himalayas where rugged terrain also hinders field work. Also the lineaments which are hard to identify on ground, can easily be seen from satellite imagery. Therefore, IRS LISS III data can be used to enhance lithological discrimination and lineament identification and improve the overall mapping performance.

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