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RESEARCH ARTICLE

LITHO-STRUCTURAL MAPPING USING REMOTE SENSING AND FIELD WORK TECHNIQUES: A CASE STUDY FROM CENTRAL SALT RANGE, DISTRICT KHUSHAB PUNJAB PAKISTAN

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ABSTRACT

Litho-structural mapping in an inaccessible rugged and mountainous region like the Central Salt range has frequently been a great challenge and importance for geologists. For this purpose, in the present study, litho-structural mapping was carried out based on enhancement and interpretation of Landsat 8 USGS data by the application of remote sensing and GIS technology and further verified by the data which was collected in field work to the study area. Different band combinations 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 purpose of our field work was a comprehensive mapping of Geology and related structural aspects of Kufri, Jhalar, Chamnaki, Surraki, Khura and Naushehra area, Central Salt Range, district Khushab Punjab Pakistan in the Central Salt Range Pakistan. It includes Litho-structural Mapping at scale of 1:10,000. The results and conclusion of this study demonstrate that the processing and interpretation of Satellite data set can be employed as a powerful tool to improve lithological discrimination and enhance the overall mapping performance in the rugged and hilly terrain like Salt range.

KEYWORDS

Mapping; Remote sensing; GIS; Salt range; Digitization; Field data.

1. INTRODUCTION

Lithological mapping is a very important component of geology. These Lithological maps are very significant in distributing rocks of different types over the earth surface. The history of lithological maps dates back to late 18th and 19th centuries, since then contributed significantly when it comes to understanding the earth's history and help save many problems related to land use such as frequently occurring earthquakes, volcanic activities, underground water quality control and many other natural hazards like flooding and landslides. In the past Litho-structural mapping was carried out by geologists traveling for miles through tough terrains observing the characteristics of rocks and marking different structures and details for that area based on those observed information's. These lithological maps provide huge amount of information. The colors used in lithological maps as patterns mark the distribution of different geologic features on earth surface.

Recent advancements in the available techniques includes interpretation from aerial photography to satellites based remote sensing. As long as the advancement in the field of remote sensing and GIS continues researchers have achieved great success related to different aspects of geosciences and has become as a first-hand tool in lithological mapping. Researchers are very frequently using data from satellites and remote sensing techniques for identification of various lithology-based research. Previous research deduced different approaches discriminate and map different rock types using multispectral data like principal component analysis (PCA) data, band ratio data, classification based on multiband data, etc (Davis et al., 1993; Gillespie et al., 1986; and Pirasteh et al., 2007).

Salt range is composed of a very complex geology associated with active Himalayan terrain which makes the mapping in region a difficult task to carry out, but satellites composites have proven very useful for the identification and demarcation of these complex geologic segments Remote sensing technology based on multi spectral satellites can efficiently help build lithological maps of those geologically complex regions of Himalayas at very low cost. In order to confirm the accuracy and precision of the obtained results from these digital based techniques requires further information through field work. This present research is carried out to enhance the quality of lithological mapping. This paper first introduces the location and tectonics of the study area and then discuss the methodology of the paper. After that it discuss the procedure of field data and digitization of different lithological units. At the end it discusses result and conclusion of the research.

2. LOCATION AND ACCESSIBILITY OF STUDY AREA.

The study area soon valley is in the north west of Khushab District, Punjab, Pakistan. Its largest settlement is the town of Noshera. The valley extends from the village of Padhrar to Sakesar, the highest peak in the Salt Range. The valley is 35 miles (56 km) long and has an average width of 9 miles (14 km). It covers a 300-square-mile (780 km2) area.

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Figure 1: Google Earth Image of The Study Area

The study area is located 250 Km S-E from the Islamabad, the capital of the country. It is easily accessible by Motorway (M-2) from the capital of the country and other cities. Noshehra is 55 km far from Khushab, 90 Km from Sargodha. Sabhral, kufri, chamnaki, Dhaka and khura are the main villages in the study area which are connected by good network of metaled roads. The study area is located in the central Salt Range and the Litho-structural mapping of the kufri, khura, jhalar, sodhi, dhaka and surakki, chamnaki, kathwai and sabhral areas were done during the field work. Important places of the study area are Noshara Surakki and the Khura villages. This area is rich in minerals and rocks such as Coal, Laterite, Fire clay Limestone, Dolomite and Sandstone.

3. Structural and Tectonic Setting of Salt Range

The upper Indus Basin Pakistan has the phenomenal Salt Ranges that consist of spectacular Himalayan Front Thrust fault system, which marks the last progressive thrust fault of the Himalayan orogeny. The Himalayan orogeny is result of the India and Eurasian continental- continental collusion took place in Eocene. Thrust fault represents surface expressions features in the form of decollement exist in Cambrian to Eo-Cambrain Evaporates (Seeber and Armbuster, 1981). The Cambrian age Salt Range Formation is exposed throughout the Salt Ranges and its very demanding on the erosion thus forming the classical stratigraphic section throughout the Salt Ranges (Khewra, Nilawahan and Warchha gorges) (Yeats and Lawrence, 1984). A fault-bend fold (although the shape of this anticline differs from the fault-bend fold because of its lack of a frontal and is due to the ductile behavior of the salt at the base of thrust sheet) is present in the Salt Ranges and is thin-skinned fold-and-thrust belt (Lillie et al., 1987; Butler et al., 1987).

From seismic data, a series of Salt Anticlines has been marked in subsurface. The roof sequence has been folded into sharp, salt cored anticlines and broad flat synclines, which in its southern most part disrupted frequently by forward and back verging thrusts and almost vertical dipping apparent normal faults (Qayyum, 1991). The presence of the decollement thrust exists because of massive incompetent Salt Range Formation at the base of the sedimentary sequence. Overall, Salt Range strata dip northwards that ultimately merge into the Potwar Basin, going more northwards the MBT (Main Boundary Thrust) is present (Sameeni, 1997). Because of the presence of MBT the Salt Range thrust developed, and salt Range Formation rises to the surface (Yeats and Lawrence, 1984).

The strike of the Salt Range Formation is ENE-WSW trending and is 180 km long range merge into the Potwar Plateau (Sameeni, 1997). The Salt Ranges is bounded by the Main Boundary Thrust (MBT) in North, South by Salt Range Thrust, West by Kalabagh fault and in East by Jhelum fault (Sarwar and De Jong, 1979; Yeats and Lawrence, 1984; Coward et al., 1985). The Salt Range can be divided into Eastern, Western and Central Salt Ranges and the main Salt Range thrust is emergent in Central and Western parts and folding predominates in these parts suggested that the difference in the structural style between East and West is the result of eastward thinning of evaporates (Lillie et al., 1987; Davis, 1985).

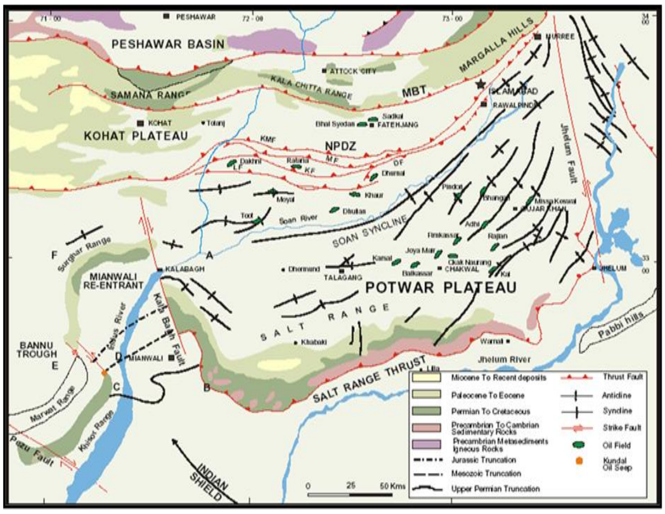

Figure 2: Geological Map of Salt Range and Trans Indus Ranges showing Salt Range Thrust (SRT).

4. Methodology

Methodology of this paper consist of two parts. First one is conventional methodology, and the second part is lithostructural mapping using remote sensing and GIS technology. By using conventional mapping techniques and toposheets of the Geological Survey of Pakistan (GSP), base map of the study area is prepared. Tracing techniques are used to prepare the base map from the topographic sheets of Geological Survey of Pakistan. The base map includes the sheet of survey of Pakistan topographic sheet no. 43 D/2, of 1:50000 scale. The base map is enlarged 5 times, and the litho structural mapping is done at the scale of 1: 10,000. Latitude and Longitude of the Base map are:

72° 05′ 00″ E to 72° 14′ 00″ E

32° 30′ 00″ N to 32° 34′ 00″ N

Figure 3: Topographic Map (Scale 1:250000) of The Study Area Which Has Been Used in Field Work (USGS)

It was used to locate the particular area for fieldwork, exact location, elevation, geomorphology of that area. It gives the sense to judge the elevation or depression and steep slope or gentle slope from the contours on it. The pictures of different sedimentary structures are taken and the contacts of different lithostratigraphic

4.1 Existing Data

Existing geological map of Salt Range was also used which provided information related to rock formations like Archean, Cambrian, Permian, Triassic, Jurassic, Cretaceous, Recent (Alluvium) present in the area. So, this information from Geological map 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 satellite image and the resultant layer was obtained related to presence of lithology.

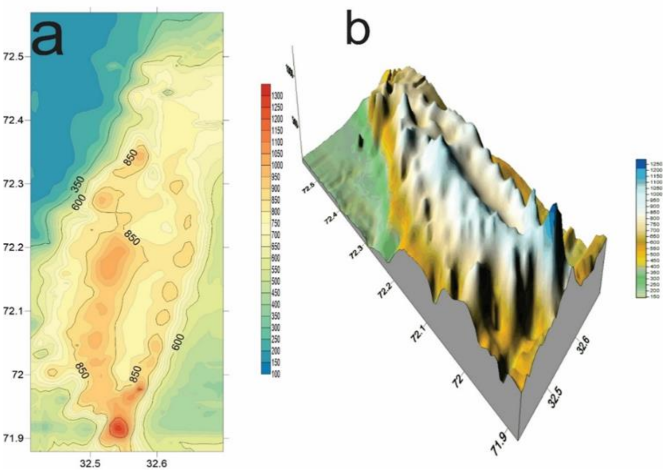

Figure 4: (a)Contour map and (b) 3D surface map of the study area prepared for field work by surfer 14.

4.2 Field Work 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 Topographic map (figure 3) 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 satellite 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 Soon Sakesar valley 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.

Figure 5: (a) Mianwali formation Kathwai member near Surakki village (b) Intra formational conglomerate of Kamlial Formation at the south of kufri village (c) Solution holes in Sakesar Limestone At the south of Mustafabad village (d) Hangu Formation Laterite bands at Rakh Surakki village.

4.3 Digitization of Lithological Units

Special software's were used for the purpose to digitization so as to help delineate the spatial extent for those features which we are investigating. The process of digitization mainly involves the conversion of lithological unit's contacts and highlighting lineaments through imagery (based on tones colors, textures, shape and different patterns) and converting the existing geological map to digital formats using Arc GIS (Ali and Ali, 2013). Enhancement of the image from 421 band combinations and making it more contrasting can have good results while performing lithological mapping. Lithologies marked on geological maps are in close relation to the types of rocks marked and indicated on satellite images which were further verified by field work. Identification and digitalization of the lineaments were carried out through satellite images with respect to correlation with roads and the pattern of drainage in the area. These digitized rock types from Landsat 8 USGS data images were also verified carrying out field in the area and after the verification a complete and precise final map was deduced for the area which is showing in the results portion of the paper.

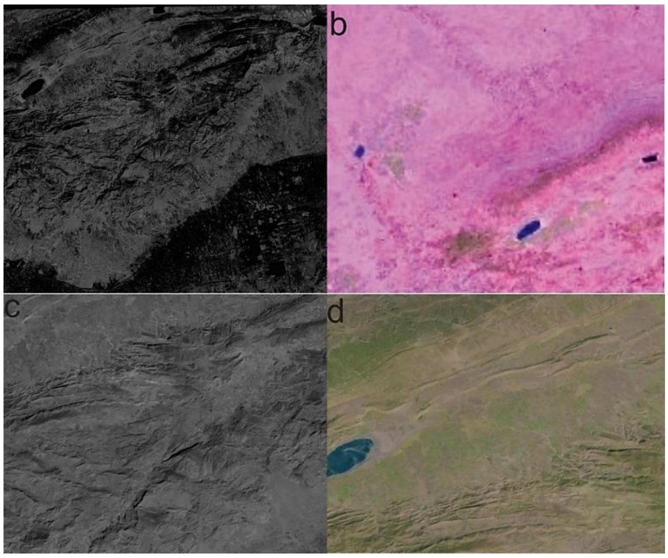

Figure 6: Landsat 8(USGS) Images Which Has Been Used Further in Digitization and Mapping for Field Work

5. Results and Discussions

Different kind of techniques were applied to enhance Land sat 8 data images (figure 6) which helps converting lithological units and their contacts into a format that is more digital and modern. The main hinderance while identifying the lithology was caused by the vegetation cover. These vegetational covers make it difficult to capture direct radiations which are very important in any lithological interpretation work. Composites of different colors must be created to display an image having multi spectral in color i.e Green, Red and Blue every one of which exhibits its own characteristics. Combining different colors patterns are tested and found useful in distinguishing various lithological boundaries hence selected while digitizing different lithological units using visual image interpretations. Different rock Lithologies identified with the help of data from satellite differ from each other in their texture, tone, drainage pattern system. The results are also confirmed in field. The list of observed formations and their description are given in Table 1.

Table 1: List of Observed Formations

Age	Formation	Lithology	Description
Pleistocene	Kalabagh Conglomerate		Conglomerate
Miocene	Kamlial Formation		Sandstone
Eocene	Sakesar Formation		Limestone and marl
	Nammal Formation		Limestone and shale
Paleocene	Patala Formation		Shale
	Hangu Formation		Sandstone and laterite
Triassic	Mianwali Formation		Limestone, shale and dolomite
Permian	Wargal Limestone		Limestone
	Warcha Sandstone		Sandstone and shale interbeds
	Dandot Formation		Sandstone and shale interbeds
	Tobra Formation		Tilitic Facies, Fresh Water Facies

LEGEND: Conglomerate, Marl, Laterite, Dolomite, Limestone, Shale, Sandstone, Tillite

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Another aspect of the study includes drainage pattern which is use as additional aid during lithological mapping. Examining the patterns indicated by drainage or drainage density can provide handful clues about lithology even if the rocks under the study are lacking direct exposure. The reason for this can be more, drainage density of hard rocks(basalts) as it is difficult for water to infiltrate down compared to rocks having loss textures (alluvium) where infiltration of water downward is easy which results in low drainage density.

5.1 Mapping & Structure Set Up of the Study Area

The basic purpose of field work was geological mapping and verification of the GIS based data. Toposheet constitutes the base map for geological mapping. Toposheet number 43 D/2 of the Geological Survey of Pakistan was enlarged up to 5 times for the mapping purpose. The project area is located in Central Salt Range, where the zone of decollement has been provided by the evaporites of Salt Range Formation. All the structures are controlled by Salt Range Thrust. Normal faulting is common in the Study area and drag folding and many structures associated with the normal faulting are obvious in the study area. Ridges and depressions area also common in the study area. Ridges are formed of younger formations while depressions are formed of older formations filled with recent to sub recent alluvium.

5.1.1 Dhok Patial Thrust

A section line E-F is drawn in N-S direction. A thrust fault observed along this cross section named as Dhok Patial thrust. Wargal Limestone is overriding the Sakesar Limestone, are exposed along its North-Western flank and South-Eastern flank. Also, section line M-N is drawn in N-S direction. A thrust fault is observed along this cross section named as Dhok Patial Thrust. Chhidru formation is overriding the Minawali formation, are exposed along its North Western and South-Eastern flank.

5.1.2 Dhok Patial Syncline

A section line M-N is drawn in N-S direction. A syncline is observed along this cross section having Alluvium in its core and Sakesar Limestone, Hangu Formation, Minawali Formation and Chhidru formation in its eastern and southern flank.

5.1.3 Sukh Wahan Thrust

A section line E-F is drawn in N-S direction. A thrust fault observed along this cross section named as Sukh Wahan thrust. Chhidru Formation is overriding the Mianwali Formation, are exposed along its North-Western flank and South-Eastern flank. Also, section line G-H is drawn in NW-SE direction. A thrust is observed along this cross section near Sukh Wahan, named as Sukh Wahan Thrust. Chhidru formation is overriding the Minawali formation near Sukh Wahan observed in this section.

5.1.4 Sukh Wahan Anticline

A section line E-F is drawn in N-S direction. An anticline observed along this cross section named as Sukh Wahan anticline having Wargal limestone in its core. Mianwali Formation and Hangu Formation are exposed along its North-Western flank and South-Eastern flank.

5.1.5 Sukh Wahan Syncline

A section line E-F is drawn in N-S direction. A Syncline observed along this cross section near Sukh Wahan, named as Sukh Wahan Syncline having kalabagh conglomerate in its core and Sakesar Limestone, Hangu Formation, Minawali Formation and Chhidru formation are present along its eastern and southern flank.

5.1.6 Jhalar Thrust

A section line M-N is drawn in N-S direction. A thrust is observed along this cross section near Jhalar, named as Jhalar Thrust. Minawali Formation is overriding the Sakesar lime Stone near Jhalar and observed in the section.

5.1.7 KHURA ANTICLINe

A section line G-H is drawn in NW-SE direction. An Anticline is observed along this cross section near Khura, named as Khura Anticline having Wargal limestone in its core and Minawali formation at the top is eroded.

5.1.8 Khura Normal Fault

A section line G-H is drawn in NW-SE direction. A Normal fault is observed along this cross section near Khura, named as Khura Normal fault where Chhidru formation is overriding the Minawali formation.

5.1.9 Sodhi Thrust

A section line B-C is drawn in N-S direction. A thrust is observed along this cross section near Sodhi, named as Sodhi Thrust. Minawali formation is overriding the Sakesar Limestone near Sodhi observed in this section.

5.1.10 Chamnaki Anticline

A section line B-C is drawn in N-S direction. An anticline observed along this cross section near Chamnaki, named as Chamnaki anticline having Wargal limestone in its core. Minawali formation and Chhidru formation are present along its Southern and Eastern flank and at the top Minawali formation is eroded. Also observed in section line G-H.

5.1.11 Chamnaki Syncline

A section line B-C is drawn in N-S direction. A Syncline observed along this cross section near Chamnaki, named as Chamnaki Syncline having Alluvium in its core and Sakesar Limestone, Hangu Formation, Minawali Formation and Chhidru formation are present along its eastern and southern flank. And section line G-H is drawn in NW-SE direction. A syncline is observed having Sakesar Limestone in its Core and Minawali Formation and Chhidru formation in its eastern and southern flank. Also observed in section line M-N is drawn in N-S direction.

5.1.12 Chamnaki Thrust

A section line B-C is drawn in N-S direction. A Thrust observed along this cross section near Chamnaki, named as Chamnaki Thrust. Chhidru formation is overriding the Minawali formation.

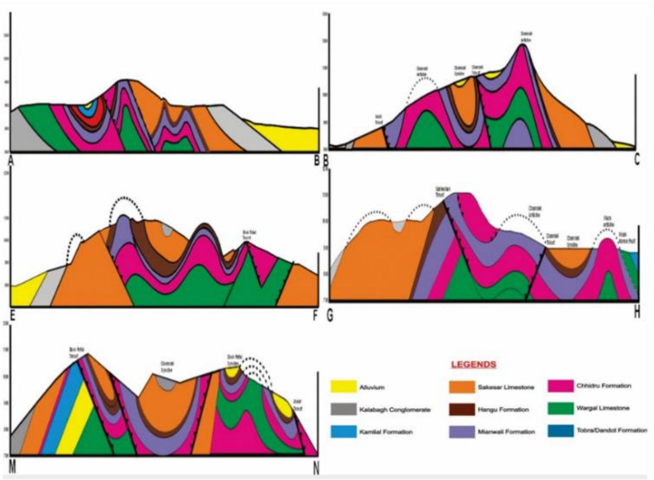

Figure 7: Cross Section along the line A-B, B-C, E-F, G-H, M-N.

While mapping lineaments, lithology and drainage network in the study area guided us to the conclusion that the study area has undergone immense deformation That signifies the influence of a major tectonic structure that surrounds the Central parts of Salt Range (Abied, 2008 and Abubaker, 2015). Hence, the present research demonstrates the importance of remote sensing and GIS to identify lithologies and lineaments in those area that are geologically very active and form complex terrains like the one we have in Central Salt Range.

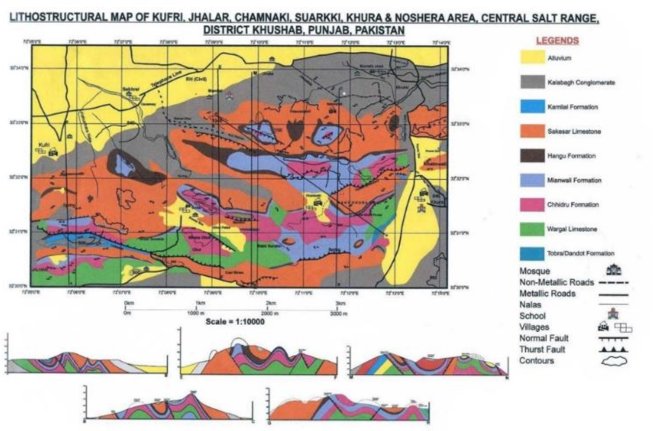

Figure 8: Litho-structural Map of Kufri, Jhalar, Chamnaki, Surakki, Khura And Naushehra Area, Central Salt Range, District Khushab Punjab Pakistan.

6. Conclusion

Techniques of remote Sensing and GIS are integrated so that to distinguish different rocks types and lineaments. The high-resolution data used for these integrated interpretations. Functions like GIS spatial analysis helps develop lithological maps with the use of different information layers that were generated, use techniques based on image processing like Principle component analysis, visual image interpretation, filtering and FCC. The type of rocks marked with the help of data from Satellite indicates a very close resemblance to those rocks present in already existing conventional maps including limestone, Conglomerate, basalt, granite, Phyllites and alluvium. The technique of edge enhancement has shown good accuracy and results for better recognition of lineaments that are tough to trace down in field mapping. Although there are some hinders when we use the techniques of satellite remote sensing in the pursue of carrying out lithological mapping as it will indicate some sort of spectral similarity among some lithological units maybe be due to same kind of vegetational covers but we can remove these difficulties by field work. Further it is very hard to identify lineaments on ground but can be very easy to see from Satellite imaging. Hence, Satellite imaging can be very useful to enhance the quality of lithological mapping and identification of lineaments.

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