LITHOSTRUCTURAL MAPPING OF HANNA LAKE AND ITS SURROUNDING AREA: A 3D GEOLOGICAL MAPPING ANALYSIS OF FORMATION PRESENCE

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Abstract

Lithostructural mapping of Hanna Lake and its surrounding area in Quetta, Pakistan, was conducted using a combination of 3D mapping techniques and geological mapping to identify the lithostructure of the area and the geologic formations present. The 3D mapping techniques included satellite imagery, aerial photography, and ground surveys. The geological mapping included the identification of rock types, structural features, and stratigraphic relationships. The lithostructural mapping revealed that the Hanna Lake area is composed of a variety of geologic formations ranging from Middle Jurassic (Chiltan Limestone) to Holocene (Hanna Group). The sedimentary rock present in the assigned area, both marine and non-marine (fluvial) environments, indicates the eustatic sea level change and closure of Neo Tethys Sea. The 3D mapping techniques were used to create a three-dimensional model of the Hanna Lake area. This model was used to identify elevation changes in the area. The geological mapping was used to identify the age and relationships between the different rock formations.

The results of this study provide a comprehensive overview of the lithostructure of the Hanna Lake area and the geologic formations present. This information can be used for a variety of geological purposes.

Keywords: Lithostructural mapping, 3D mapping, Geologic formations, Hanna Lake, Quetta, Remote sensing, GIS

INTRODUCTION

Lithological mapping is the process of identifying and mapping different rock types on the Earth's surface. It is a fundamental aspect of geology, and has played a significant role in our understanding of the planet's history and evolution. Lithological maps are also used to inform a wide range of land use decisions, including mineral exploration, groundwater management, and natural hazard mitigation. The first lithological maps were created in the late 18th and 19th centuries by geologists who traveled long distances to observe rocks and map their distribution. This was a time-consuming and arduous task, but it produced invaluable information about the Earth's geology. In recent decades, lithological mapping has been revolutionized by the advent of remote sensing technologies such as aerial photography and satellite imagery. These technologies allow geologists to map large areas quickly and efficiently, and to identify rock types that are difficult to access or observe on the ground. Lithological maps are typically created using a combination of field observations and remote sensing data. Geologists first identify and map rock outcrops in the field. They then use remote sensing data to extrapolate the distribution of rock types between outcrops (Davis et al., 1993; Gillespie et al., 1986; and Pirasteh et al., 2007).

The study area lies in the Quetta district of the Baluchistan which is part of the Sulaiman Fold Thrust Belt and represents thick Mesozoic-Cenozoic sedimentary succession deposited in a range of different depositional settings (Treloar et al., 1993). The oldest Jurassic age sedimentary outcrop is exposed in the SFTB (in the study area) known as oldest lithostratigraphic unit (Khan et al., 2018). The Jurassic to Eocene lithostratigraphic units of the SFTB dominantly consists of marine carbonates and representing a range marine depositional setting, while the overlying is formed in a non-marine fluvial system which was developed after deformations of the lithostratigraphic units due to collision of Indian and Eurasia continents (closing of Tethys Ocean) (Ahmed & Khan, 2016). Hanna Lake is a man-made reservoir located in Quetta, Pakistan. It is one of the main sources of drinking water for the city and is also a popular tourist destination (Hussain, 2012). The lake is surrounded by a variety of geologic formations, ranging from Middle Jurassic (Chiltan Limestone) to Holocene (Hanna Group). The lithostructure of the Hanna Lake area is complex and has not been well-studied (Khan et al., 2018).

LOCATION AND ACCESSIBILITY OF STUDY AREA

Hanna Lake is located approximately 17 kilometers east of Quetta city, Pakistan. It is easily accessible by road, with a paved road leading directly to the lake. In addition to the road access, there is also a helicopter landing pad located near the lake. This could be used to transport equipment and personnel to and from the study area, if necessary. The Hanna Lake area is located in a mountainous region, so the weather can be unpredictable. It is important to check the weather forecast before traveling to the area and to be prepared for all types of weather conditions. The Hanna Lake area is also a popular tourist destination, so it can be crowded during peak season. It is important to plan your trip accordingly and to be aware of the crowds. There are some security concerns in the Hanna Lake area, so it is important to be aware of your surroundings and to take precautions to protect yourself and your belongings. Study area location map and satellite image map of the study area is shown in the Figure 1.

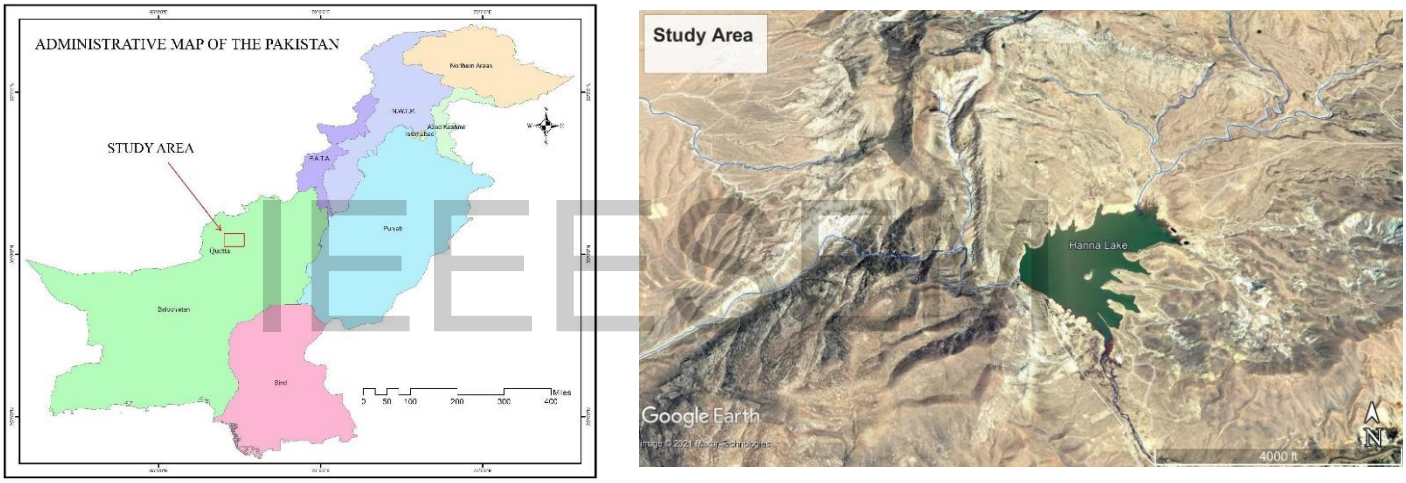

Figure 1: On the left side showing location of study area and on the right showing Satellite imagery of the study area (Hanna Lake and surroundings).

METHODOLOGY

The methodology of this paper consists of two parts: conventional methodology and lithostructural mapping using remote sensing and GIS technology.

Conventional Methodology

The first step was to prepare a base map of the study area using conventional mapping techniques and toposheets of the Geological Survey of Pakistan (GSP). To do this, tracing techniques were used to create a base map from the topographic sheets. The topographic map (34 N/3), which contains the assigned area, was used to determine self-location and to mark contacts between adjacent lithostratigraphic units (as shown in Figure 2). This data was then converted to construct a detailed geological map. The primary data was digitized in software such as ArcGIS.

Lithostructural Mapping Using Remote Sensing and GIS Technology

The second part of the methodology involved lithostructural mapping using remote sensing and GIS technology. This was done by using Landsat 8 satellite imagery and GIS software to identify and map rock types and structural features. The satellite imagery was used to identify different rock types based on their spectral characteristics. GIS software was then used to map the rock types and structural features, and to generate a litho-structural map of the study area. We used this for the 3D mapping of the area.

Latitude and Longitude of the Base map are:

$67^0$4’30”E to $67^0$6’0”E

$30^0$16’15”N to $30^0$16’0”N

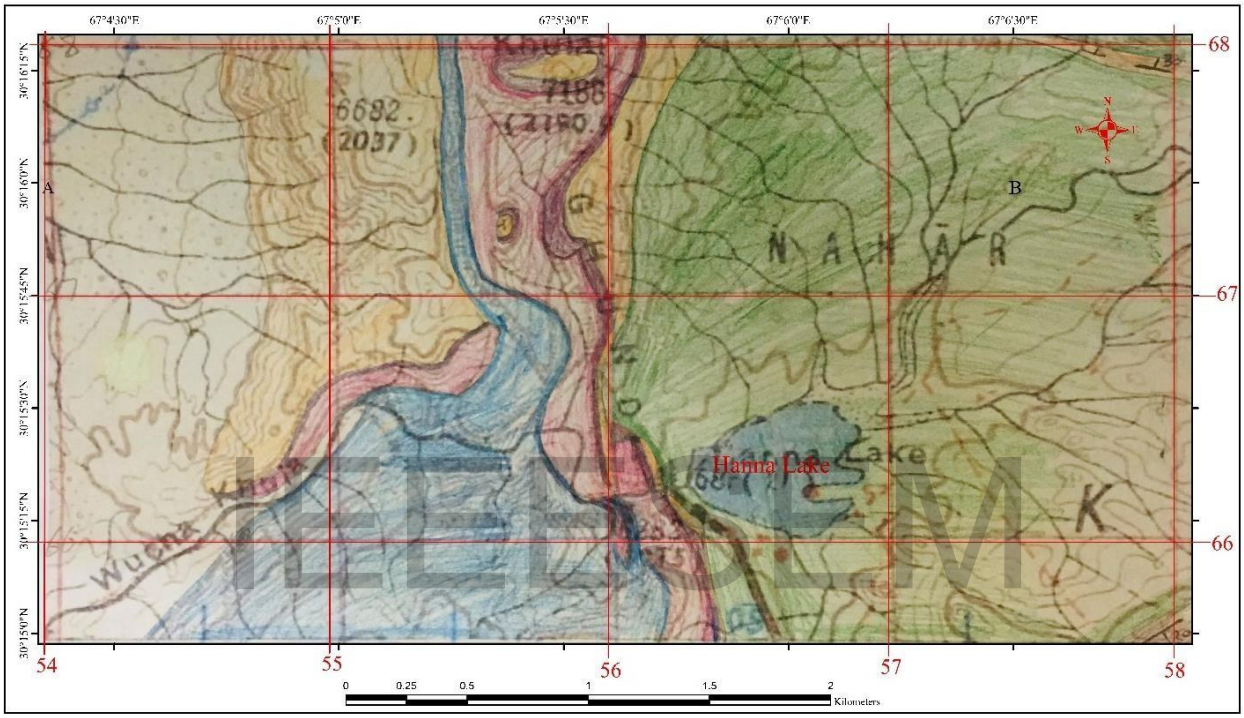

Figure 2: Figure shows the base map of the study area.

FIELD WORK DATA

Prior to embarking on fieldwork for ground assessments, thorough planning is essential. This planning should encompass decisions on the specific data to be gathered and the locations to be chosen, guided by the existing road network. Utilizing the Topographic map (Figure 2) of the study area, a road map for the study region was meticulously devised. This road map was instrumental in guiding our journey to various locations where we could verify the lithology and lineaments observed in satellite imagery with the actual lithological composition and structural features present in the field.

In preparation for our fieldwork, we equipped ourselves with digitized maps displaying the lithology and lineaments of Hanna Lake. Additionally, we carried a map highlighting the precise locations where data collection was imperative for different rock types and geological structures. These ground-based data collection efforts served as a crucial source of information, contributing significantly to our mapping endeavors and enhancing the overall accuracy of our findings. The

observed formations, structures, fossils and different lithologies are shown in the Figure 3.

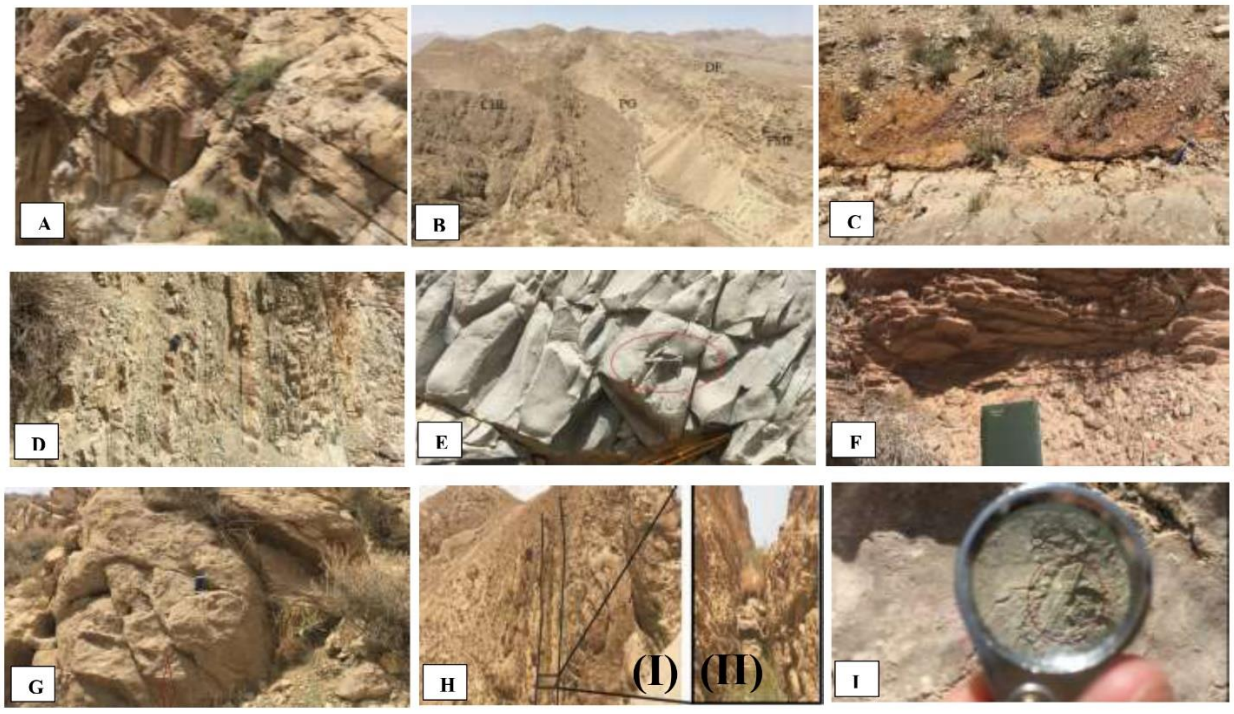

Figure 3: **(A)** Field photo shows thick bedded Chiltan Limestone. **(B)** Field photo shows Chiltan Limestone (CHL), Parh Group (PG), Fort Munro Formation (FMF) and Dungan Formation (DF), are exposed in the northern part of the Hanna Lake area. **(C)** Field photo shows d disconformable contact between (Jurassic & Cretaceous) theChiltan Limestone and the Sembar Formation. **(D)** Field photo shows argillaceous limestone interbedded with marl in the SembarFormation. **(E)** Field photo shows the belemnite fossil which is exposed on bed surface in the SembarFormation. **(F)** Field photo shows thin bed maroon color marl and underlying shale in the GoruFormation. **(G)** Field photo shows dolomitic bed in the upper part of Parh Limestone. (H) Field photo shows unconformity between the Fort Munro Formation and DunganFormation and the (I) is a distinct view of disconformity and (II) is a close-up view of disconformity. **(I)** Field photo shows assilina in the Dungan Formation.

RESULTS AND DISCUSSION

Different kind of techniques were applied to enhance Land sat data images which helps converting lithological units and their contacts into a format that is more digital and modern. 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: The observed formations of the study area.

GROUPS	FORMATIONS	LITHOLOGY	FOSSILS	AGE
Hanna Group	Hanna Conglomerate	Poorly to well compact conglomerate	No fossils	Holocene
	Ghazij Formation	Mudstone, sandstone conglomerate, limestone, and coal	Bivalves, gastropod, coral pelecypods	Middle Eocene
	Dungan Formation	Limestone	Assilina, nummulites, and bivalves	Early Eocene
Disconformable contact				
	Fort Munro Formation	Limestone	Orbitides and Pelecypods	Late Cretaceous
Disconformable contact				
Parh Group	Parh Limestone	Thin bedded limestone with dolomite and chert	Globotruncanids	Late Cretaceous
	Goru Formation	Marl, shale, and argillaceous limestone	Globotruncanids	Middle Cretaceous
	Sembar Formation	Calcareous shale, marl, and argillaceous limestone	Belemnites and Globotruncanids	Early Cretaceous
Disconformable contact				
	Chiltan Limestone	Limestone, pisolite limestone and massive bedded	Corals, bivalves	Middle Jurassic
Base not exposed in our study area but in other areas it is conformable with Shirinab Formation.				

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 34 N/3 of the Geological Survey of Pakistan was enlarged up to 5 times for the mapping purpose. The project area is located in Sulaiman Fold Thrust Belt, The Jurassic to Eocene lithostratigraphic units of the SFTB dominantly consists of marine carbonates and representing a range marine depositional setting, while the overlying is formed in a non-marine fluvial system which was developed after

deformations of the lithostratigraphic units due to collision of Indian and Eurasia continents (closing of Tethys Ocean).

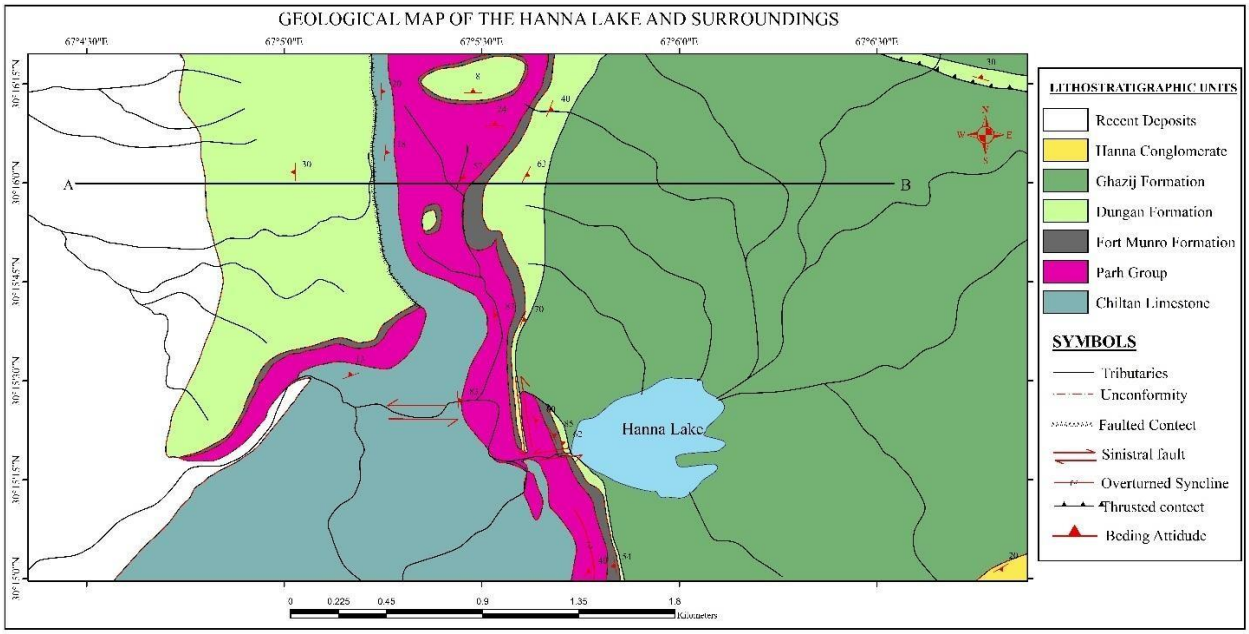

Figure 4: Shows geological map of the Hanna Lake and surroundings (modified after Jones, 1961).

Cross section shows fault is a normal fault, which means that the rocks on the downthrown side of the fault have been displaced downwards relative to the rocks on the up thrown side of the fault. The cross-section also shows that the mountain has been folded. The folds are synclines, which means that the layers of rock dip inwards towards the center of the fold. The exposure of different layers of rock in the mountain suggests that the mountain has been uplifted and eroded. The uplift of the mountain has exposed the underlying rock layers, and the erosion of the mountain has removed the upper layers of rock. The cross-section provides a valuable insight into the geological history of the area. It shows that the area has been subjected to a variety of geological processes, including faulting, folding, and uplift.

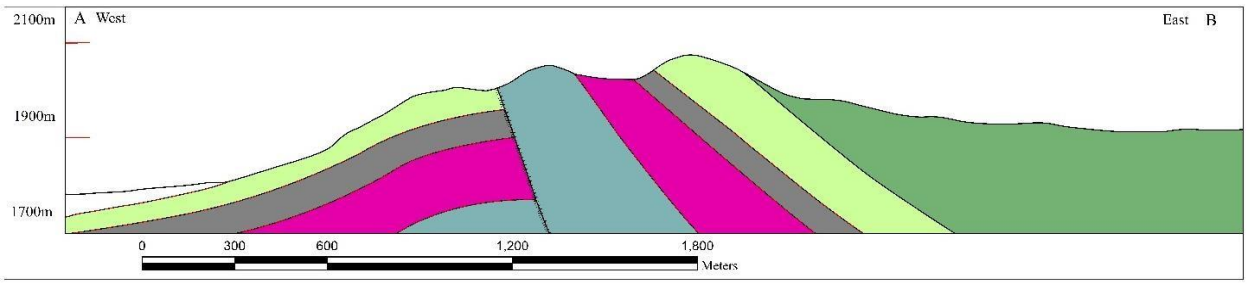

Figure 5: Geological cross-section along line A-B.

While mapping lineaments, lithology and drainage network in the study area guided us to the conclusion that the study area has undergone deformation that signifies the influence of a major tectonic activity (Collision of Indian and Eurasia continents). 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 Quetta at Hanna Lake near the highly active Chaman Fault.

3D map show the topography of the area. Topography is an important factor in groundwater flow and landslide susceptibility. For example, areas with steep slopes are more susceptible to landslides than areas with flat slopes. The 3D map will also show the presence and orientation of faults and folds. Faults and folds are important geological features that can control the flow of groundwater and the susceptibility of an area to landslides and earthquakes. The 3D map of Hanna Lake, reveals a complex geological landscape with a variety of rock formations ranging in age from Middle Jurassic to Holocene. The lake itself is located in a basin surrounded by mountains. The mountains to the north and east of the lake are composed of Jurassic and Eocene limestones, while the mountains to the south and west are composed of younger sedimentary rocks and alluvium.

The map also shows a number of faults and lineaments in the Hanna Lake area. These faults and lineaments are likely the result of the collision of the Indian and Eurasian continents, which closed the Tethys Ocean around 50 million years ago.

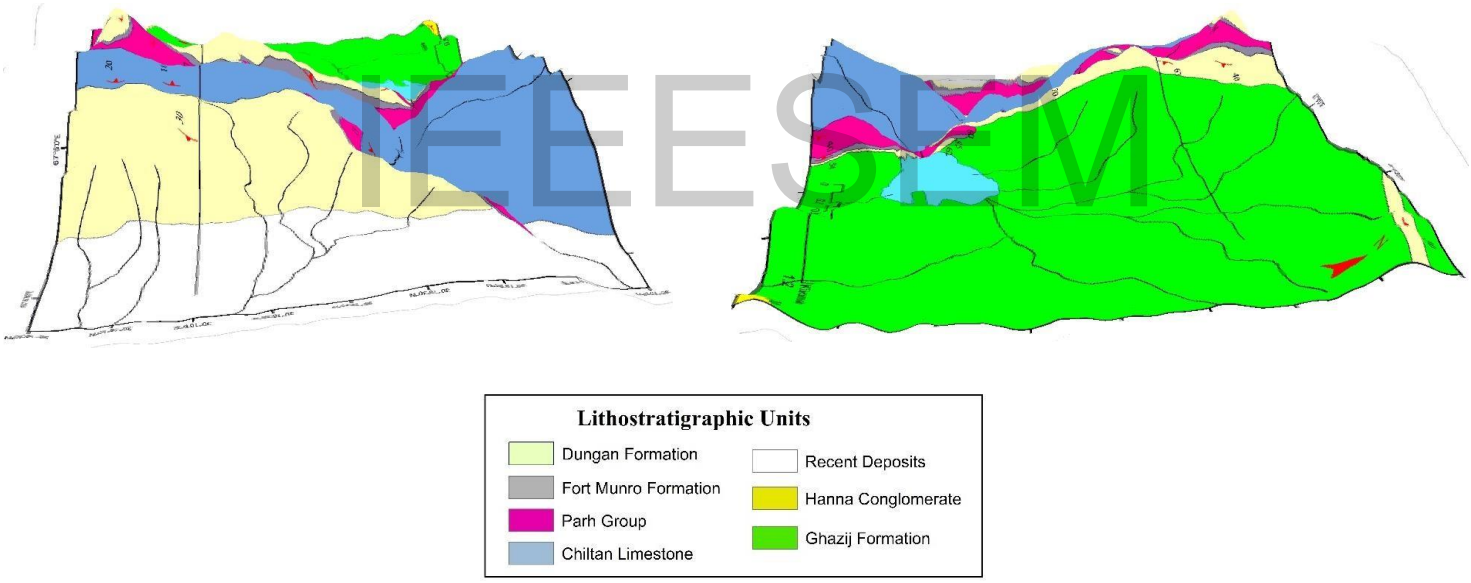

Figure 6: Figure shows the 3D image of the geological map.

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, and filtering. 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. 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. 3D mapping is used for the purpose of different risk assessment.

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Ms. Rani Ummay Farwa, she received Gold Medal in Geology She has strong Academic Foundation and Software In 2022, she participated in the prestigious Imperial Barrel award, AAPG and secured an impressive 5^{th} position in the competitive Asia Pacific region. Currently she received an offer as a development fellow at the Geological Survey of Pakistan, She is actively contributing to the advancement of geological sciences. Her dedication to research work is evident in her focus on pivotal areas such as tectonic studies, sedimentology, core digitization, and machine learning applications.

Mr. Khlieeq Ul Zaman graduated with a Bachelor's degree in Geology with a specialization in Petroleum Geology from the University of Sargodha in June 2023. He is an active member of the Society of Petroleum Engineers (SPE) and PAPG student chapter Sargodha University. He was the captain of a team that secured 4th place in the AAPG IBA-2023 competition.

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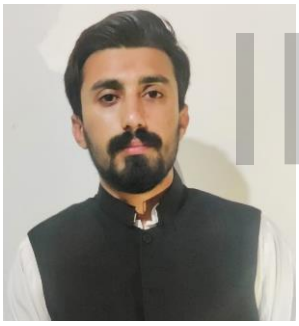
Ms. Aliha Shakeel holds a Bachelor of Science degree in Geology from the University of Sargodha, with a specialization in mineralogy. Throughout her academic journey, she actively participated in numerous geology workshops. Currently serving as an office intern at the University of Sargodha, she demonstrates a strong dedication to her research and studies, showcasing enthusiasm for her ongoing research endeavors.



Mr. Hassan is a geologist with specialization in Petroleum and Structure geology from University of Sargodha. During my studies I participated in International competition which was organized by AAPG and our team took 4th position in Asia Pacific Region. I have interest in Geotoursim, geosites conservation, geoheritage research especially travertine in Pakistan and it's usage in construction of archeological sites. I am also an active member of AAPG and PAPG.