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Geological Setting and Sub Surface Interpretation of Tulanj Area Kohat

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Abstract

Kohat Foreland and Fold-Thrust belt lies on the Southern fringes of Himalayan orogenic belt and is a product of ongoing collision of Indian and Eurasian plates. The structural geology of the Kohat Plateau is a series of north-dipping, low angle imbricate thrust faults underneath a blind roof thrust. The surface structural geology is dominated by east-west trending anticlines having both limbs overturned and steep down plunged ends. The anticlines are separated by broad synclinal valleys in which the Neogene fluvial foreland basin deposit crops out. These anticlines are formed as detachment folds and pressure ridges above complex, positive flower structures that represent north to south shortening. The study area lies adjacent to Kohat-Fatah Jang road in a village named Tolanj. The main objective of the study is to conduct detail structural mapping and structural analysis (fracture analysis of kohat formation) of the selected area in the Northern Kohat Plateau which revealed two phases of deformation. First i.e North-South compressional deformation results in East West trending Folds and Faults. Second i.e. gravity collapse of the elevated rocks occurs. The exposed stratigraphy in the study area mainly composed of Panoba shale, Sheikhan, kuldana, Kohat, Murree and kamlial formations ranging in age from Eocene – Miocene. The

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Northern Kohat Fold and Thrust belt is dominantly controlled by East West trending Anticlinal and Synclinal Folds, Thrust Faults and large scale over Thrust sheets. Structures which are present in the study area, Shindand Anticline, Tolanj anticline, ToghBala Anticline, Gandiali Overturned Anticline, Tolanj Syncline, Tolanj Fault and Gandiali Fault. Two traverses are done which are traverse A-A′ includes ToghBala Anticline. The section passes through the following formations Murree, Kuldana, Kohat and Alluviums and traverse B-B′ contains Gandiali overturned Anticline, Tolanj Anticline, TolanjSyncline and Tolanj fault. This cross section passes through the Murree, Kuldana, Kohat, Panoba and Alluvium. GPR was used for determine the near surface geophysical method for investigation of the subsurface fracture analysis. The 400 MHz antennas was used at the top of Kohat formation, over 390 meter traverse was done and got the 5 feet depth data in which observed the three layers, 1st layer of soil 2nd of clay and third of bed rock limestone and observed the disturbance and fractures with in the Kohat limestone.

Introduction

General Description

Kohat Foreland and Fold-Thrust belt lies on the Southern fringes of Himalayan orogenic belt and is a product of ongoing collision of Indian and Eurasian plates. Kohat Basin forms the North- Western margin of the Himalayan Foreland Fold and Thrust belt. The Kohat Basin is located in Sub Himalayas of Pakistan and contains the mollase sediments and Eocene sediments. The contact between mollase sediment and the underlying Eocene sediments is unconformable (Thakkur V.C, 1992).It is bounded to the North by Main Boundary Thrust MBT and South by Bannu Basin, South-East

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by Surghar Range. On the Eastern side Indus River separates Kohat Plateau from Potwar Plateau. On the Western side Kohat Plateau is bounded by Kurram Fault. MBT is a regional Fault that brought the Mesozoic-Cenozoic shelf sediment of Hill Ranges against a pile of Mollase sediment, deposited in the Foreland Basin of Potwar and Kohat (Yeats and Hussain, 1984). The stratigraphic units of the area fall within the following two major groups.

1. Rawalpindi Group (Miocene)
2. Cherat Group (Eocene)

The cherat group is represented by:

i. Kohat Formation
ii. Kuldana Formation
iii. Sheikhan Formation
iv. Panoba Shale's

While the Rawalpindi Group is represented by :

1. Murree Formation
2. Kamlial Formation

The area is greatly influenced by regional tectonics dominated by Thrusting and strike slip Fault. The general trend for major structures is East-West trend. The major structures in the field area is Shindand Anticline, Tolanj Anticline, Gandiali Overturned Anticline, Tolanj Syncline, Ghandiali fault and Tolanj Fault.

Aims and Objective

Tectonically the study area is very unstable. The structure of the area is complex, so requires a great attention.

Our thesis work is aimed:

1. To construct a detailed Geological map of the area

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2. To collect the field data about of different feature like Fault, Folds and joints etc.
3. To mark the contact of the different Formations.
4. To establish a stratigraphic sequence of the mapped area.
5. To do the geometric analysis of the different structural entities and their relation to the regional structures.

Study Area

Location and Accessibility

The study area is accessible by the metaled Kohat-Fatah Jang Road which passes adjacent to the entire area. Several metaled and unmetalled side roads run East-West in the area which provide excellent sectional views. Many paths connecting local villages provide a good chance to study the rocks and sections from different views.

Figure1.1 Showing Accessibility Map from Peshawar to Study Area

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Topography of the Area

The topography of our area comprises that Kohat Basin and it is situated in Northern Pakistan and located between lat. 32° and 34° N and, long. 70°and 74 E. It is an onshore Basin bounded on the North by Main Boundary Thrust Fault MBT, on the West by Kurram Fault, on the South by Surghar and Salt Ranges and on the East river Indus separates it from Potwar Basin. The Kohat Basin is a portion of Indian plate deformed by Indian and Eurasian plate collision.

Climate of the Area

Kohat area has extreme climate with a long hot summer season and cold, dry lasts from May to September and winter lasts Winters Season. Summer from November till February, In summer the temperature reaches 42°C to 45 °C and in winter average temperature is 15C- 20°C.

Methodology

The instruments that we used for the entire mapping includes Base Maps:

i. Silva compass
ii. Hand lens
iii. GPS
iv. Hammer
v. GPR

The 2 Traverses were planned across the regional Dip and Strike and the lithology's were mark on the Map. The reason for the taking many traverses was to observe maximum possible geological details. Dip strike data was collected in the field area and it was plotted on the map. The Silva Compass and GPS were used for locating ourselves in the field and for marking contacts.

The structural map is formed by following the following steps:

- 1st of all I find my study area in Google Earth software as shown in figure 1.1.1

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- Then I started line work in Google Earth and marks different formations and geological structures as shown in figure 1.1.2
- Then I exported this line work into kml format
- Then imported that kml files into GIS and covert that into shape files as shown in figure 1.1.3
- Then did digitization in GIS as shown in figure 1.1.4
- And at last gave I gave color to different formations and marked traverse as you will see in final map

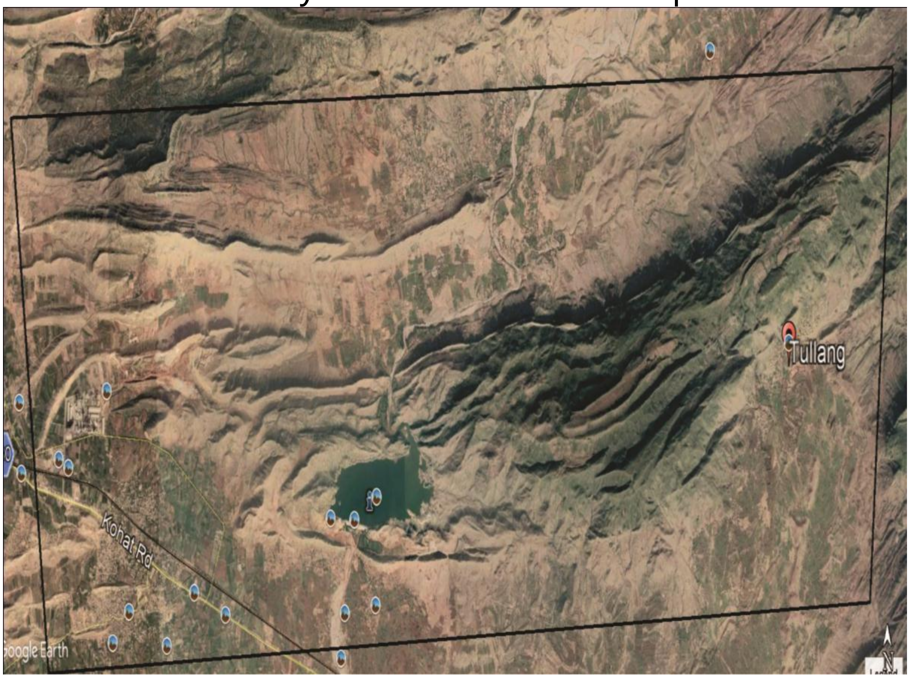

Figure 1.1.1 Showing Study Area Polygon

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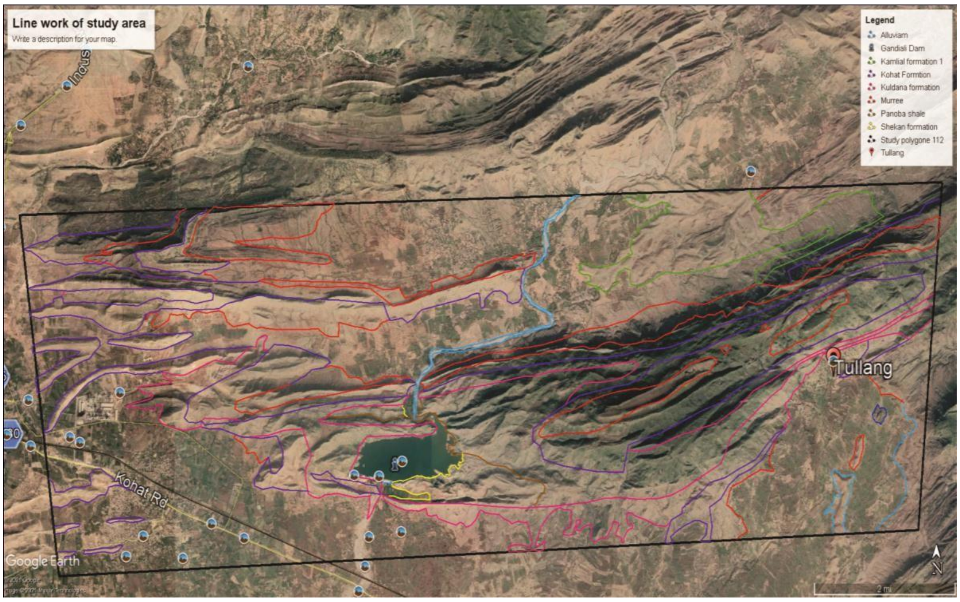

Figure 1.1.2 Showing Line Work In Google Earth Software.

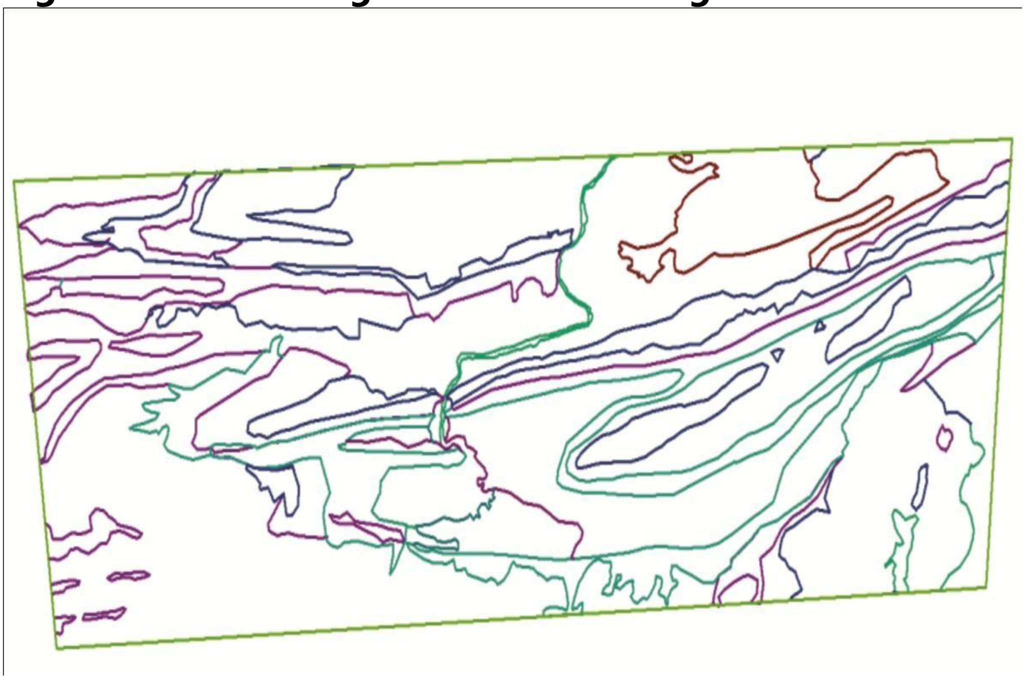

Figure 1.1.3 Shows Shapefile in GIS

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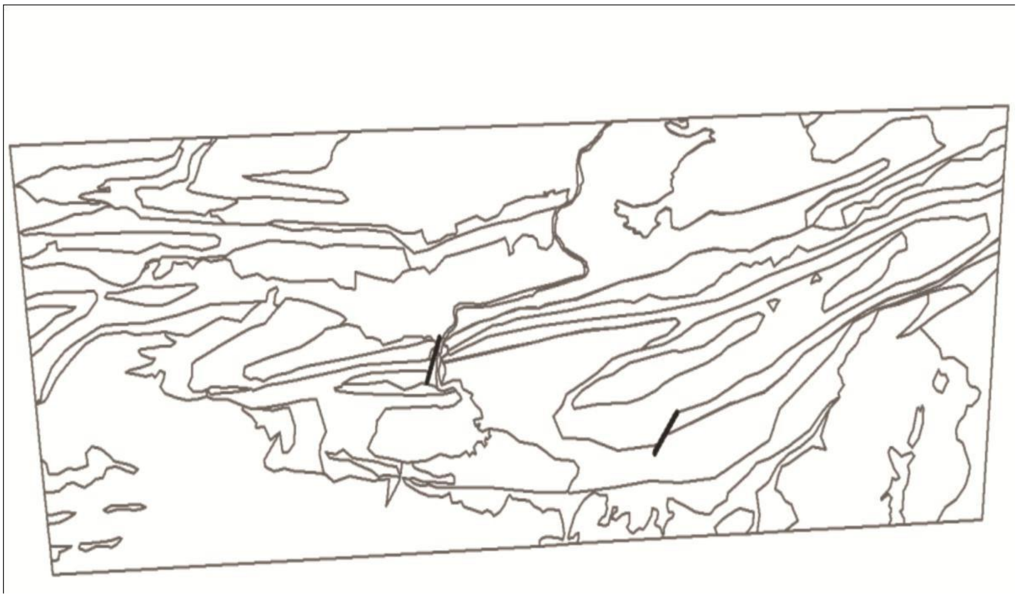

Figure 1.1.4 Showing Digitization in GIS.

Literature Review

The Kohat Plateau has been frequently investigated by workers since Burnes (1832) reported the occurrence of salt in the Kohat Plateau. The salt deposits of Kohat Plateau have also been referred in various reports and articles by a large number of earlier geo-scientists of the Geological Survey of India (Oldham. 1890; Wynne, 1879, Pinfold, 1918 and Davies, (1926). Gee (1945) presented a regional overview regarding the age and stratigraphic relationship of the Salt Range and the Kohat salt deposits. Raza and Khattak (1972) of the Geological Survey of Pakistan published a useful report on the gypsum deposits of the Kohat area. Fatmi (1973) has produced an excellent pieceork by establishing the lithostratigraphic units of the Kohat region. Significant contribution owes to Meissner eta/. (1974, 75) regarding the geology of the Kohat Plateau. They conducted detailed geological investigations and prepared a geological map at a scale of 1:250,000, including the lithostratigraphic boundaries and structural details. Well (1984) Worked out the depositional environments of the Cenozoic rocks in detail. McDougall and Hussain (1991} prepared a balanced cross section through the Eastern Kohat Plateau and Surghar Range to

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describe the Fold and Thrust propagation beneath the Kohat Plateau. Abassi and McElroy (1991} outlined a structural model for the plateau utilizing North-dipping, low-angle imbricate Thrust Faults underneath a Passive roof Thrust. An alternate interpretation of the plateau suggests that it is a complex, hybrid terrain consisting of strike-slip and compressional features (Pivnik, 1992; Pivnik and Sercombe, 1993; Sercombe etal. 1994 a, b). They suggested that the majority of early Cenozoic rocks exposed in the plateau crop out in the core of Anticlines and forms detachment Folds and pressure nudges above complex, positive flower structures that represents considerable amount of North to South shortening.

Regional Tectonic

Tectonic Setting

The major structural divisions of the Kohat-Potwar fold and thrust belt are the Kohat Plateau, the Bannu Sub-basin, the North Potwar Deformed Zone (NPDZ), the Soan Syncline, the Salt Range and the Trans-Indus Ranges (Meissner et al, 1975; Treloar and Izzat, 1993; Pivinik and Wells, 1996) (figure 2.1). The Kohat plateau, an approximately 10,000 km2 area of rugged, un vegetated hills is bounded to the north by the Main Boundary Thrust fault system (MBT) (Pivinik and Wells, 1996) (figure2.1) which contains highly deformed, Pre-Cambrian-Cenozoic sedimentary rocks(Yeast and Hussain, 1987).

The structural geology of the Kohat Plateau is a series of north-dipping, low angle imbricate thrust faults underneath a blind roof thrust (Abassi& McElroy,1991; McDougal &Hussain, 1991). The surface structural geology is dominated by east-west trending anticlines having both limbs overturned and steep down plunged ends. The anticlines are separated by broad synclinal valleys in which the Neogene fluvial foreland basin deposit crops out. These anticlines are formed as detachment folds and pressure ridges above complex, positive flower structures that represent north to

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south shortening (figure 2.2) (Pivinik and Wells, 1996; Sercombe et al.,1998).

Himalaya, the youngest and perhaps the most magnificent of all the mountain belts and continent-continent collisions on the earth was created due to the collision Involving Eurasian plate in the North with the Indian plate in the South at about 65-50 Ma (Gansser, 1964; LeFort, 1975; Molnar and Tapponier, 1975; Fraser et al., 2001). The Himalayas are often referred to as 'Roof of the world' because they contain the Highest peaks in the world. This mountain belt has North-West trend in India, East- West to North-South along the Western border of Pakistan (Ahmad, 2003). The Himalaya originated as a result of the separation of the Indian plate from the Mother Gondwana land and its Northward drift at about 130 Ma ago (Johnson et al., 1976).

As a result of this Northward drift of Indian plate the Neo-Tethys started shrinking which was located between the Indian and Eurasian plates (McKenzie and Sclater, 1976). An intra-oceanic Subduction generated Nuristan, Kandahar and Kohistan-Ladakh arcs at the time of Neo-Tethys closure (Treloar and Izzat, 1993; Searle, 1991). For a time of almost 40 Ma, this arc magmatism continued (Petterson et Al, 1985). The Kohistan-Ladakh arc collided onto the Eurasian plate in the North Forming an Andean type of continental margin as a result of the back arc Basin Closure. According to Coward et al. (1986) the collision between Kohistan-Ladakharc And Eurasian plate gave birth to a boundary named as the Main Karakorum Thrust (MKT) at 70-100 Ma ago. The Main Karakorum Thrust (MKT) separates igneous, Metasedimentary and deformed sedimentary rocks of the Southern Eurasian plate From the Kohistan Island Are (KIA) terrain situated in the North. Subduction of the Neo-Tethys continued underneath the Kohistan-Ladakh arc till the complete consumption of the leading edge of the Indian plate that finally collided with the remnant of Kohistan-Ladakh arc (Powell, 1979). This collision occurred Between 65-50

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Ma and as a result the Main Mantle Thrust (MMT) was formed (Chamberlain and Zeitler, 1996; Tonarini et al. 1993; Maluski and Matte, 1984; Smith Et al. 1994).

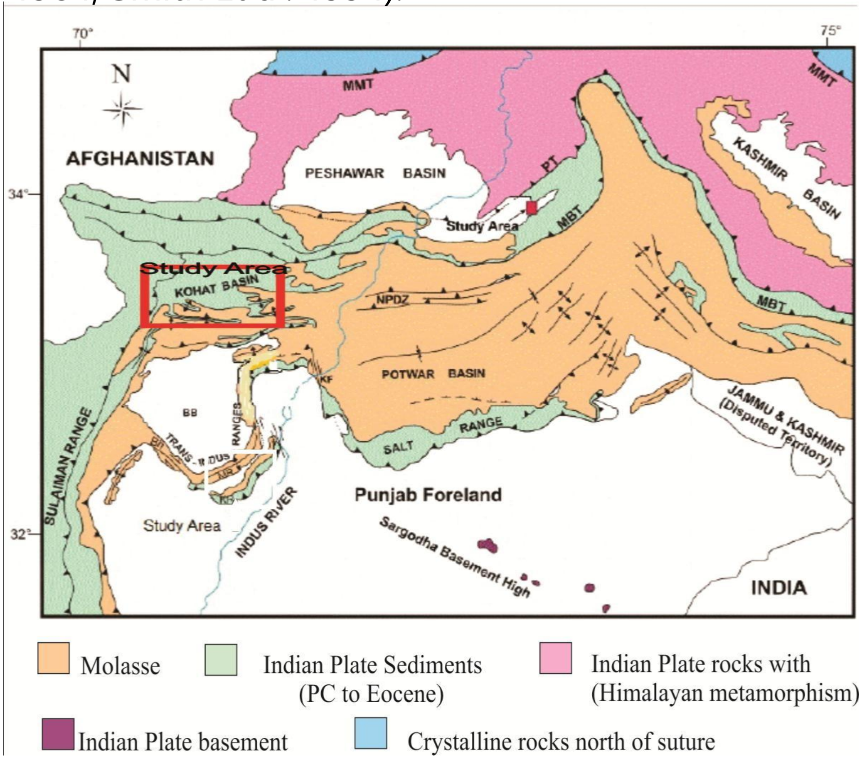

Figure 2.1 Map showing the location of the area.

Structural Setting

The Pakistani Himalayas have been divided into five litho-tectonic domains by four Regional scale Fault systems; the Main Karakorum Thrust (MKT), the Main Mantle Thrust (MMT), the Main Boundary Thrust (MBT) and the Salt Range Thrust (SRT) And Trans Indus Range Thrust (TIRT) (Khan, 2011). These lithotectonic domains Include Karakorum Block, Kohistan Island Arc, Northern Deformed Fold and Thrust Belt, Southern Deformed Fold and Thrust Belt and Punjab Foredeep (Ahmad et al., 2004) as shown in Figure 2.1. The regional Fault system and lithotectonic domains From North to South have been briefly discussed as follow:

North Karakoram block

Main Karakoram Thrust (MKT)………… Kohistan Island Are

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Main Mantle Thrust (MMT)................ Northern Deformed Fold and Thrust Belt Main Boundary Thrust (MBT)............. Southern Deformed Fold and Thrust Belt Salt Range Thrust (SRT)...............
Punjab Foredeep OR Indo-GangatieForedeep South

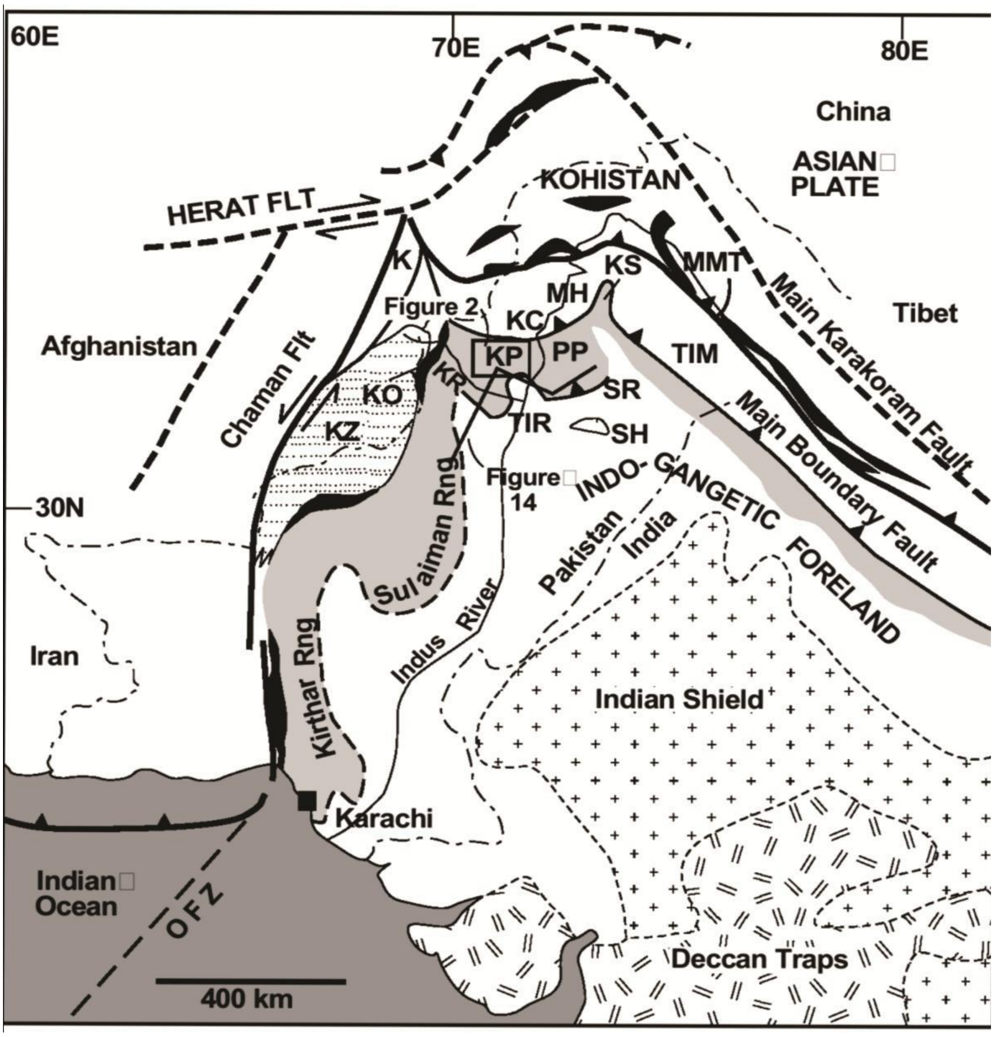

Figure 2.2. Tectonic map of northern Pakistan (inset showing location of the study area) and position of the Asian plate, the Kohistan Island arc, the telescoped northern Indian continental margin (TIM), major ophiolities (black), the deformed basin(light shaded), the undeformed Indo- gangtic foreland and indian Shield. Abbreviations are; K- Kabul Block; KC- Kala Chatta Range; KO- Khost Block; KP-Kohat Plateau; KR- Kurram River; KS- Kashmir Syntaxis; KZ- Katawaz Flysch Basin; MH- Margalla Hills; MMt- Main

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Mantle Thrust; OFZ- Owen Fracture Zone; PP- Potwar Plateau; SH- Sarghodhah Hills; SR- Salt Range; TIR- Tans Indus Ranges (modified from Treloar and izzat 1993 and Pivinik and wells, 1196).

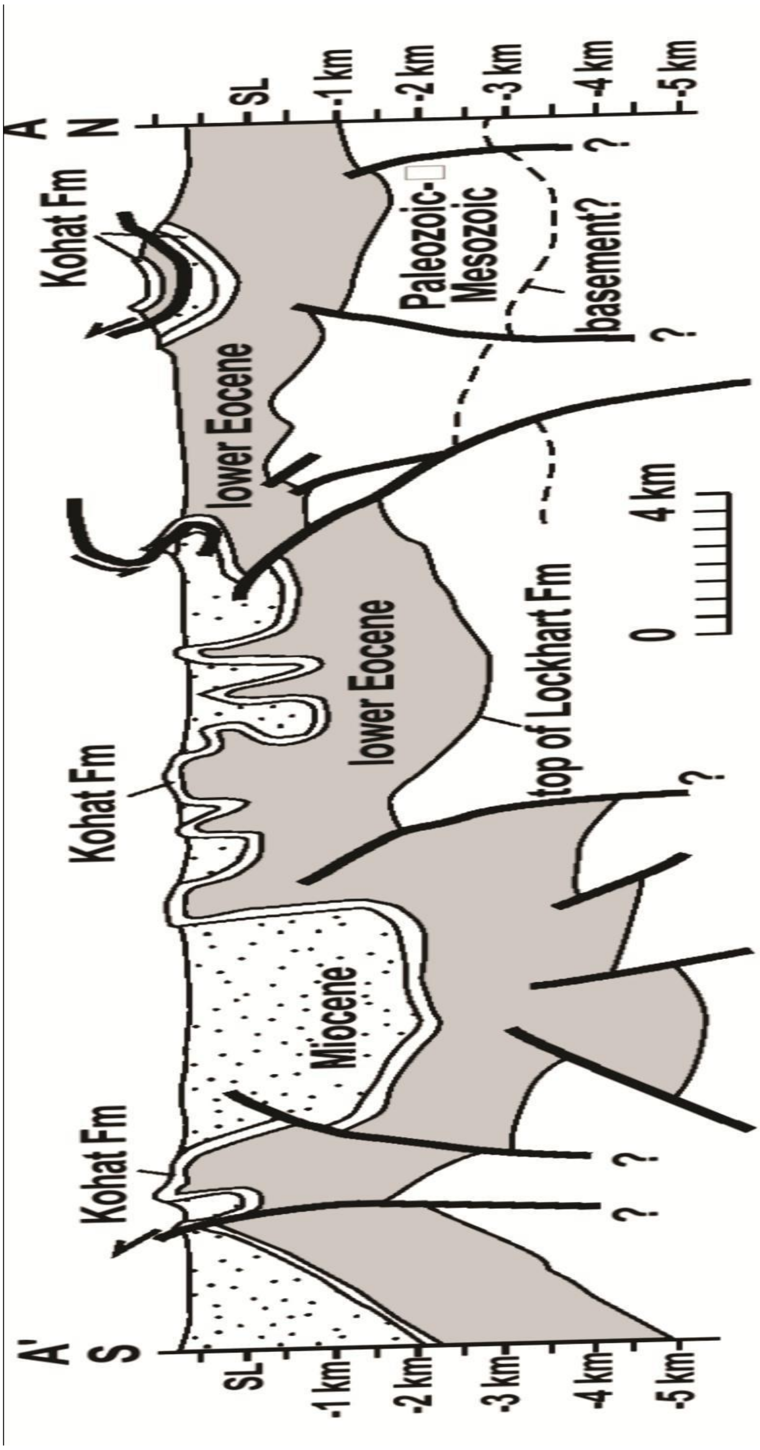

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Figure 2.3. Structural cross section across the Kohat Plateau. The anticline in the Kohat plateau are cored by high angle, oblique reverse faults. An earlier system of the thrust faults has been folded above the reverse faults (modified from Pivinik and Well, 1996).

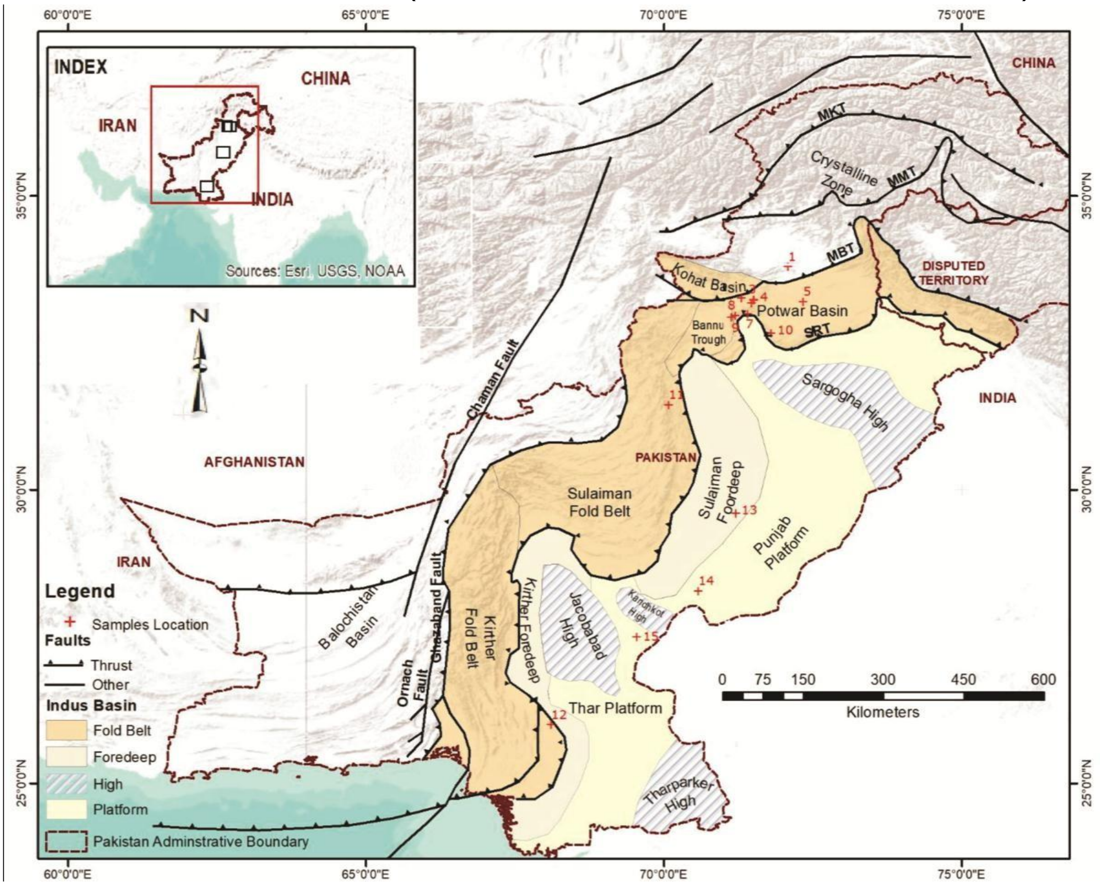

Figure 2.4 Map Showing Major Tectonic Zones Of Pakistan. (Ali Et Al, 2020)

The Karakorum Block

Consisting of complex assemblages of heavily deforms sedimentary Metasedimentary and Innes roes of the Southern Eurasian plate, Karakorum block lies between Pamir in the North and KohistanLadakh are in the South The Karakorum block and KohistanLadakh are collided with each Other 70-100 Ma ago and gave birth to MRT (Yoshida et al. 1997; Treloar et Al. 1989).

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The Main Karakoram Thrust (MKT)

The Main Karakorum Thrust (MKT) is making the Southern boundary of Karakorum block. In Northern Pakistan MKT is present as a major tectonic feature. The Main Karakorum Thrust has resulted from collision of the North lying Karakorum plate and Southward Kohistan Island Arc (KIA) (Tahirkheli, 1979, 1982, 1983). Pudsey et al. (1985) named it as Northern Suture.

Kohistan Island Arc (KIA)

The Northward drift of Neo Tethys beneath Eurasian plate in the time period of late Jurassic to Cretaceous led to the development of the Kohistan Island Arc (Hamidullah and Onstot, 1992; Searle et al., 1987; Tahirkheli, 1979). The Indian plate is separated from the overlying Kohistan Island Arc marked by a suture zone characterized by the presence of blue Schist facies rocks. Volcanic rocks, calc-alkaline plutonic, ultramafic and mafic comprise of a thick cover of 40 km and cover 36000 km2 in Western Himalaya, Karakorum and Hindukush constitute the Kohistan Island Arc (Hamidullah and Onstot, 1992). The orientation of the Arc is East West comprising of plutonic and volcanic deformed and rocks with subsidiary sedimentary rocks, which are metamorphosed to some degree. The North South trending Nanga Parbat Haramosh Massif divides the arc further into Kohistan and Ladakh arcs and Indian plate is lying under it (Seeber and Armbuster, 1979). Kohistan Island Arc is bordered by MKT and MMT in the North and South respectively, and join each other in Tibet and India laterally to form a distinct suture, the Indus Tsangpo Suture Zone (Ahmad, 2003). Both these Faults join together to merge in the left lateral Kunar Fault in the vicinity of Afghanistan (Ahmad, 2003).

The Main Mantle Thrust (MMT)

The Main Mantle Thrust (MMT) lies in the North of the Northern Deformed Fold and Thrust Belt (NDFTB). It involves the lower crust and is dipping towards North between 25-45 degree (Bard, 1983; LeFort, 1975; Malinconico, 1986). Due to major swing in its trend

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MMT gives rise to a re-entrant, Nanga Parbat Haramosh Massif, composed of Proterozoic Gneisses and Schist's with more than 15 km thick sequence in Kohistan Island Arc (Madin, 1986). According to Zeitler et al. (1982), differential movement of the blocks on either side of the MMT ceased since about 15 Ma. However, the Formation of MMT did not stop the convergence and continued at a rate of 5mm per year since Eocene that resulted in continent-arc-continent collision (Karakorum- Kohistan-India) (Patriate and Achache, 1984).

The Northern Deformed Fold and Thrust Belt

Comprising of heavily deformed sedimentary, metasedimentary and igneous rocks, the Northern Deformed Fold and Thrust Belt (NDFTB) is bordered by MMT in the North and MBT in the South distinguishing it from the South lying Southern Deformed Fold and Thrust Belt. The NDFTB is stretched from Kurram region near Afghan border in the West up to the Kashmir Basin in the East (Khan, 2011). A system of South youngling Faults has developed due to the gradual propagation of deformation towards Southward. The Main Boundary Thrust (MBT) and the Salt Range Thrust (SRT) are the major members of this Fault system (Yeats and Hussain, 1987; Zeitler, 1985; Zeitler et al., 1982).

The Main Boundary Thrust (MBT)

The Main Boundary Thrust (MBT) is extended along the front of the Northern Fold and Thrust Belt around Hazara-Kashmir syntaxes from North-East to South-West, representing the Southward migration of Himalayan de Formation from the site of MMT in the North. The hanging wall of MBT carries the pre- collisional Paleozoic and Mesozoic sedimentary and metasedimentary rocks of the Northern Deformed Fold and Thrust Belt and post collisional Folded Miocene Foreland Basin deposits in its Footwall (Khan, 2011). The MBT zone Consists of a series of parallel or en-echelon Thrust Faults dividing the North- Western Himalayan sequence into a deformed sedimentary Southern zone or Foreland zone and

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a deformed and metamorphosed Northern zone or the Hinterland zone (Pivnik and Wells, 1996; Dipietro et al., 1996). According to Seeber and Armbuster (1979); and Yeats and Lawrence (1984) The MBT is connected to the Hazara and Murree Faults that bound the Northern margins of Hazara and Kalachitta range. The MBT is bedding Parallel and exposes somewhere in the molasse of the Northern Potwar and Kohat Plateaus (Izzat, 1993). Continental shortening was transferred along the Detachment of the Main Boundary Thrust, after movement on the MCT and MMT (Ledford, 1975; Bird, 1978).

The Southern Deformed Fold and Thrust Belt

The Southern Deformed Fold and Thrust Belt (SDFTB) rim the Himalayan Mountain belt from Ganges Delta in India up to the South Waziristan Agency In Pakistan. It has East West orientation and is underlain by a thick pile of Fluvial sediments. This belt was the main depocenter of the synorogenic Sediments influx, which started in early Miocene (Ahmad, 2003). The Southern deformed Fold and Thrust Belt is further divided into Kohat Plateau In the West and Potwar Plateau in the East of Indus River. Potwar Plateau Comprise internally less deformed Fold and Thrust Belt with approximate Width of 150 km in North South direction (Kazmi and Rana, 1982). Salt Range Thrust (SRT) and Trans Indus Range Thrust (TIRT) lies in the South of the SDFTB separating it from Punjab Foredeep. Deformation is mostly restricted To the Northern Potwar Deformed Zone (NPDZ), which is located in the North Of the Plateau (Baker et al., 1988; Leather, 1987). The SRT & TIRT represent an active deformational front along which Cambrian to Paleocene rocks are Thrust onto the Punjab.

The Salt Range Thrust (SRT)

The Salt Range Thrust (SRT) forming the Southern margin of the Salt Range: apparently continues Eestwards along the Southern margin of the SurgharShinghar and Khisor-Marwat Ranges (Gee, 1989). The Thrust is largely covered by Alluvium and

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Fanglomerates (Kazmi and Jan, 1997). However, at place the Thrust is exposed and show the Paleozoic rocks overlying the quaternary deposits of the Jhelum plain (Gee, 1945, 1989; yeast et al, 1984).

The Punjab Fore Deep

The Punjab Foredeep rims the Southern-most extension of Himalayan mountain chain in Indo- Pakistani shield, Unconsolidated Quaternary sediments overlie the Punjab Fore deep and it is also the present day depocenter for the eroded debris from the Himalayan chains in the North (Ahmad, 2003).

Structral Framework of Northern Kohat Plateau

The Northern Kohat Plateau is marked by the Main Boundary Thrust (MBT) in the North and North-West and SumariBala Fault in the South. Due to its close occurrence with MBT, the Northern Kohat Fold and Thrust Belt was the first to experience the imprints of South migrating deformation, The MBT is a regional Fault that brought the Mesozoic-Cenozoic shelf sediments of the Hill Ranges (Margalla, Kalachitta, Kohat and Samana Range) against a pile of molasses sediments, deposited in the Foreland Basins of Kohat and Potvar (Burbank, 1983; Yeats and Husain, 1987). The stratigraphic record of Northern Kohat Fold and Thrust Belt shows that it was a restricted Basin till the middle Eocene followed by a period of unconformity during late Eocene to Oligocene and became a synorogenic Foreland Basin since Miocene. Three major units that is Paleocene, Eocene and Miocene rocks represent the area. The Plio-Pleistocene Siwalik Group rocks are not Exposed in this part of the Kohat Plateau because the Foreland Basin was migrating Southwards in response to the uplift and tectonism associated with MBT, which Started during Miocene (Burbank, 1983).

Stratigraphy

Introduction

The exposed rocks in the area under study ranging in age from Eocene to Miocene. The exposed Eocene Succession consists from bottom to top of Panoba Shale, Sheikhan Formation, Kuldana

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Formation and Kohat Formation. The exposed Miocene sequence consistsMurree Formation. The nomenclature for different Formations used in this study is derived from the work of Meissner et al (1974), Gardezi et al (1976), Shah (1977) and Wells (1984). The rock description is based on observation of exposures in the study area and literature.

Age	Formation	Lithology	Description
Miocene	Kamlial		The formation consists of purple-grey and dark brick-red sandstone which is medium to coarse grained and contains interbeds of hard purple shale and yellow and purple intraformational conglomerate
	Murree		The formation consist of Clay & Sandstone with subordinate conglumerate
Eocene	Kohata		The Kohat Formation consists of interbedded limestone and shale
	Kuldana		The formation comprised of red to brownish red clay with Inter bedded Sandstone layers. It forms red colored gullies
	Shekhan		The Formation mainly consists of Limestone and Shale
	Panoba		The formation mainly consists of shale with occasional band of sandstone. The shale is olive green in color
Paleocene	Patala		The lithology consists of Thick-bedded to massive, light grey current-bedded sandstone with silty, sandy, glauconitic shale..
	Lockhart		Limestone
	Hangu		The Formaion consists of sandstone with grey shale intercalations.
Cretaceous	Kawagarh		The formation is typically a lithographic to sub lithographic, grey, olive grey and light grey limestone with subordinate marl and shale
	Lumshiwal		The lithology consists of light grey sandstone with silty, sandy, glauconitic shale
	Chichali		The type locality, consists of dark green, glauconitic sandstone, with dark grey, greenish grey, sandy, silty, glauconitic shale
Jurassic	Samanasuk		The Formation consists of Limestone with subordinate marl, shale and Sandstone

Table 3.1 Shows Generalized Stratigraphic Column

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Age	Formation	Lithology	Description	Field Photos
Miocene	Kamlial		Clay and Sandstone	
	Murree		Clay & Sandstone with subordinate conglumerate	
Eocene	Kohata		Limestone	
	Kuldana		Clay and Sandstone	
	Shekhan		Limestone	
	Panoba		Shale and Sandstone	

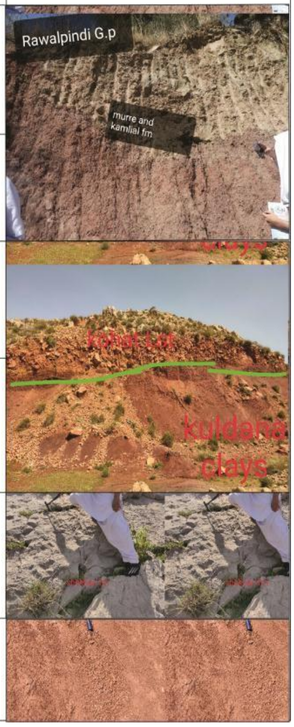

Table 3.2 Shows Stratigraphic Column of the Study Area

Eocene Succession

The Eocene rocks exposed in the study area are represented by the following Formations:

1.Kohat Formation
2.Kuldana Formation
3.Sheikhan Limestone
4.Panoba Shale

Panoba Shale

In the study area, the Formation mainly consists of Shale's with occasional bands of Sandstone. The Shale is olive green in color. In the mapped area, the lower contact of the Panoba Shale is not exposed where as its top is conformable with the overlying Sheikhan. Limestone near Sumari village. Where as in some parts it is Unconformable underlying Kuldana Formation. It is also form in the eroded cores of Sumari Payan Anticline.

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Figure 3.3 Showing Panoba Shale

Sheikhan Limestone

In the study area, the Formation mainly consists of Limestone and Shale. Sheikhan Formation to represent the Limestone beds. The Limestone is yellowish grey, thin bedded to massive and nodular. Limestone and Shale are most prominently interbedded. Sheikhan Formation is conformably overlying Kuldana Formation and underlying Panoba Shale. In study area Sheikhan Formation is exposed in the eroded core of Spine Anticline. Foraminifer's, Corals, Mollusca's and Echinoids are also reported (Shah, 1977).

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Figure 3.4 Showing Sheikhan Formation

Kuldana Clay

The Kuldana Formation is well developed in the study area and can be easily identified in the field as red to brownish red clay with Inter bedded Sandstone layers. It forms red colored gullies because of Being soft as compared to Kohat Formation. Kuldana Formation is mainly Composed of clays and Sandstone. Clays are red colored, soft and calcareous, While Sandstone is reddish brown, thin bedded, hard and medium to coarse Grained. Kuldana Formation is fluvial origin and deposited by flowing.

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Figure 3.5 Showing Kuldana Clays

Kohat Formation

The Kohat Formation consists of interbedded limestone and shale. The lower Kaladhand Members composed predominantly of limestone which is light grey, hard, compact and thin- bedded with shale intercalations, particularly in the lower part.

Figure 3.6 Showing Kohat Formation

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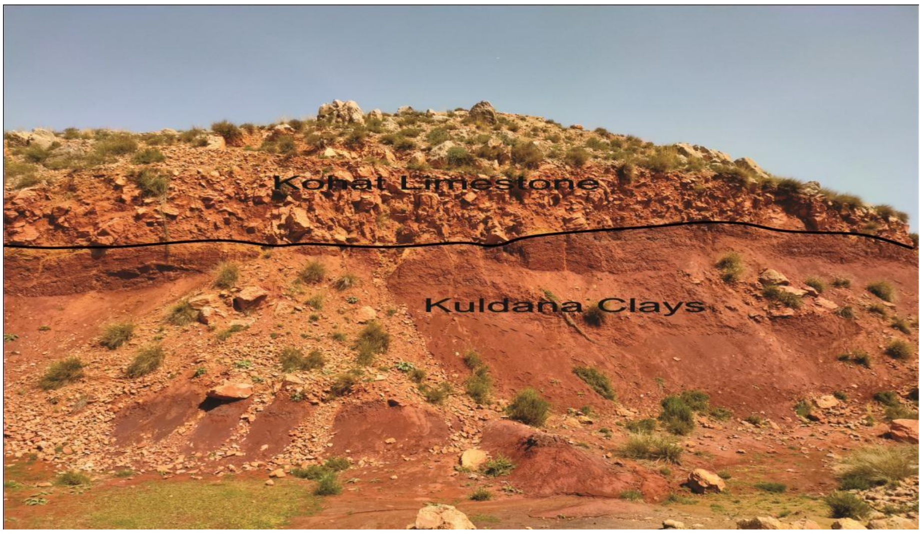

Figure 3.7 Showing Contact Between Kohat Limestone and Kuldana Clays

Miocene Sequence

Kamlial Formation

The formation consists of purple-grey and dark brick-red sandstone which is medium to coarse grained and contains interbeds of hard purple shale and yellow and purple intraformational conglomerate. It is distinguished from the underlying Murree Formation by its usually spheroidal weathering and heavy minerals content in which tourmaline dominates over epidote.

Murre Formation

The Formation is mainly composed of dark red Sandstone Clays With subordinate Conglomerates. The base Murree Formation is marked by unconformity with the underlying Kohat Formation.

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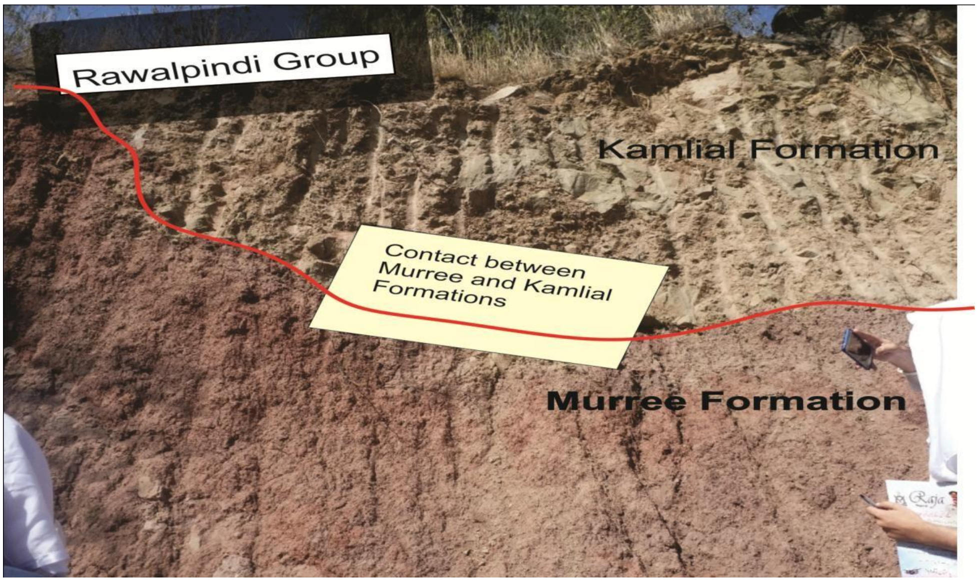

Figure 3.8 Showing Murree and Kamlial Formations

Structural Geology

Introduction

The pioneer work of Meissher et.al (1974) provides good basic information about lithology and structure or the Kohat plateau; especially in Northern part recently the detailed mapping of Kohat plateau has been carried by Ahmad (2003). For further investigation and working out minor details a small area selected in Northern Kohat Basin in Tolanj village.

The study area located immediatly South of MBT and constitutes the hanging to sequence of the MBT, so the Southward propagation of Himalayan deformation associated with MBT is well recorded in area. On surface tight Anticlines and open to tight Synclines are present. The trending of Anticlines and Synclines are East-West. Additionally the area is well comprised by East-West trending Thrust Faults. In the study area, the formation consists of Panoba Shale, Sheikhan Formation, Kuldana Formation and Kohat Formation of Eocene succession Kamlial Formation and Murree Formation of Miocene secession.

The geological map of the area was prepared at 1:75,000 in software Geographic Information System using existing geological

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map, Google Earth imagery, field mapping and 2D Move. The specified area contains Anticline, Synclines, Folds and Faults.

Subsurface Structuralstyle

The structure of the Kohat Basin generally follows an east west trend. However, there is a prominent swing in the general trend towards west and south east of the basin. The arcuate nature of the outcrops in the region is fairly open and broad within Kohat Basin. Three contrasting models explain the structural genesis of the outcropping rocks in the Kohat Basin. One of these models depicts the structures within the exposed rocks as part of a passive roof thrust that is translating northwards in a thin-skinned fashion. This passive roof thrust is underlain by an active wedge ofsouth-directed thrust slices of Pre-Tertiary stratigraphy that form a passive roof duplex (McDougal and Hussain, 1991 and Abbasi and McElroy, 1991). The second model suggests that the structural evolution of the Kohat Basin has been greatly influenced by strike-slip faulting related to thick-skinned deformation. These strike-slip faults are not recognizable at the surface but are deep-rooted in the basement and expose themselves as anticlinal trends in the Paleogene to Oligocene cover (Pivnik, 1992; Pivnik and Sercombe, 1993 and Sercombe et al., 1994 a and b). A third model for the structural genesis of Kohat Basin suggests that the surface structures do not mimic the subsurface structures and decollement related thrusting within Paleocene and older rock tips at the base of Eocene sequence and Miocene age rocks. Eocene rocks are mainly deformed by disharmonic folding further complicated by shale/evaporate diapirism (Ahmad, 2003).

Complex structures at surface do not mimic the underlying simple structures and vice versa. The anticlinal axis here runs ENE-WSW in the central and western area, while its course changes towards NE-SW in the east. To the northeast it is tectonically terminated against the Tolanj Fault

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On the southern side the anticline is bounded by Tolanj Syncline where the rocks of Murree formation. The trend of Gandiali anticline here also follows the same general trend as that of Shindand anticline to the north, and like the anticlinal axis the synclinal axis also terminates against the Ghandiali Fault further to the east. The Togh Bala Anticline is not sharply folded, but at the surface has a broad crest with dips to the north of the crest axis not more than 15° about one kilometer away from crest axis, whilst along the axis itself the beds are Near to horizontal.Along the northern flank of the fold the dips progressively increase towards the GandialiFault where a maximum of 48° is recorded on the outermost bed of the fold in contact withGandiali Fault. The southern limb is relatively steep with dips ranging from 20-45°. The northern most is the TolanjFault which in outcrops is marked by steep dips and is often marked by the development of small scale folds and intense shearing. The Gandiali Fault demarcates the northern flank of the Tolanj Anticline and is found to be a high angle thrust fault. There is a lack of concordance and absence of correlation in the structural trends on the up thrown side with that of the down thrown side showing that the thrust might also be accompanied by some lateral translation as well. South of the Tolanj Syncline lies the Kohat monocline that moderately to steeply dips northeast wards. The Kohat monocline forms the hanging wall succession of the frontal bounding Tolanj Fault which juxtaposes Paleogeneto Miocene age rocks against the Siwaliks in the southeast direction.

Map Description

Major structures present in our area are:

I. Shindand Anticline
II. Tolanj Anticline
III. ToghBala Anticline
IV. Gandiali Overturned Anticline
V. Tolanj Syncline

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Major faults present in our study area:

I. Tolanj Fault
II. Gandiali Fault

Shindand Anticline: is exposed in the study are in Kohat Formation. This formation is mainly composed of interbedded limestone and shale.

Tolanj anticline: is exposed in study area in Kuldana Formation. This formation is composed of clays and Sandstone. Clays are red colored, soft and calcareous, While Sandstone is reddish brown, thin bedded, hard and medium to coarse Grained. Kuldana Formation is fluvial origin and deposited by flowing.

Togh Bala anticline: is exposed in Kuldana Formation in study area

Gandiali overturned anticline: is exposed in Panoba Shale's. This formation consist of Shale's with occasional bands of Sandstone. The Shale is olive green in color.

Tolanj syncline: is exposed in Murree Formation. This formation consist of dark red Sandstone Clays With subordinate Conglomerates

Tolanj fault: is between kuldana formation and kohat formation as shown in figure.

Gandiali fault: is between kuldana, kohat and murree formations.

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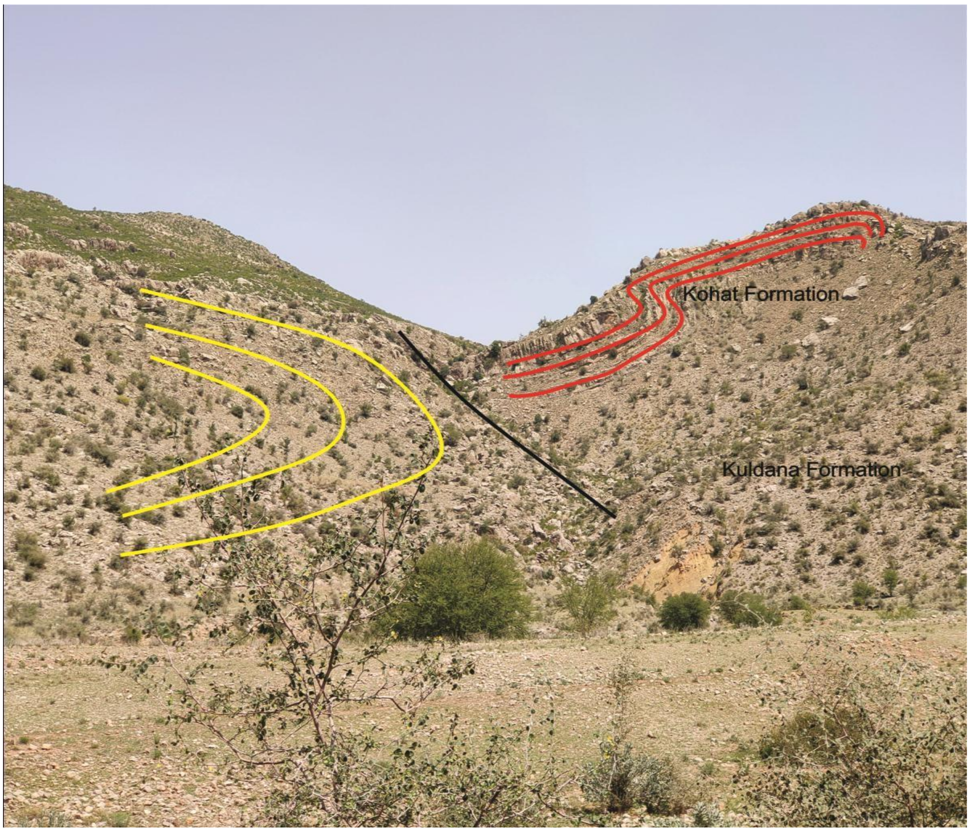

Figure 4.1 Showing Tolanj Fault and Fan and Monoclonal Fold Structure

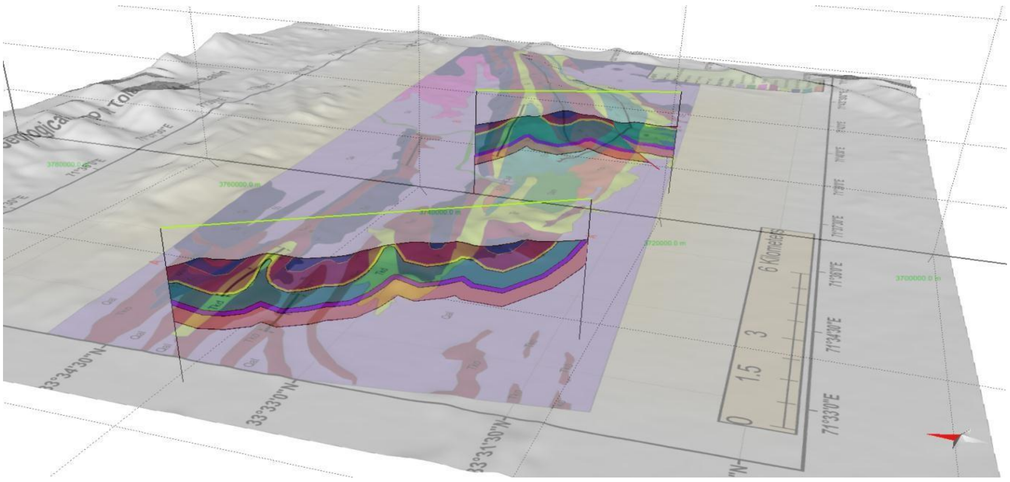

Figure 4.2 Showing the 3D view of Map of the Study Area

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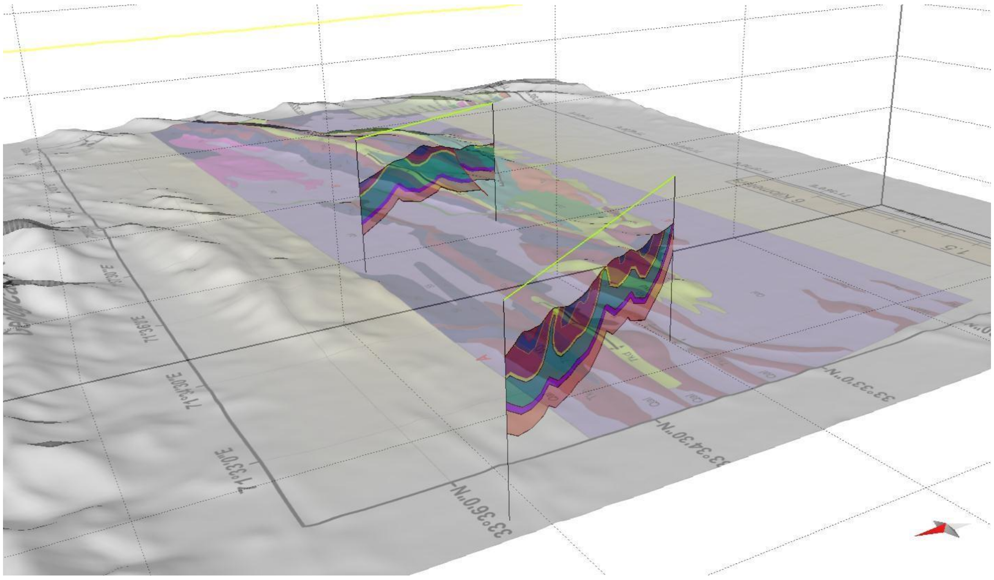

Figure 4.3 Showing the 3D View of the Cross Section A-A′ and B-B′. Towards NNW

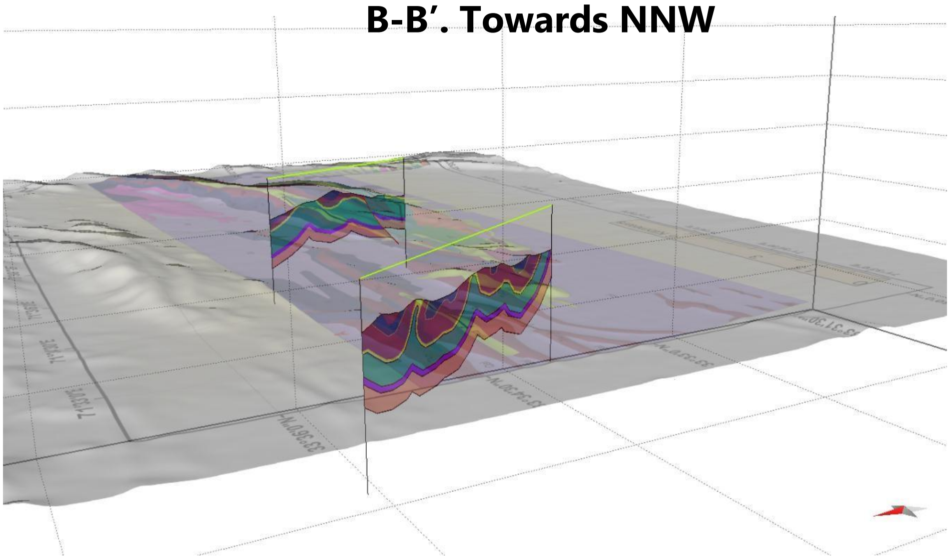

Figure 4.4 Showing the 3D view of the cross section A-A′ and B-B′. Towards SSE

Cross Sections

Cross Section A-A

The structural transect along the section A-A′ is perpendicular to the trend of the major structures present in the area and in North-Northwest oriented. The dips of the formation are mostly northwest which are mostly gentle but get steeper along faults.

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The southern part of the study area is covered by alluvium .the oldest rocks which are exposed on the southern side of our study area represent panoba shale of Eocene. The youngest rock exposed in the northern part of our study area represent by Miocene. The major fault in the study area is Tolanj Fault. This is a south verging fault. Few other secondary associated fore thrust are also present in the study area. The displacement along the tullaj fault is about upto 250m which has brought Eocene rocks over the youngest sequence of Miocene age. The other associated thrusts of the MBT do not Show a huge stratigraphic throw as they have sliced the whole rock package at regular intervals. There are few back thrust attached to these associated faults forming a pop up structure. All these faults are listric in their form and have a very steep near surface angles but their dips keep becoming gentle as we move into subsurface were they join the subhorixontal basal decolma at the level of Lochart and patala formation.(Fig 4.4)

Since this section is located along the Southwestern part of the study area; it represents greater amounts of deformation.The cross section A-A′ includes ToghBala Anticline. This cross section passes through the following formations Murree, Kuldana, Kohat , Alluviums and the deformational events goes through the Paleocene successions. The southern limb is relatively steep with dips ranging from 20-55°..(Fig 4.5).

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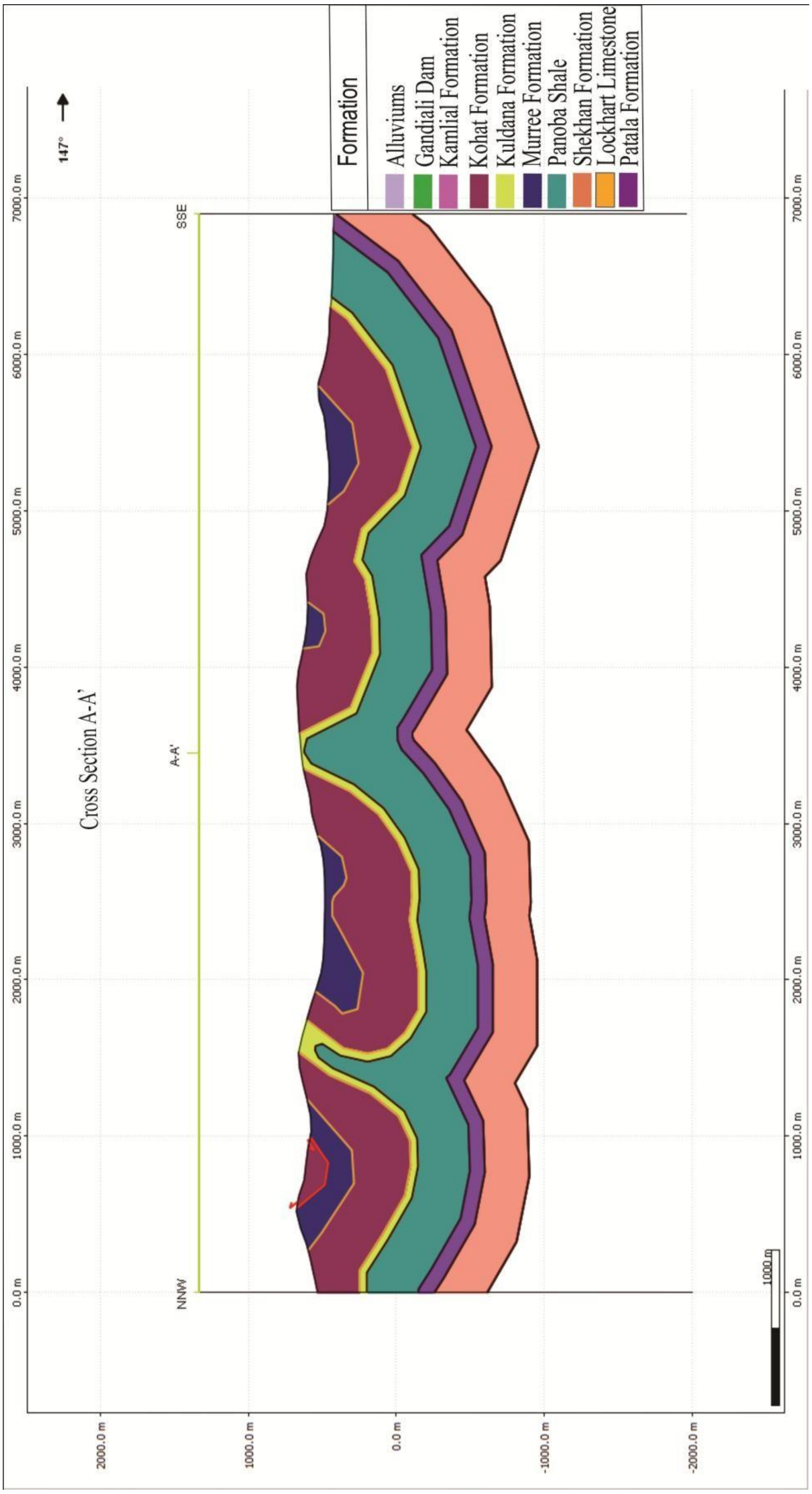

Figure 4.5 Showing Cross Section View of A-A'

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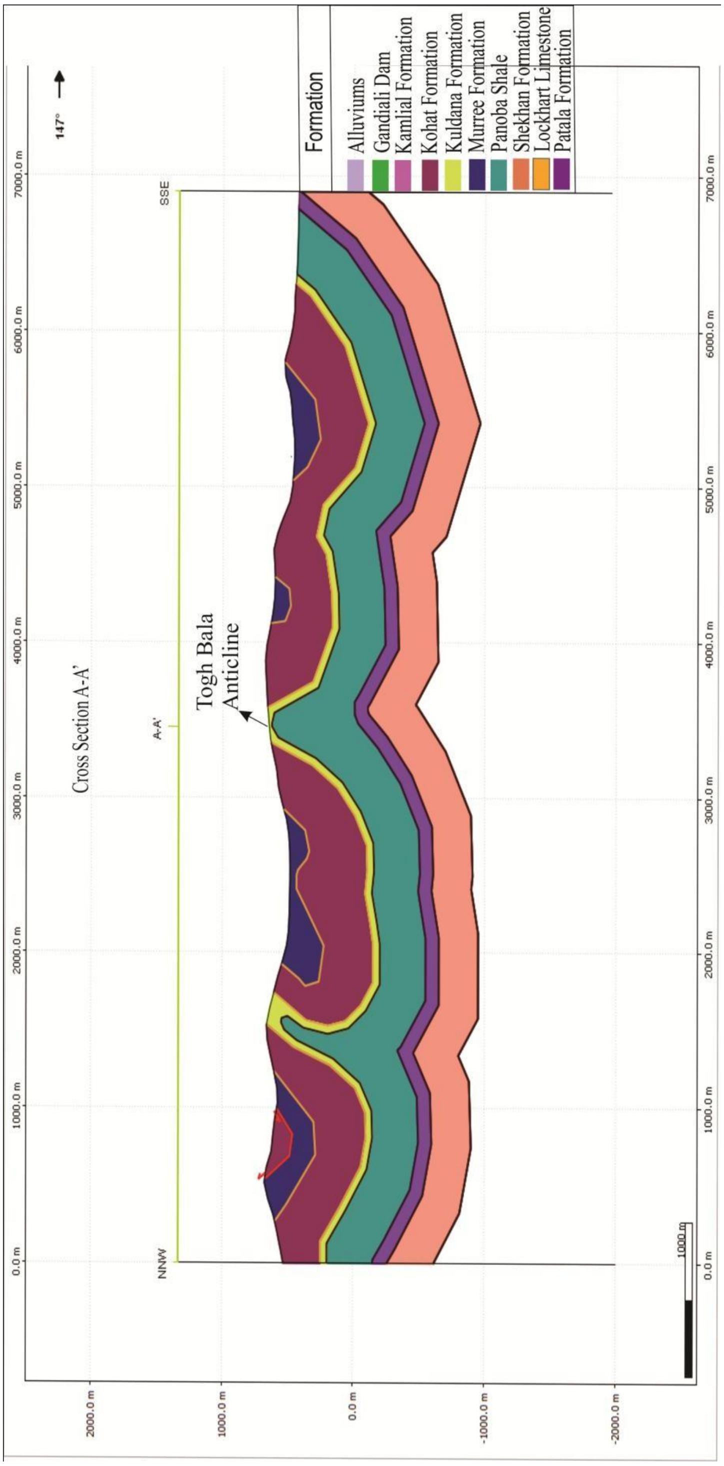

Figure 4.6 Showing Cross Section View of A-A′ with Labeled Structure

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Cross Section B-B

It there for shows eastern extension of the structures depicted in the section line B-B′.

Deformation in the eastern part is mild as compared to the western part and therefore fold are much open and faults show lesser offsets. All the faults are again south verging and havelistric geometrics.

The anticlinal axis here runs ENE-WSW in the central and western area, while its course changes towards NE-SW in the east. To the northeast it is tectonically terminated against the Tolanj Fault. On the southern side the anticline is bounded by Tolanj Syncline where the rocks of Murree formation. The trend of Gandiali anticline here also follows the same general trend as that of Shindand anticline to the north, and like the anticlinal axis the synclinal axis also terminates against the Ghandiali Fault further to the east.

The basal decolma is at the depth of almost 2800m where as Kohat, Murree, Panoba, Shekhan and kamlial formation is repeated in the whole section between the thrust slices. At some places normal faulting is also noticed which is limited to near surface deformation and these normal faults do not penetrate to greater depths. These gravity induced movement along different blocks indicates that these rocks influence of gravity.Thetolanj faults extended upto the Paleocene age rocks. The overturn anticline moves go through the south-southestern part of the tolanj fault. The maximum dipping of the overturn anticlines ranges from 20-45°(Fig 4.6).

The cross section B-B′ contains Gandiali overturned Anticline, Tolanj Anticline, Tolanj Syncline and Tolanj Fault (Fig 4.7) This cross section passes through the following formations Murree, Kuldana, Kohat, Panoba and Alluviums.

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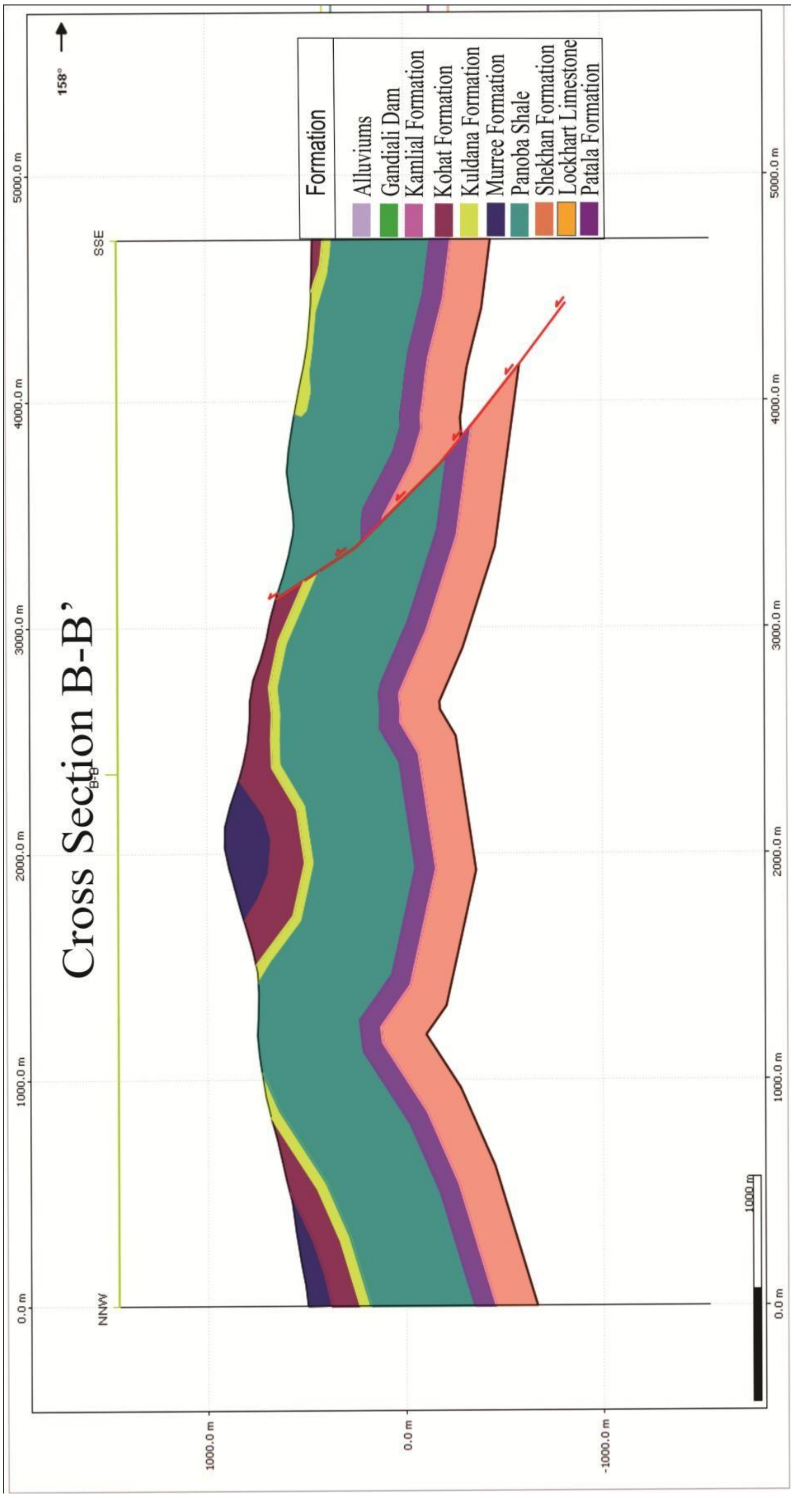

Figure 4.7 Showing Cross Section View of A-A′

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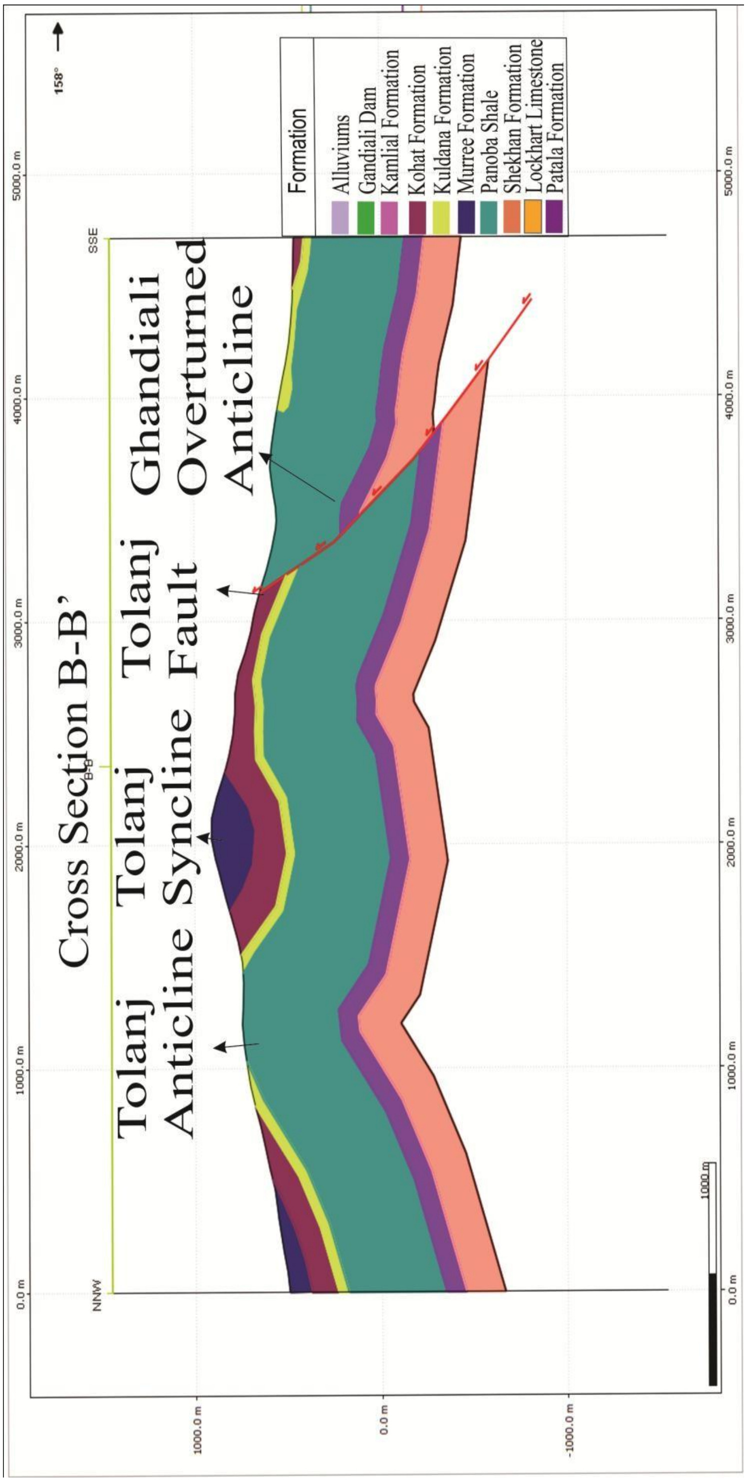

Figure 4.8 Showing Cross Section View of A-A' with Labeled Structure

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Ground Penetrating Radar

Introduction

GPR is a near surface geophysical method that uses radar pulses to image the subsurface zone. It is a non-invasive method of surveying the sub-surface to investigate underground utilities such as concrete, asphalt, metals, pipes, cables or masonry. This nondestructive method uses electromagnetic radiation in the microwave band (UHF/VHF frequencies) of the radio spectrum, and detects the reflected signals from subsurface structures. GPR has been used successfully too in constraining problems in diverse field such as archaeology, environmental site characterization, glaciology, hydrology, land mine/unexploded ordinance detection, sedimentology and structural geology,GPR can have applications in a variety of media, including rock, soil, ice, fresh water, pavements and structures. In the right conditions, practitioners can use GPR to detect subsurface objects, changes in material properties, and voids and cracks.

Applications

No digging, excavation or ground disturbance is necessary and is less expensive then others. It detects metals and non-metals objects as well as voids and underground irregularities.

GPR is used across many aspects of construction and engineering from utility locating to structural assessments. The testing methodology is fast and safe and efficient method for scanning. It is used to detect obstructions in concrete such as rebar, post tensional cables and conduits before cutting meaning that engineers can identify the best location and avoid damage it also provides a picture of what is below the earth's surface, it can play a valuable role in environmental studies. It is useful for locating buried drums of oil tanks which could leak and contaminate the earth and map the extent of contaminant and determine the direction of contamination.

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GPR is also used by the military as a tool for detecting unexploded items and detecting and mapping underground tunnels. It is often used in conjunction with other geophysical techniques along with GPS. It is widely using in structural geology to evaluate the subsurface geological structures i.e fold, fault etc.

Usage Method

GPR uses high-frequency (usually polarized) radio waves, usually in the range 10 MHz to 2.6 GHz. A GPR transmitter and antenna emits electromagnetic energy into the ground. When the energy encounters a buried object or a boundary between materials having different permittivity's, it may be reflected or refracted or scattered back to the surface. A receiving antenna can then record the variations in the return signal. The principals involved are similar to seismology, except GPR methods implement electromagnetic energy rather than acoustic energy, and energy may be reflected at boundaries where subsurface electrical properties change rather than subsurface mechanical properties as is the case with seismic energy.

The electrical conductivity of the ground, the transmitted center frequency, and the radiated power all may limit the effective depth range of GPR investigation. Increases in electrical conductivity attenuate the introduced electromagnetic wave, and thus the penetration depth decreases. Because of frequency-dependent attenuation mechanisms, higher frequencies do not penetrate as far as lower frequencies. However, higher frequencies may provide improved resolution. Thus operating frequency is always a trade-off between resolution and penetration. Optimal depth of subsurface penetration is achieved in ice where the depth of penetration can achieve several thousand meters (to bedrock in Greenland) at low GPR frequencies. Dry sandy soils or massive dry materials such as granite, limestone, and concrete tend to be resistive rather than conductive, and the depth of penetration could be up to 15 meters (49 ft.). However, in moist or clay-laden

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soils and materials with high electrical conductivity, penetration may be as little as a few centimeters.

Ground-penetrating radar antennas are generally in contact with the ground for the strongest signal strength; however, GPR air-launched antennas can be used above the ground. Cross borehole GPR has developed within the field of hydro geophysics to be a valuable means of assessing the presence and amount of soil water.

Explanation

GPR was used for determine the near surface geophysical method for investigation of the subsurface fracture analysis. The 400 MHz antennas was used at the top of Kohat formation, over 390 meter traverse was done and got the 5 feet depth data in which observed the three layers, 1st layer of soil 2nd of clay and third of bed rock limestone and observed the disturbance and fractures with in the Kohat limestone. During the field investigation the data was run by the RADON software for investigate the analysis of field evidence.

After collection the data it was observed that the zone is highly fractured and deformed. This subsurface deformational features marked that the Kohat fold and thrust belt have the blind roof thrust system due to which generates the geometries of anticlines and syncline series of detachments fold and ridges. In the GPR acquired data from 0 – 390 meters shows the different fractures and small scale thrust systems (Fig 5.1- 5.11).

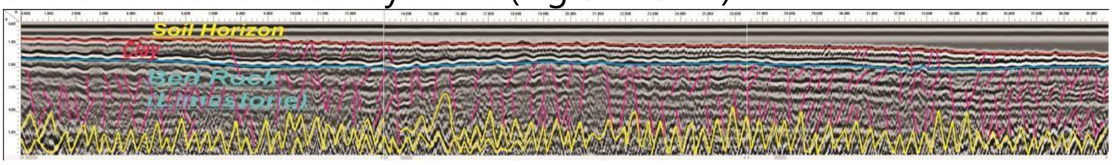

Figure 5.1 Showing GPR Data From 0 To 40 Meters With Depth of 5 Feet

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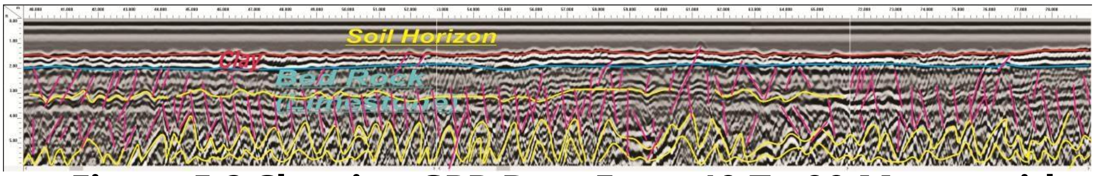

Figure 5.2 Showing GPR Data From 40 To 80 Meters with Depth of 5 Feet

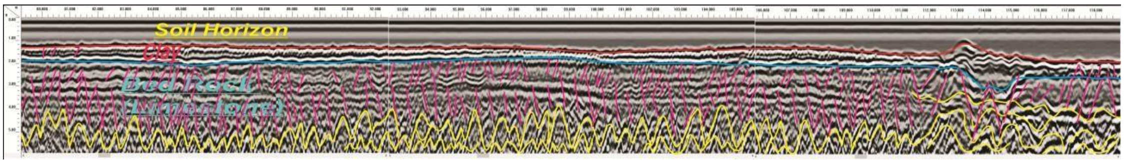

Figure 5.3 Showing GPR Data from 80 to 119 Meters with Depth of 5 Feet

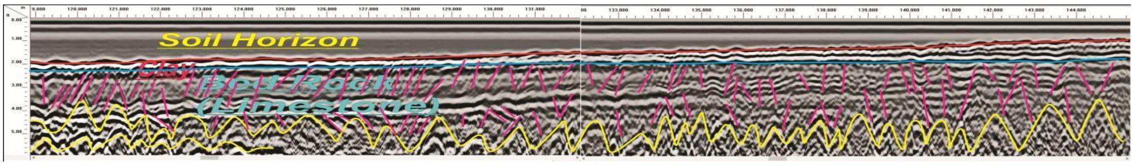

Figure 5.4 Showing GPR Data From 119 to 146 Meters with Depth of 5 Feet

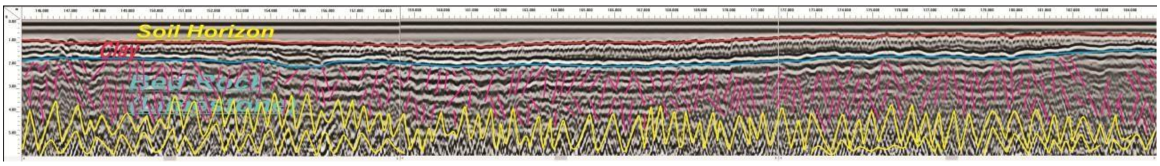

Figure 5.5 Showing GPR Data from 146 to 185 Meters with Depth of 5 Feet

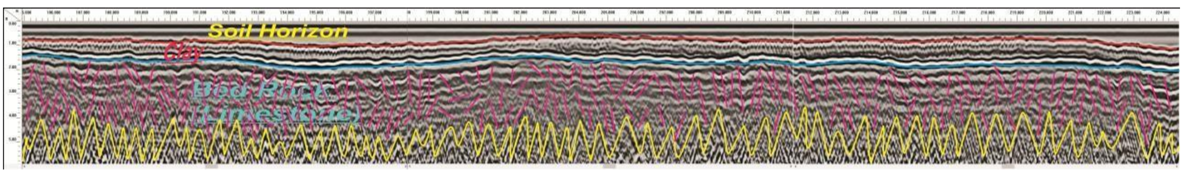

Figure 5.6 Showing GPR Data from 185 to 225 Meters with Depth of 5 Feet

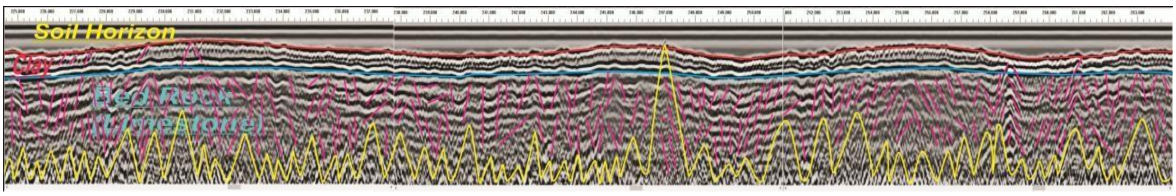

Figure 5.7 Showing GPR Data from 225 to 265 Meters with Depth of 5 Feet

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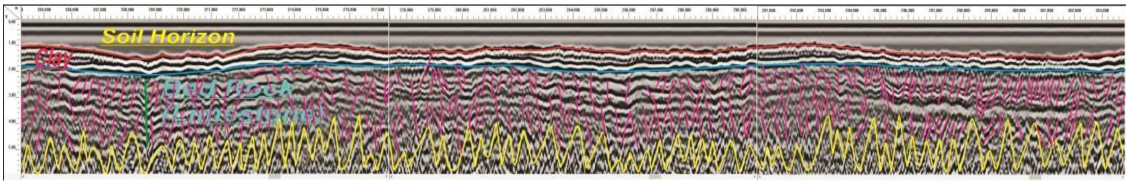

Figure 5.8 Showing GPR Data from 265 to 304 Meters with Depth of 5 Feet

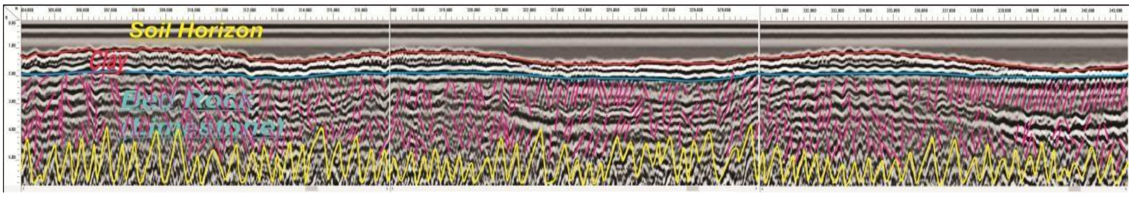

Figure 5.9 Showing GPR Data from 304 to 344 Meters with Depth of 5 Feet

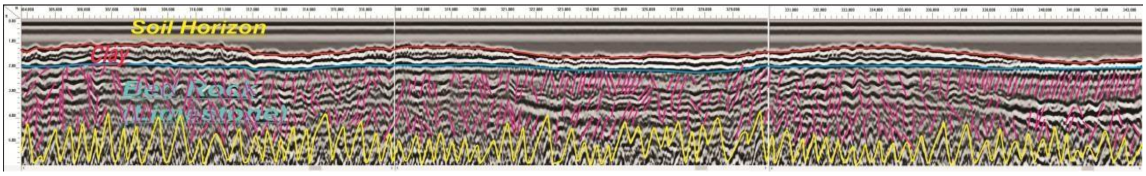

Figure 5.10 Showing GPR Data from 344 to 370 Meters with Depth of 5 Feet

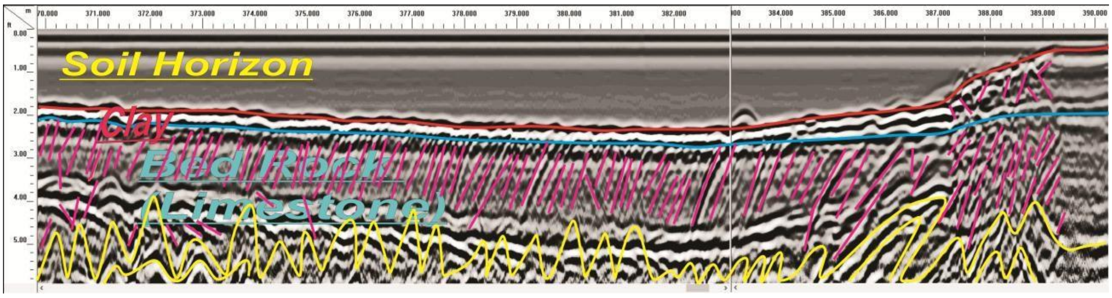

Figure 5.11 Showing GPR Data from 370 to 390 Meters with Depth of 5 Feet

Conclusion

The present study lead to the conclusion that the study area has undergone North-South compressional deformation. The normal fault present South of sumari payan Anticline suggest that after initial deformation gravity collapse of structurally elevated rocks were occur. From the above discussion it is proved that in the study area the deformation occur in two phases D1 and D2. D1 phase is responsible for North-South compressional deformation

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and D2 phase resulted in the gravity collapse of the structurally elevated rocks.

The trend of the geometries generated in the study area was trending towards East-West. The EW trending deformational histories shows the tight anticlinal, open synclinal Fold and the Thrust Faults system having NS vergence. This EW orientation of the structures suggest that initial deformation have experienced NS compressional stresses. In the study area, major structures present are:

- Shindand Anticline
- Tolanj Anticline
- ToghBala Anticline
- Gandiali Overturned Anticline
- Tolanj Syncline

Major Faults present in our area are:

i. Tolanj Fault
ii. Gandiali Fault

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