Structural Evolution of South Eastern Kohat Deciphered Through 3D Geoseismic Model, Shakardarra Area, KP Pakistan

By

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ABSTRACT

Geologically the Shakardarra area is evolved through multiple episodes of deformation. In the current research structural evolution of south eastern Kohat is deciphered and shown through 3D geoseismic model. The model is generated by integrating surface structural geological data and subsurface seismic reflection data. At the surface doubly plunging anticlines and synelines are truncated by thrust faults along their limbs. The tight anticlinal and broad synclinal folded structures evolved on evaporites as detachment folds which are later on truncated by thrust faults. In subsurface, stratigraphic packages are marked on seismic sections based on regional stratigraphic studies and dominant reflections. The seismic sections show that the thrust faults emanate from basal detachment located at sedimentary crystalline interface cutting upsection to surface or lose their displacement by originating back thrusts. The cross section shows that these back thrusts are emanating from forethrusts at much shallower depths as compared to fore thrust. At surface the Shakardarra fault Tolabangi fault, Chorlaki fault and axial trend of fold change their strike from EW te NS which narrate that thrusts and axial trend of folds are rotated along vertical axis b influence of Kalabagh strike slip fault. The current research suggests that Shakardarr is sequentially evolved in three episodes of deformation. In the first phase detachmen folds are on Eocene evaporites which are truncated by thrust faults emnating fro basal detachment in the second phase. In the third phase early formed folds and faul are rotated along vertical axis by the influence of Kalabagh strike slip fault.

CHAPTER– 1
INTRODUCTION

1.1 General information

The Kohat Fold and Thrust Belt (KFTB) is an integral part of the Himalayan Fold and Thrust System located in the Sub Himalayas. The KFTB extends from Main Boundary Thrust (MBT) in the north (Sarwar et al., 1979; Yeats et al., 1984; Coward et al., 1985) to Surghar range in the south (Ahmed et al., 1999). It is separated from its eastern counterpart Potwar Fold and Thrust Belt (PFTB) by Indus River and its western boundary is marked by the Kurram Fault (Kazmi and Rana, 1982). The KFTB and PFTB in their evolution are genetically related to Himalayan induced deformation (Ahmed, 1995; Ali, 1995; McDougal and Hussain, 1991; Abbasi and McElroy, 1991) in general and transpressional tectonics (Pivnik and Sercombe.,1994) in particular. However, Structural complexity is more pronounced in KFTB and the difference in structural style is attributed to the nature of decollment at base and secondary levels and role of strike slip faulting (Ahmed, 1995; Ahmed 2003; Ali, 1995; Dougal and Hussain, 1991; Abbasi and McElroy, 1991 Pivnik and Sercombe, Chen and Khan, 2010 Khan et al, 2012). In the north of Shakardarra east-west trending structures change their orientation to north–south. The previous models (Abbasi., 1991, McDougall and Hussain., 1991) showed the lateral ramp in the subsurface causing the surface structures to change their orientation across it. Recent published work of (Khan et al., 2012) on the nature and kinematics of Kalabagh fault shows its active nature and its presence as a lateral ramp in the northern part. The previous models developed had not taken the role of strike slip faulting in the deformational history as its presence in the near vicinity with still active nature cannot be avoided. The exposed structures at Shakardarradonot comply completely to the concept of lateral ramp. As the west vergence of thrust at the Hukni and continuation of these structures in north of Shakardarra with east-west trend are raising questions about the sole presence of lateral ramps in subsurface effecting the structures above.

Previous work was unable to address the below mentioned issues that’s why the current research is conducted to get a better understanding of the following:

(1) The presence of pop up zones and back thrusts in subsurface totally with the concept of thrust tectonics.

(2) West vergence of thrusts across previously shown lateral ramp, ideally it should be east vergent according to the theoretical concepts of lateral ramps.

(3) To what extent the secondary decollment surface in Eocene at KFTB had influenced the structural development?

(4) 3D model of faults and folds to show their extent of development and compatibility with other structures.

(5) The role of strike slip fault in overprinting the structural geology of the area.

(6) The previous models due to their limited approach are unable to show deformational setup of structures related to different origins in their evolution.

The current research is designed to address the above said issues and to present the advance geological model of the area with integrated approach of Geology and Geophysics. Shakardarra and surrounding areas are selected to conduct this research. The research for its selection is that: it is present on the between KFTB and PFTB with active Kalabagh strike slip present in south of it figure 1.1. All geological formations exposed in the KFTB are present in the hanging wall sequence of thrust faults. Shakardarra is developed as an oil field in the recent past so abundant well bore and seismic data is also available (Published and unpublished). The area is deformed multiply through thrust and strike slip related deformation on multi detachment horizons giving a unique experience of working on different deformation mechanisms at the same place.

1.2 Study area

The current research is carried out in Shakardarra (study area) located in south eastern part of KFTB. The study area is 70 km in southeast of Kohat city and is located between longitudes 71^0 26 E to 71^0 33 E and Latitude 33^0 09 N to 33^0 17 N.

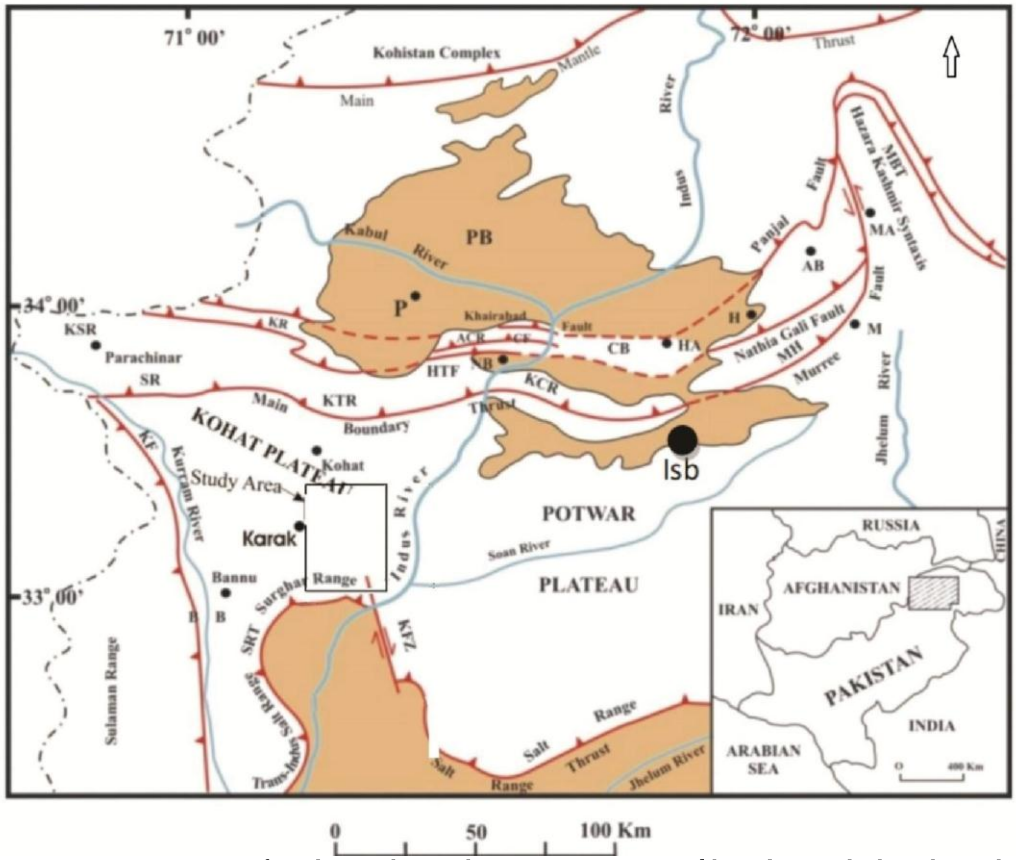

Figure 1.1. Tectonic map of northern Pakistan showing major structural boundaries. The box shows the location of the project area (Hylland et al., 1988).

1.3 Previous work

Researchers have shown a keen interest in the Kohat fold and thrust belt. Burnes in 1832 was the first to report the occurrence of salt in this area. The geological mapping was done by Meisnner et al in 1974. Different rock units and formations were interpreted by them and they carry out detail structural and stratigraphic work. A balanced cross section was prepared by the McDougall and Hussain across the KFTB from the main boundary thrust to Surghar range thrust by the help of seismic data shown in figure 1.2. According to them fault bend folds associated with the blind thrust are present in Kohat fold and thrust belt with flat fold crests that conform with the underlying flat thrust. Ductile deformation and distortion with kink geometries is evident at the surface in the Kohat plateau.

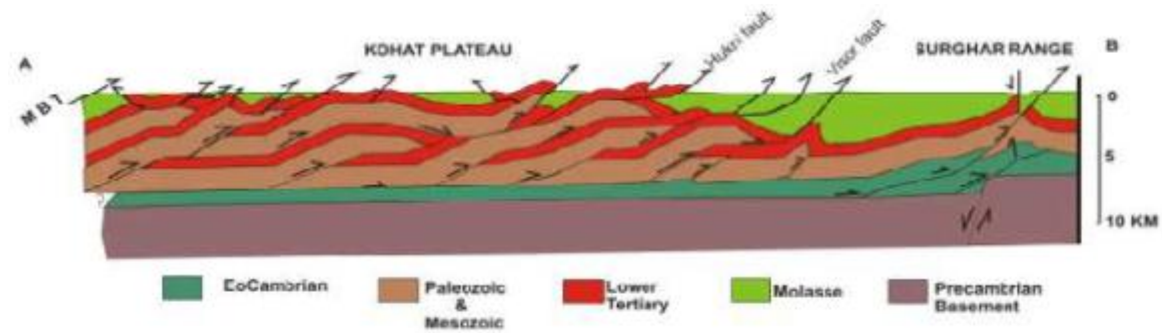

Figure1.2. Cross section AB/ extends from MBT near Kohat city to the eastern Surghar range near Kalabagh (McDougall and Hussain, 1998).

According to Abassi and McElory (1991), Kohat has a distinct passive roof duplex geometry, formed of thrust slices of pre-Tertiary stratigraphy shown in Figure 1.3. There is a blind thrust between the MBT and Shakardarra. They also concluded that the Hukni lateral ramp overlies the branch point between the two levels of detachment of the Kohat and the single basal level underneath the Potwar. The amount of shortening across both portions of the compartmentalized thrust belt is similar, despite the distinct geometries. Kinematic compatibility across the Hukni lateral ramp results from greater elevation of a narrower thrust wedge to the west (Kohat plateau), and a wider thrust belt of lower structural relief to the east.

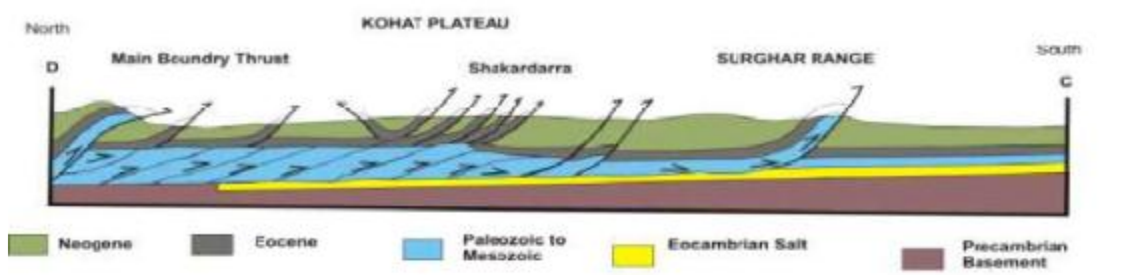

Figure1.3. Balanced cross section across Shakardarra Kohat showing deformation on multiple detachment horizon (Abbasi, 1991).

Pivnik and Sercombe (1993), Sercombe et al. (1994) and Sercombe et al. (1998) suggested transpression related wrench fault that is responsible for the structures exposed at surface and subsurface. According to Ahmad (2005) this area is thin skinned deformed fold and thrust belt assemblages superimposed by thick skinned structures. The major part of the plateau is dominated by compressional structures; however strike-slip faulting is confined to southern kohat plateau.

1.4 Objectives

(1) To prepare a 3 dimensional integrated Geoseismic model of the area and working out the genetic relationship between the structures at surface and subsurface.

(2) To work out the structural evolution of the area in relation to fold and thrust kinematics.

(3) To work out the role of active strike slip faulting in reshaping the structures at surface and subsurface.

(4) To work out the nature of previously documented lateral ramps and their role in structural evolution of the area.

(5) To workout the future petroleum prospects of the area.

1.5 Methodology

(i) Revised geological mapping of area at RF 1:50,000 by integrating published maps, Google earth imagery and field data.

(ii) Seismic sections of line 865-NK-02, 05,08,11,15 967-SHD-317,318,319 and Well log data of Chanda deep-01 and Chanda 2 are used for interpretation, depth to basement calculation. Figure 1.4 showing the Base map of the study area.

(iii) Preparation of deformed geoseismic balanced cross section by integrating surface geological data, seismic and well bore data in 2D move.

(iv) Preparation of 3D model in 3D move by integrating 2d balanced cross sections, generating surfaces, ramps and fault planes to show the 3D structural geometries at surface and subsurface.

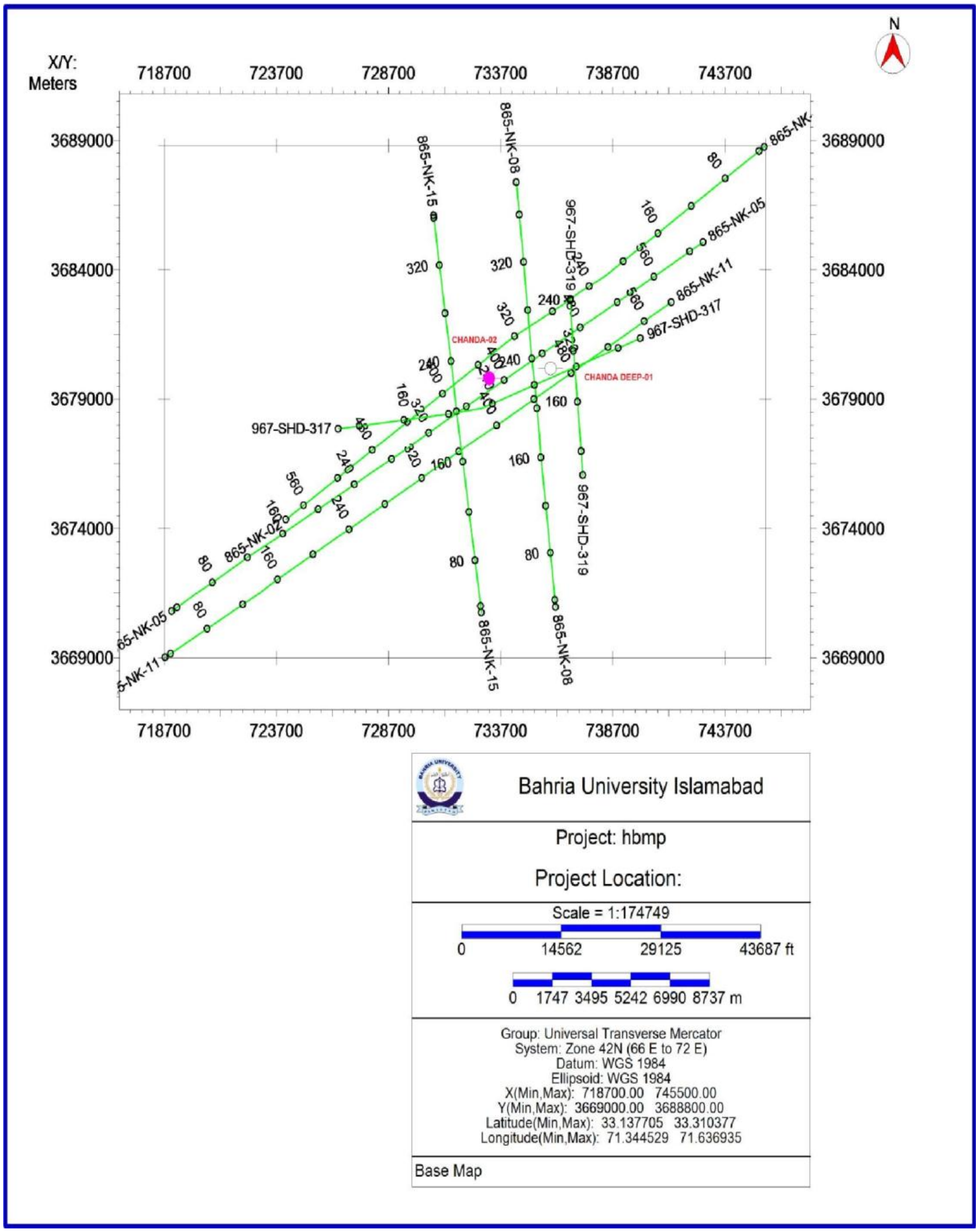

Figure 1.4. Base map of the study area.

CHAPTER 2

TECTONIC SETTINGS

2.1. Regional tectonics

In the southern hemisphere, the Pangea was assembled nearly 225Ma ago surrounded by Panthalassa ocean. But nearly 200Ma ago it broke into two parts one was northern part known as Laurasia and the other southern part Known as Gondwana land. At about 130Ma ago the Indian plate separated from Australia at rate of 35-45mm/y and 90 Ma ago Madagascar which resulted in the increasing of speeding rate (150-170mm/y). 70 million years ago in the age of upper cretaceous the Indian plate moving at the rate of 15 cm/y collided with Eurasian plate. Gnos et al (1996) shown that intra oceanic subduction which was initiated between 70-65Ma. The final trusting ended in Eocene and the Tethys Ocean was closed in 50 Ma Shown in Figure 2.1.

Due to the Indian –Eurasian collision the world's youngest orogenic belt came into being which is extended from Nepal (East) to Pakistan (west) known as Himalaya (Kazmi and Jan, 1997). Oroclinal trend of Himalaya changes from places to places that is it is NW-SE in Indian, EW in Pakistan and become NS along western border of Pakistan.

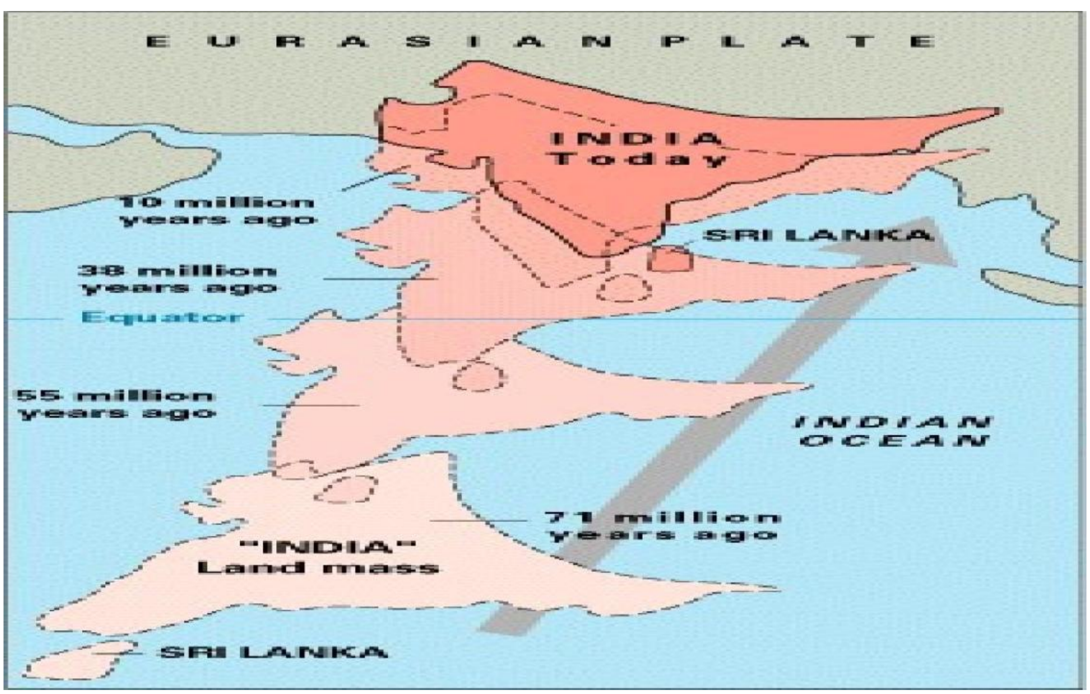

Figure 2.1. Geodynamics of Indian plate before its collision with Eurasian plate (USGS 1998).

2.2. Himalayan thrust system and tectonic terrains in Pakistan

In the Cenozoic era the most significant event was the collision of Indian and Eurasian plate and the closure of Neo-Tethys. The orogeny of Himalaya was not continuous but it was occurring in phases of total period of about 50 Ma and multiple episodes of uplift, deformation, metamorphism and magmatism was involved in it (Kazmi and Jan, 1997). Himalayan thrust system is bordering major tectonic terrain which is explained as follows.

2.2.1 Karakorum block

This block is composed of metasedimentary, sedimentary and igneous rocks between Pamirs and KohistanLadakh arc. Main Karakorum Thrust (MKT) represents the collision of the Karakorum block and the Kohistan Ladakh Arc in the Cretaceous time (Treloar et al., 1989; Tahirkheli, 1979). The southern Pamir fault separate the Karakorum blocks from Pamir block shown in figure 2.2 (Desio, 1979).

2.2.2 Kohistan-Ladakh island arc

Kohistan-Ladakh island arc was formed 130 Ma ago due to the intra oceanic subduction in Neo-Tethys during the age of Cretaceous (Searle 1991; Treloar and Izzat, 1993). This EW oriented arc is composed of subordinate sedimentary and plutonic rocks which have undergone a varying degree of metamorphism and deformation.

2.2.3 Main Mantle Thrust (MMT)

In the Eocene age along the Main Mantle Thrust the Indian plate collided with the Kohistan island arc (Tahirkheli, 1979). The major uplift occurred between 30-15 Ma and there was obduction along MMT of Kohistan island arc (Tahirkheli et al., 1979; Zeitler et al., 1985). MMT lies to the north of the Northern deformed Fold and Thrust belt.

2.2.4 Northern deformed fold and thrust belt (NDFTB)

Northern deformed fold and thrust belt (NDFTB) is 300 km wide lying in the south of the MMT. This Fold and Thrust belt is mainly composed of deformed metasedimentary, sedimentary and igneous rocks extending from kurram area in the west upto Kashmir basin in the east. It is separated from the southern deformed fold and thrust belt lying to its south by Main boundary thrust (MBT) Shown in figure 2.2.

2.2.5 Main boundary thrust (MBT)

The MBT is representing southward migration from MMT of Himalaya deformation. NW Himalayas are divided into hinterlands and foreland due to the presence of parallel thrust faults in the MBT zone (DiPietro et al., 1996; Pivnik and Wells, 1996). Hazara Kashimir syntaxis is formed by the MBT because it is trending EW along the foreland basin but in the west of Jhelum River it forms a major bend forming the Hazara Kashmir Syntaxis Shown in Figure 2.2.

2.2.6 Potwar fold and thrust belt

PTFB is covered by the molasses deposit which resulted due to Himalayan orogeny and PFTB is E-W oriented. It is less deformed. Its northern boundary is marked by the Margalla ranges and southern boundary is marked by the Salt range Thrust (SRT). Most of the deformation in this zone has occurred in the northern part of the zone which is known as Northern Potwar Deformed zone (NPDZ) (Leather, 1987; Baker et al., 1988).

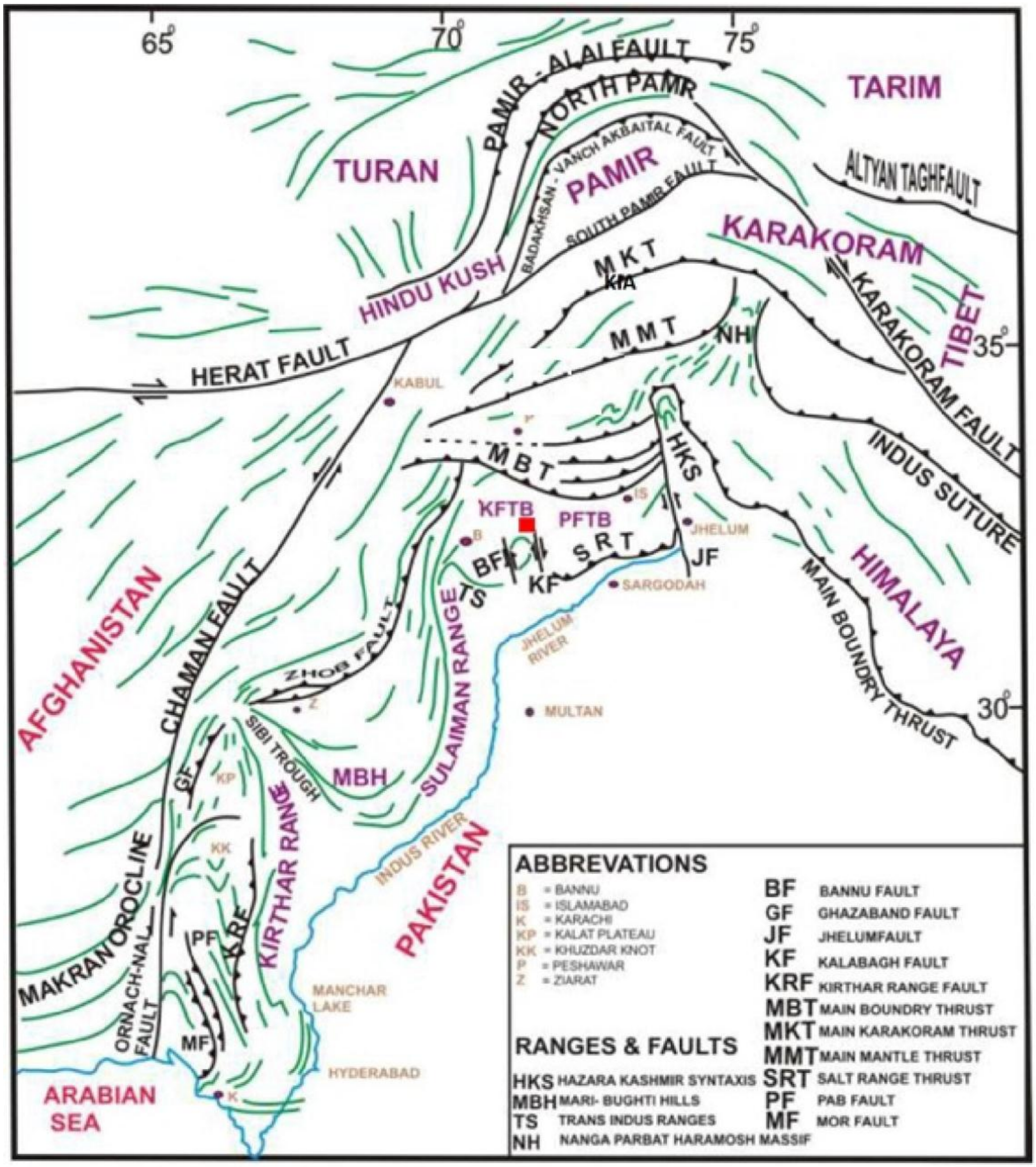

Figure 2.2. Map Showing location and Tectonic trends on and around North-West of Pakistan (modified after Sarwar and Dejong 1979),(Red box shows the study area).

2.2.7 Kohat fold and thrust belt

Kohat plateau is mostly comprised of Eocene and younger sedimentary rocks and is located in the west of Potwar fold and thrust belt. There are evaporates in the southern part of the plateau. In the northern region there are several thrust faults, synclinal folds and overturned folds. Low angle thrust faults are folded which are forming klippen. Evaporate sequence is missing or reduced in the northern part. Panoba shales are present in the cores.

There is E-W trending folds and reverse faults which are north and south dipping in the Kohat plateau zone. Most of the faults are fault propagation folds. The Eocene sequence present in the Kohat plateau is 300-500m thick. There are evaporates sequence in the central part of the Kohat plateau.

The structures in the Shakardarra have an E-W orientation but it abruptly change direction E-W to N-S. Hukni fault which is a large thrust fault is present in this area.

CHAPTER 3

STRATIGRAPHY

3.1 General statement

In the south eastern part of Kohat fold and thrust belt, Eocene to Pliocene stratigraphy is exposed. These units fall within Cherat, Rawalpindi and Siwalik group. The sub surface stratigraphy is explained with the help of Chanda deep-01 well. The oldest formation drilled in this well is Wargal Formation is of Permian age. The oldest formation which is exposed in this area is Jatta Gypsum. The detailed stratigraphy is explained below and shown in figure 3.1.

3.2 General statigraphy of the area

(1) DhokPathan Formation

Age: Pliocene

Lithology: DhokPathan consists of alterations of sandstones and clay beds. Sandstone is gleaming white or reddish brown, soft and cross bedded. Clay is brown and orange. (Kazmi and Jan, 1997)

Environment: Deltaic

Contact: The lower contact with the Nagri Formation is transitional.

(2) Nagri Formation

Age: Miocene

Lithology: Nagri Formation consists of sandstone with alternations of clay/claystone and traces of siltstone. Claystone is light greenish grey loose friable at places moderately hard. Siltstone is reddish brown firm and at places grading to very fine grained sandstone and slightly calcareous.

Environment: Fluvial, Deltaic

Contact: The contact with underlying Chinji Formation is conformable.

(3) Chinji Formation

Age: Miocene

Lithology: Chinji Formation consists of claystone with interclations and alterations of sandstones and traces of siltstones. Claystone is reddish brown yellowish grey soft and at some places firm partly silty and calcareous. Sandstone is light greenish grey friable loose and poorly cemented. (Kazmi and Jan, 1997)

Environment: Fluvial, Deltaic

Contact: The lower contact with Kamlial is conformable.

(4) Kamlial Formation

Age: Miocene

Lithology: It can be divided into two parts one in which clay/claystone with intercalations of sandstone is present and other in which sandstone with streaks of clay/claystone is present. Claystone is dark brown, brown at places silty and sandy, calcareous. Sandstone is dirty white, light grey very fine to fine grained.

Environment: Marine

Contact: Both contacts are conformable.

(5) Muree Formation

Age: Miocene

Lithology: Claystone is reddish brown, brick red sandy and calcareous with alternations of sandstone which is fine to medium grained and calcareous.

Environment: Fluvial

Contact: The lower contact with Kohat Formation is unconformable.

(6) Kohat Formation

Age: Middle Eocene

Lithology: Kohat Formation consists of limestone with streaks of claystone. Limestone is brownish grey, medium hard crystalline, argillaceous and dolomitic whereas clay stone is dark brown, reddish brown soft to medium hard and at places blocky, crystalline.

Environment: Shallow marine

Contact: Lower contact with Kuldana Formation is conformable.

(7) Kuldana Formation

Age: Middle Eocene

Lithology: Kuldana Formation consists of anhydrite/gypsum with streaks of clay/claystone. Gypsum id dirty white, medium hard, at places soft, at places granular. Claystone is white to dirty white, at places reddish brown, soft to firm and occasionally calcareous.

Environment: Coastal plain, tidal flat, lagoonal

Contact: Lower contact with underlying Jatta Formation is conformable.

(8) Jatta gypsum

Age: Early Eocene

Lithology: Jatta Formation comprises of anhydrite/gypsum with intercalations of clay/claystone. Gypsum is off white medium hard, and granular. Claystone is white, off white, soft to firm and slightly calcareous. (Kazmi and Jan, 1997)

Environment: Lagoonal

Contact: The contact with the underlying formation is disconformable.

(9) Patala Formation

Age: Paleocene

Lithology: Patala Formation dominantly comprises of shale with intercalations of marl and traces of limestone. Shale is grey to dark grey, black, soft to medium hard. Marl is grey, off white and soft to firm. Limestone is brownish grey, at places medium hard, dense, compact and occasionally crystalline.

Environment: Shallow marine

Contact: The lower contact with Lockhart limestone is conformable.

(10) Lockhart Formation

Age: Paleocene

Lithology: Lockhart Formation dominantly comprises of limestone with streaks of marl and thin bands of shale. Limestone is light grey, grey, off white brittle and dense. Marl is off white, grey, soft to firm, occasionally grading to argillaceous limestone.

Environment: Shallow marine

Contact: The lower contact with Hangu Formation is conformable.

(11) Hangu Formation

Age: Paleocene

Lithology: Hangu Formation comprises of sandstone with thin bands of shale. Sandstone is white, translucent, grey, and glassy; fine to coarse grained and poorly sorted. Shale is grey, dark grey, black, soft to medium hard, silt and sandy.

Environment: Shallow marine

Contact: Lower contact with lumshiwal Formation is unconformable.

(12) Lumshiwal Formation

Age: Cretaceous

Lithology: Lumshiwal Formation comprises of sandstone with traces of shale. Sandstone is grey, light grey, at places dark grey, medium hard, compact and moderately sorted. Shale is greenish grey to grey, medium hard, sub fissile and slightly calcareous.

Environment: very shallow marine to non-marine, deltaic

Contact: The lower contact with Chichali formation is transitional.

(13) Chichali Formation

Age: Cretaceous

Lithology: Chichali Formation comprises of shale with traces of sandstone. Shale is dark green, dark grey, soft to medium hard, sub fissile to fissile and at places sandy and silty. Sandstone is light green, green, dark grey, medium hard to hard, fine to medium grained, sorted and cemented.

Environment: Shallow marine

Contact: The lower contact with SamanaSuk Formation is disconformable.

(14) Samanasuk Formation

Age: Jurassic

Lithology: Samana Suk Formation is composed of grey, medium to thick bedded dolomitic limestone with inter bedded calcareous shale and marl.

Environment: Marine

Contact: The lower contact with Shinawari Formation is transitional.

(15) Shinawari Formation

Age: Jurassic

Lithology: Shinawari Formation consists of variegated lithologies having interbeds of shale, sandstone, clay/claystone, marl and limestone. Shale is grey, at places dark greenish grey, soft to medium hard and sub fissile to fissile. Sandstone is hard abrasive, very fine to medium grained and fairly sorted. Limestone is creamish whit, brownish grey, hard and dolomitic.

Environment: Shallow marine to continental

Contact: The lower contact with data formation is transitional.

(16) Data Formation

Age: Jurassic

Lithology: Datta Formation consists of sandstone with intercalations of shale and traces of clay/claystone. Sandstone penetrated in the formation is white, translucent to transparent, at places reddish brown and maroon, hard to medium hard, abrasive and moderately cemented. Shale is grey, dark grey, at places reddish brown and brick red laminated and non-calcareous.

Environment: Continental

Contact: Lower contact with Kingriali Formation is disconformable.

(17) Kingriali Formation

Age: Triassic

Lithology: Kingriali Formation consists of dolomite with streaks of shale. Dolomite is light grey to grey, hard, dense and brittle. Shale is olive grey, soft to medium hard, sub fissile to fissile and laminated. (Kazmi and Jan, 1997)

Environment: Shallow marine

Contact: Lower contact with Tredian Formation is transitional.

(18) Tredian Formation

Age: Triassic

Lithology: Tredian Formation consists of sandstone with thin bands of shale and thin bands of dolomite. Shale is ash grey, dark grey, transparent to translucent, medium hard, friable, moderately sorted and poorly cemented. Dolomite is light grey to dark grey, hard, dense, brittle and argillaceous.

Environment: Non Marine

Contact: The lower contact with Mianwali Formation is sharp and conformable.

(19) Mianwali Formation

Age: Triassic

Lithology: Mianwali formation consists of shale with intercalations of limestone, thin bands of sandstone and traces of dolomite. Shale is ash grey, dark grey, soft to medium hard, sub fissile to fissile, laminated sandy and silty, at places non calcareous.

Environment: Non marine

Contact: Lower contact with Chiddru Formation is marked by paraconformity.

(20) Chiddru Formation

Age: Permian

Lithology: Chiddru Formation consists of sandstone with alternations of shale and streaks of limestone. Sandstone is white, dirty white, medium hard, fine to very fine grained, grading to siltstone fairly sorted, moderately cemented. Shale is grey, light grey, slightly calcareous. Limestone is white, creamish white, medium hard, fairly argillaceous, at places marly.

Environment: Shallow marine

Contact: The lower contact with Wargal Formation is transitional.

(21) Wargal Formation

Age: Permian

Lithology: Wargal Formation consists of limestone with thin bands of sandstone and shale. Limestone is brown to pale, yellowish brown, medium hard to hard, dense, and compact. Sandstone is white, whitish grey, medium hard, fine grained, well sorted, and moderately cemented. Shale is grey to dark grey, soft to firm and highly calcareous.

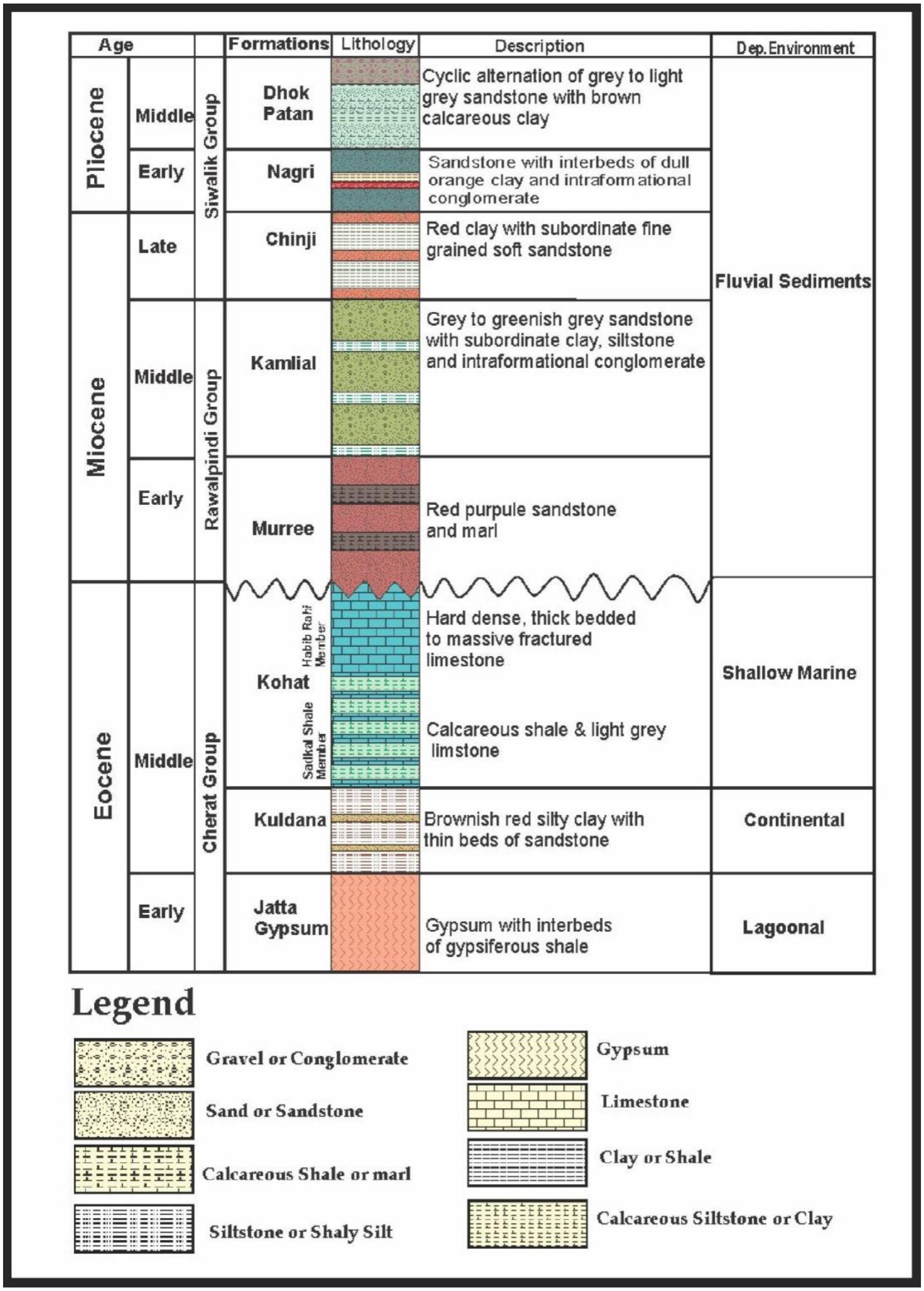

Figure 3.1. Stratigraphic column of the study area based on the well bore data (Meisner, 1974).

CHAPTER 4

STRUCTURAL GEOLOGY AND SEISMIC INTERPRETATION

The structural geology of the research area is comprised of outcropping thrust faults and folds. The general trend of the structures in the area is ENE-WNW. Fault bounded plunging anticlines and broader synclines are present at the surface and can be observed on Google earth imaginary. A lot of tight anticlines and broader synclines are present at the subsurface prominent by the help of field observations and Google earth imaginary. Therefore a revised geological map was prepared in the area at 1:50,000 in coral draw using the previous geological maps, field mapping and Google earth imaginary. The map scale deformational structures present in the area are explained below.

4.1. Faults and folds

Dartappi fault is present in the northern part of the study area. The strike of fault is ENE-WSW. From East to West the fault is thrusting Eocene Jattagypsum over Chinji Formation in the foot wall. In the western part the fault trace at surface is covered by alluvium. The average dip of fault is 40^0-45^0N.A Karrapa fault with ENE-WSW orientation is thrusting the Eocene rocks over Kamlial Formation lying in the footwall of the fault.In the north west of the study area a back thrust is presenting North of the Karrapa fault, which is thrusting Eocene rocks northward over the Kamlial Formation in footwall. E-W orientated Nandrakki fault is present in the northern thrusting. A double plunging anticline is present in the hanging wall of Nandrakki fault. The southern limb is of double plunging fold is truncated by Nandrakki fault. The Braghzaibanda fault is present in the Central part of the study area. It is a high angle thrust fault cropping out on the surface. The orientation is ENE_WSW. It is thrusting the Eocene rock which is lying on the hanging wall of the fault over the Chingi Formation lying in the foot wall. To the west of the fault an anticline is present containing Kamlial Formation in the core and Chingi Formation at the limbs. Shakradarra fault is present in the central part of the study area. The strike of fault is EW and changes to NS near the Hukni village. The fault is thrusting the Eocene rocks on the Nagri Formation to the east of area. In the centralpart of the study area this fault is thrusting the Kamlial Formation over the Chinji Formation located in its foot wall and towards west the fault is thrusting the Eocene over Kamlial located in its foot wall. A syncline is present in the hanging wall of the fault which is comprised of the Kamlial Formation in core and Eocene in the limbs**.**Bab-e-Shakradarra fault (BSF)andNarribanda fault (NBF)are thrusting Eocene Jatta gypsum over the Kamlial Formation in the footwalls. BSF and NBF are the splay faults originate in North from Shakardarra Fault (SF). Right lateral strike slip fault is present in the southern part of study area shown in figure 4.1.Steeply dipping Nagri formation is present on both sides of fault surface trace. Tola Bangikhail(TBKF) Faults is thrusting Nagri Formation in hanging wall over the Dhokpathan Formation in the footwall. The strike of fault is EW in western portion and changes to NW-SE in the eastern part. A right lateral Kalabagh fault is also present in the SE of the study area.

Banda lakhoni syncline (BLS) is a double plunging open synclinal structure plunging towards its core. It contains Nagri Formation in the core while southern limb is transected by the TBKF. Tangaibanda syncline (TBS) contains DhokPathan Formation in the core and Nagri Formation at limbs is exposed in the north eastern part of study area. It is plunging towards its core and surface axial trace of syncline is NE-SW. Ziaratbanda syncline contains DhokPathan formation in the core whereas on the south limbs Nagri Formation that is Nagri Formation is present.

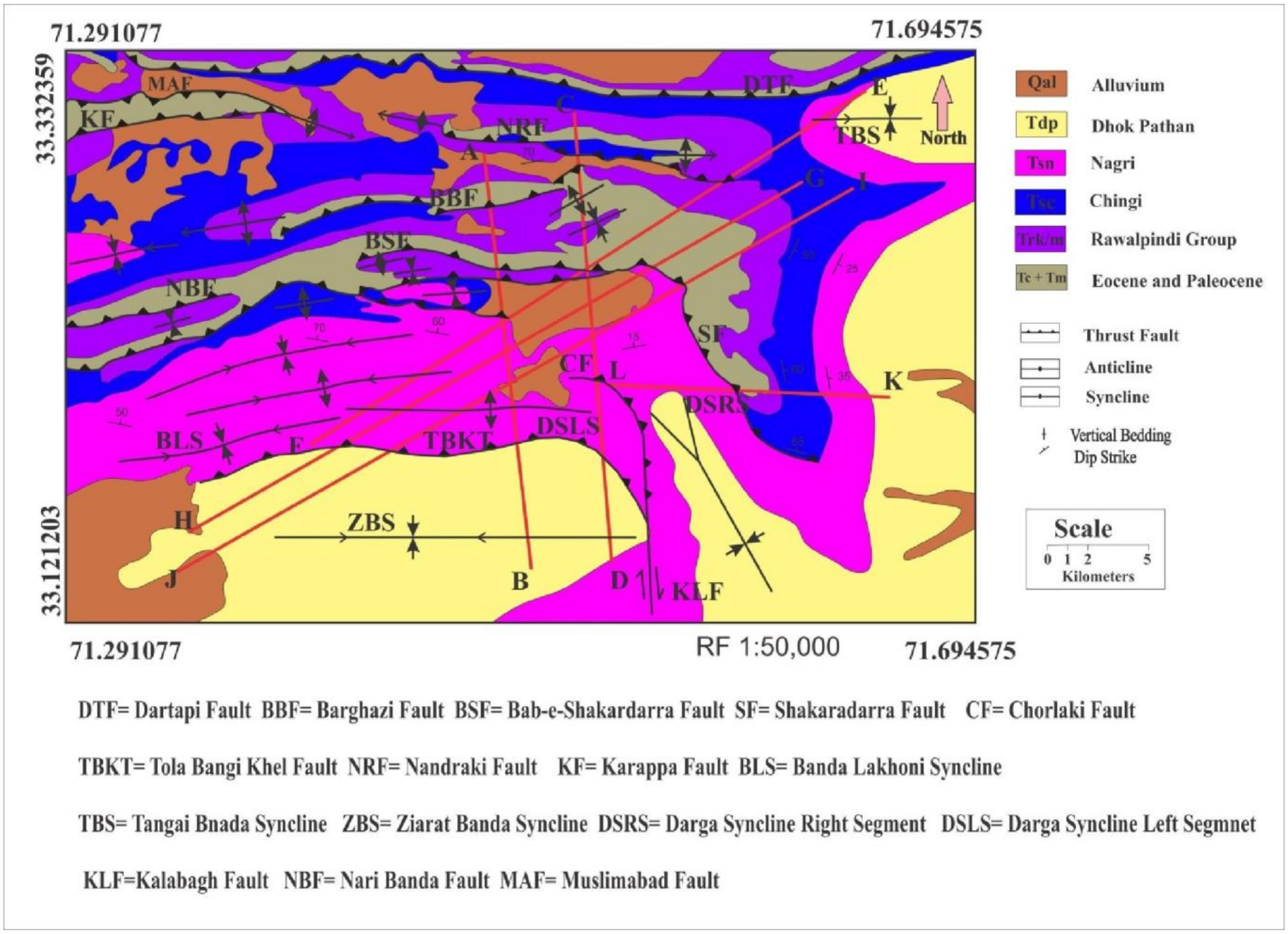

Figure 4.1. Geological map of the study area.

4.2. Seismic interpretation

The seismic lines are interpreted by solving the velocity windows panels to obtain the average velocity so that depth and time of the required package can be obtained. Petrophysika was used for this process. Strike line was first interpreted so that it can be used as a reference to interpret other lines. As wells were not present on the lines and were almost lying on equal distance from every line so one of the strike line was interpreted. Generally Eocene, Paleocene, Jurassic, Triassic and Permian Tops reflectors were marked. Basement was marked on 10 km by its presence as a prominent reflector on some seismic lines. It is also evident from previous research work as well.Some outcropping faults are correlated to seismic shot point locations. The cross sections are prepared manually by interpolation the surface geological data (contacts and orientations) and subsurface depth domain data of reflectors. The manually prepared reflectors are redrawn on 2D move software to maintain the accuracy for thickness of each horizon. Cross sections are later imported to Move for 3D model generation.

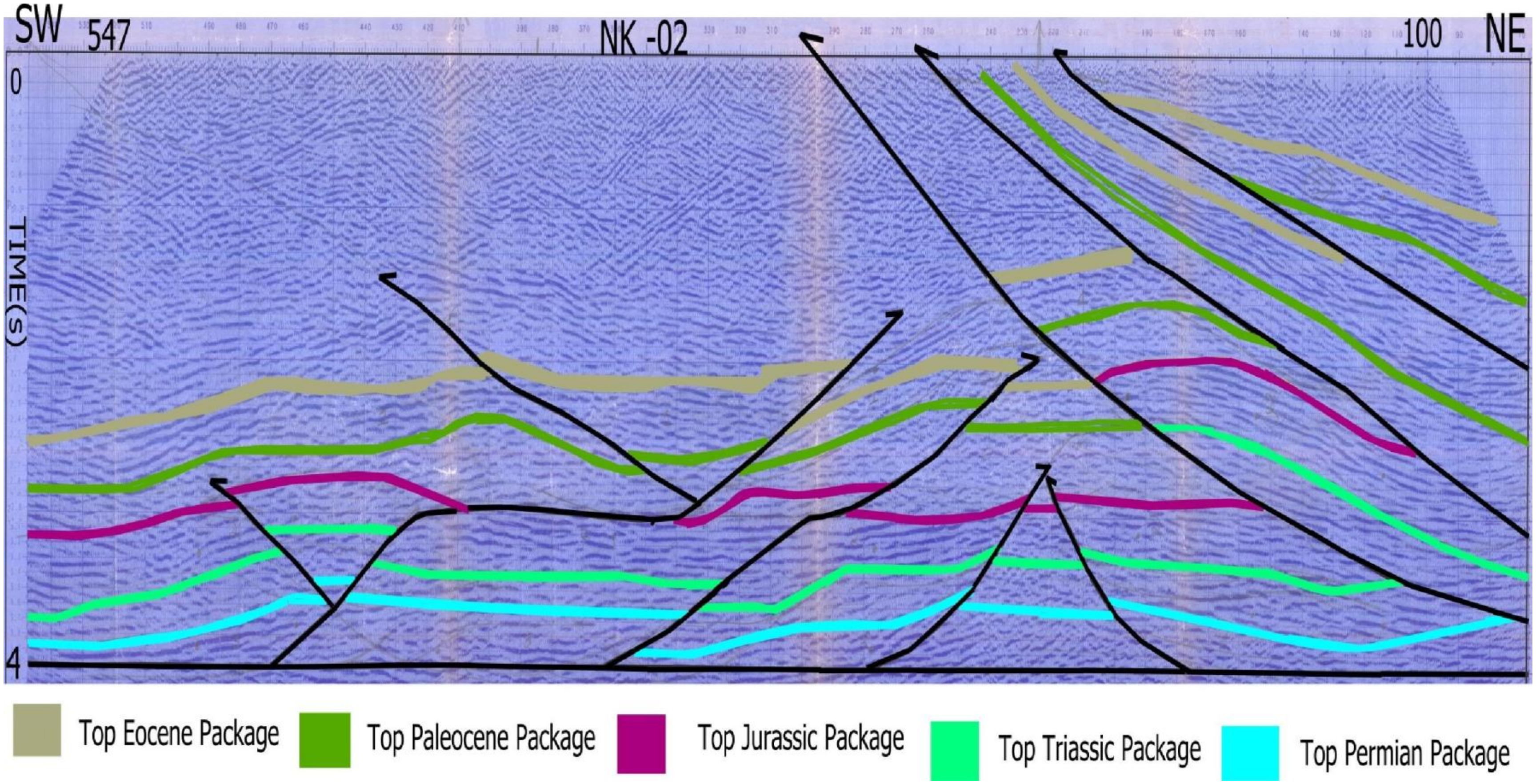

Figure 4.2. Interpreted seismic line NK 02.

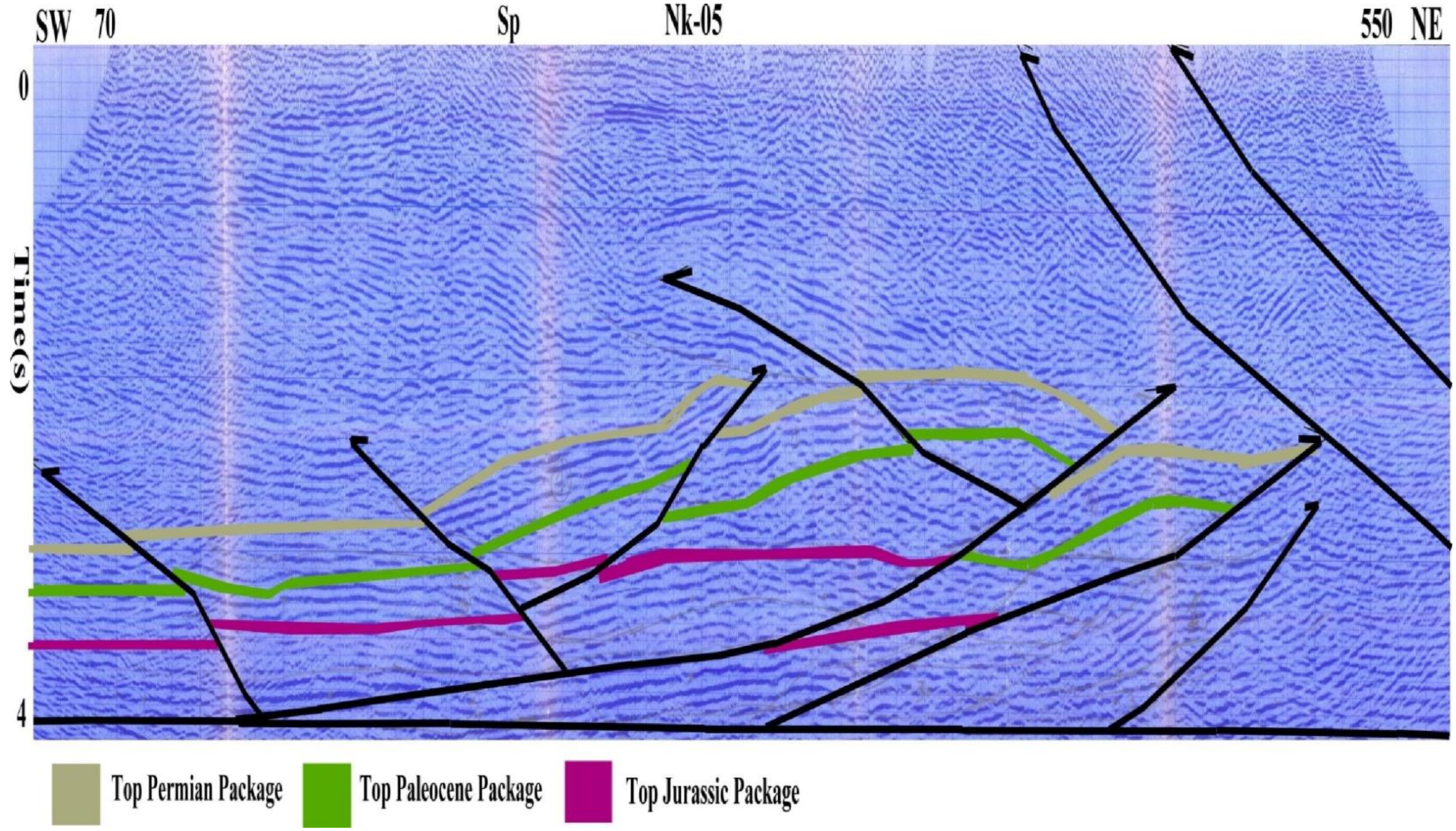

Figure 4.3. Interpreted seismic line NK 05.

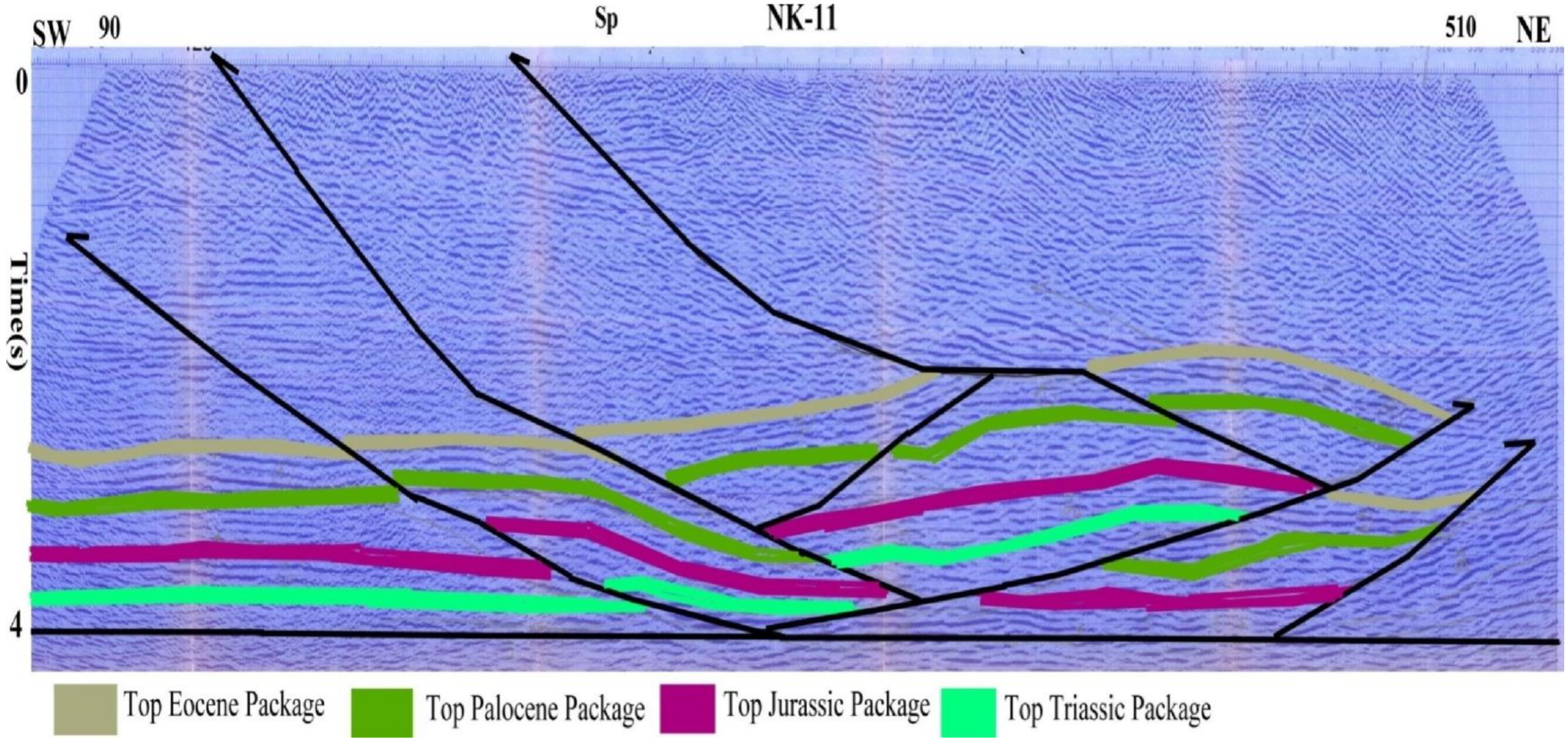

Figure 4.4. Interpreted Seismic line NK -11.

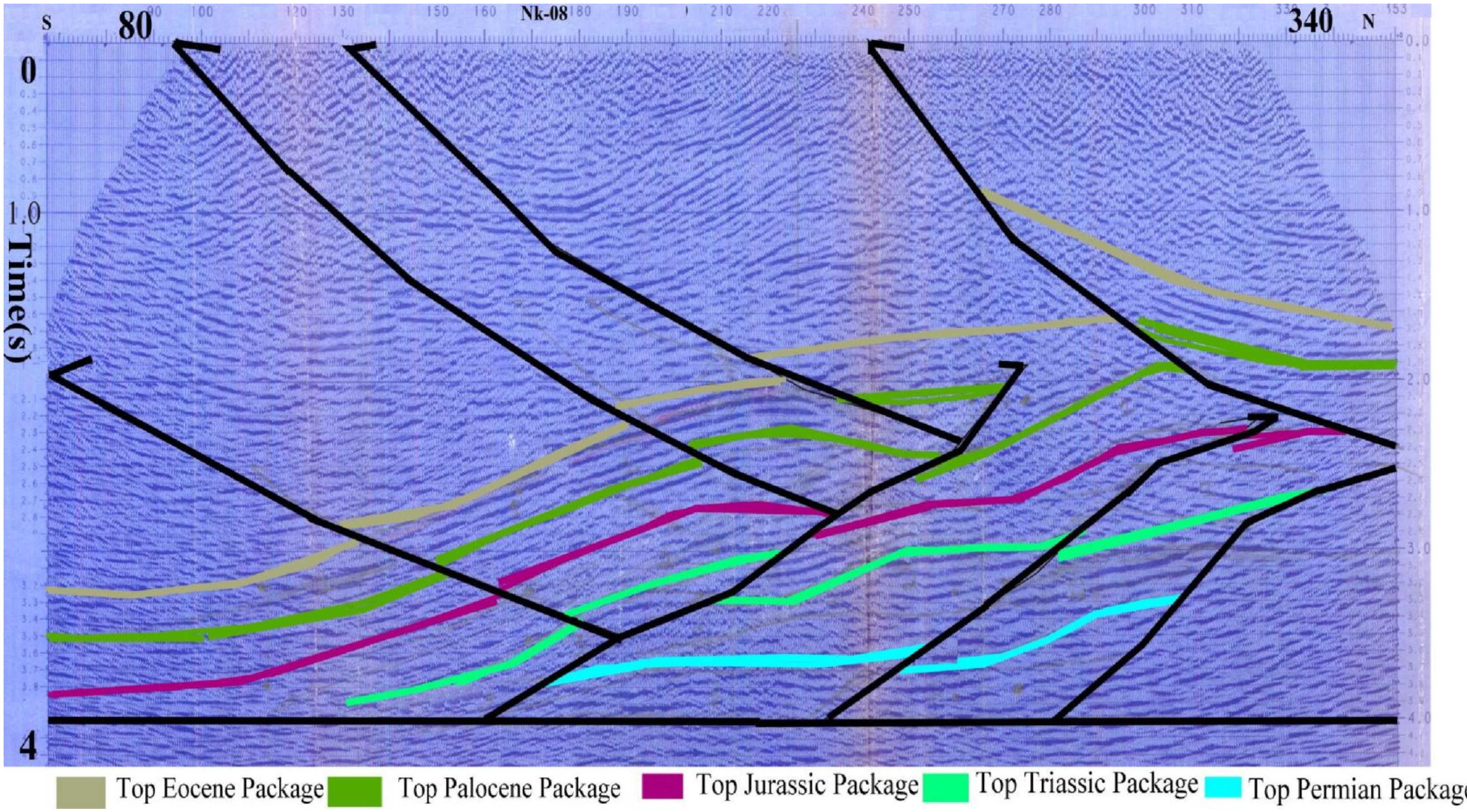

Figure 4.5. Interpreted seismic line NK 08.

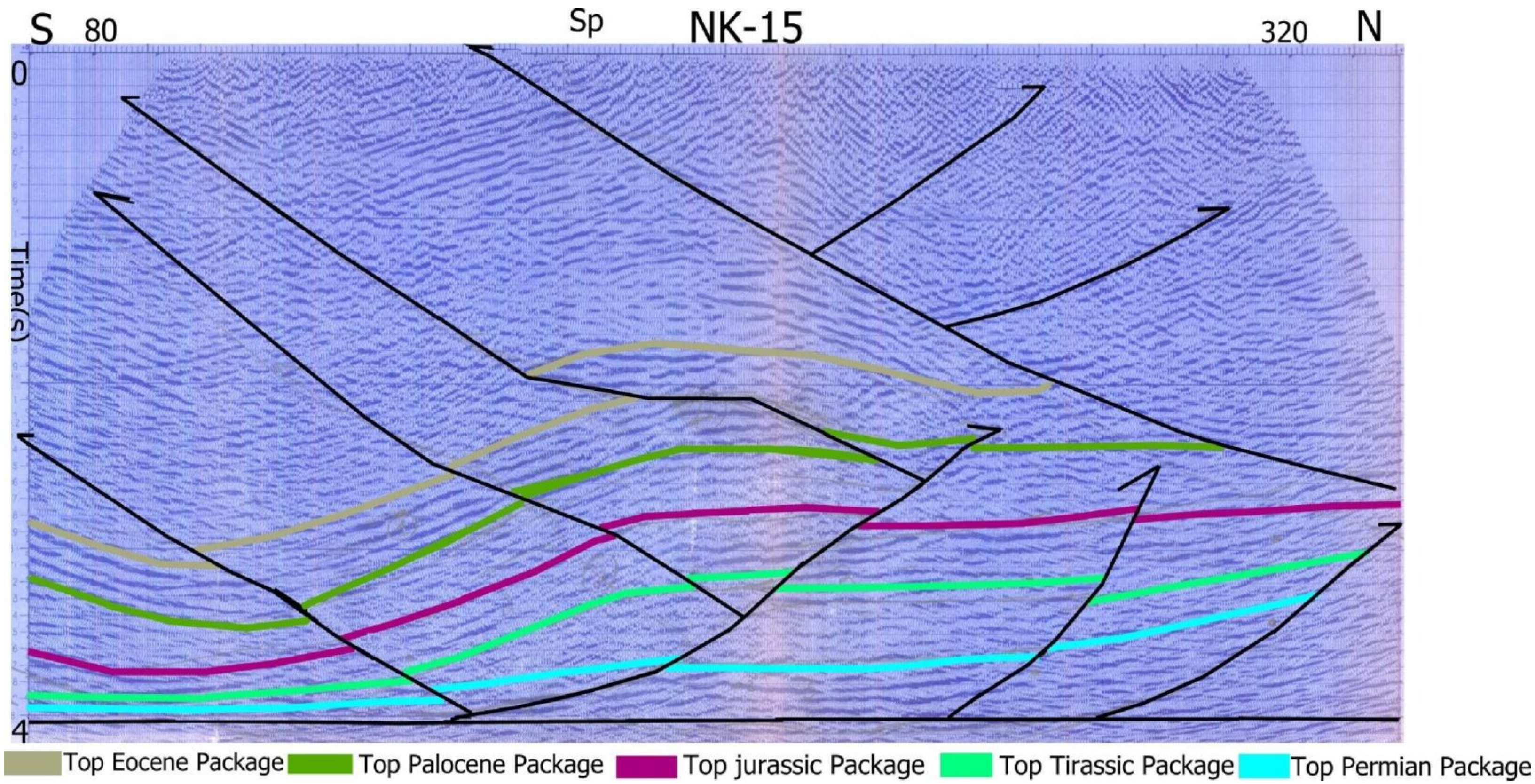

Figure 4.5. Interpreted seismic line NK-015.

CHAPTER 5
CROSS SECTIONS

Five cross sections were constructed to interpret the geometries at surface and subsurface. The cross sections are constructed in integration of surface attitude and seismic data upto depth of 10 km. The area is structurally very complex and data quality was very poor for the interpretation. Section AB and CD are constructed along the dip lines 865-NK-15 and 865-NK-08. Section EF, GH and IJ were constructed along the strike lines 865-Nk-02, 865-NK-05 and 865-NK-11 respectively. Top reflectors of Eocene, Paleocene, Jurassic, Triassic and Permian were marked by solving the velocity windows. The faults in subsurface were marked on the basis of reflectors offset while faults exposed at surface were marked on seismic section in relation with the shot points on the surface.

5.1 Section AB and CD

Both sections are north south orientated 17.5 km and 18.5 km in length.In north of section AB and CD, Naribanda fault (NRF), Bargazibanda fault (BBF) and Shakardarra fault (SF) are the thrust faults emanates from basal detachment to surface. Bab-e- Shakardarra fault (BSF) and two splay faults emanates at shallow depth in north and south of Shakaradarra fault. Eocene rocks are thrusted over younger rocks by these two thrust faults. In south of SF an open anticlinal and synclinal structure is transected by complex network of faults. In subsurface north facing thrust had uplifted the stratigraphic section toward north at deeper level. Tolabanghikhel fault and Chorlaki fault originates as south facing faults from north facing thrust at deeper level transects the limbs of folds. Triangular zones are formed at depth in between the opposing face thrust Shown in figure 5.1.

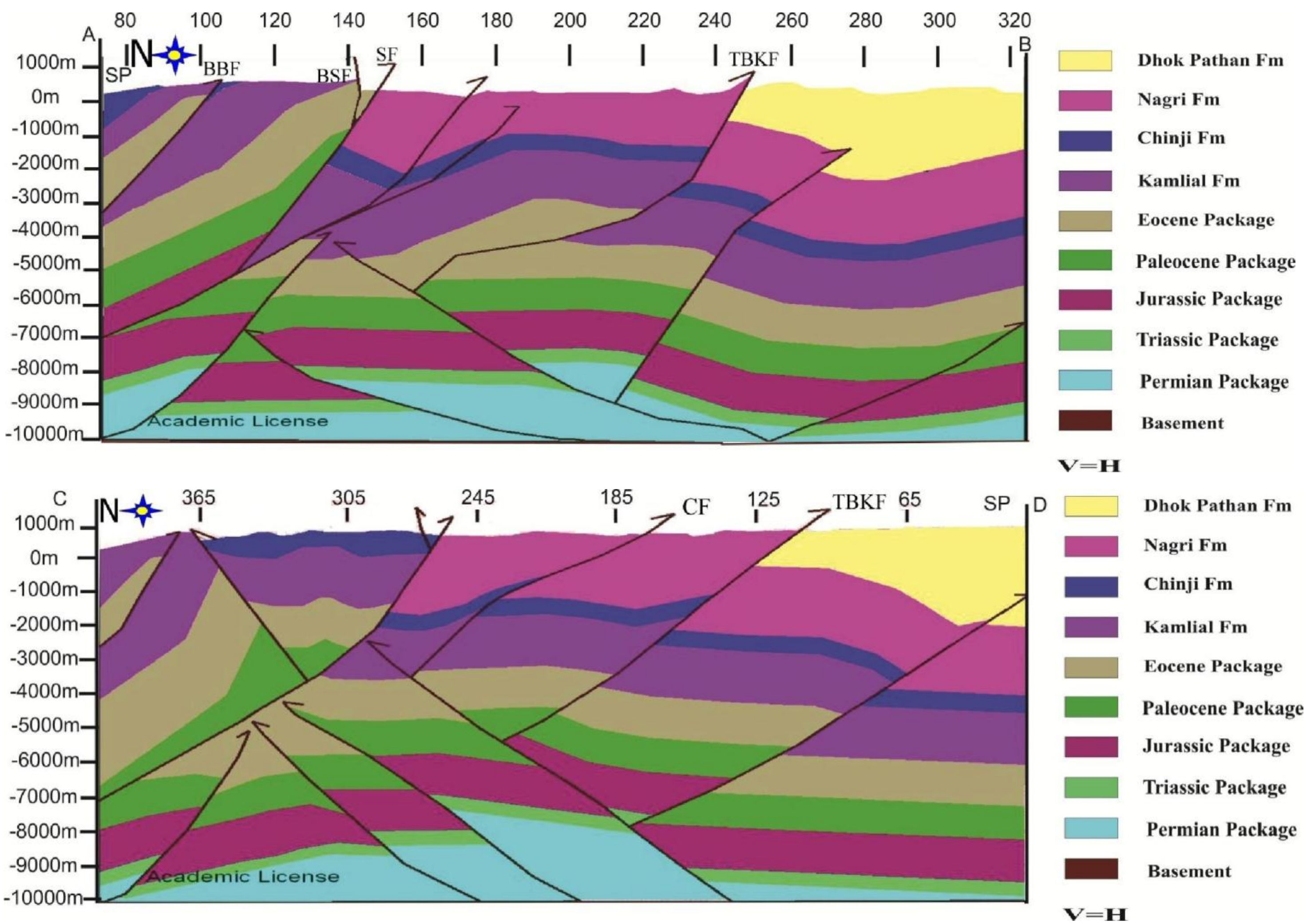

Figure 5.1. Cross section AB and CD prepared along seismic line NK-15and 08.

5.2 Section EF, GH, IJ and KL

Sections EF, GH and IJ are 27.1, 29.4 and 32.5 long orientated in NE-SW direction.Sections EF, GH, IJ are oriented oblique to the strikes of exposed structures, however section EF is east west oriented perpendicular to the strikes of structures. NRF is present in the EF section thrusting Eocene rocks over the Kamlial Formation. SF is present in all sections thrusting Eocene rocks over the Kamlial and Nagri Formations. NRF and SF are cutting up section from basal detachments to surface. TolabangiKhel fault in the sections GH and IJ is thrusting Nagri Formation in the hanging wall over the DhokPathan formation in the foot wall. In subsurface Pop-up and triangle zones are present. In section KL steeply dipping Chorlaki fault (CF) is present with less stratigraphic throw shown in figure 5.2, 5.3and5.4.

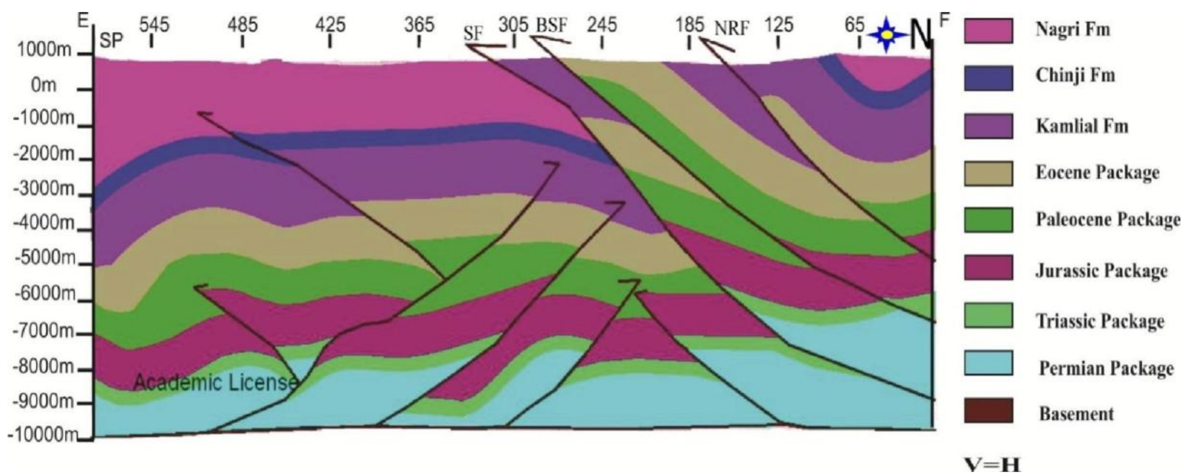

Figure 5.2. Cross section EF prepared along seismic line NK-02.

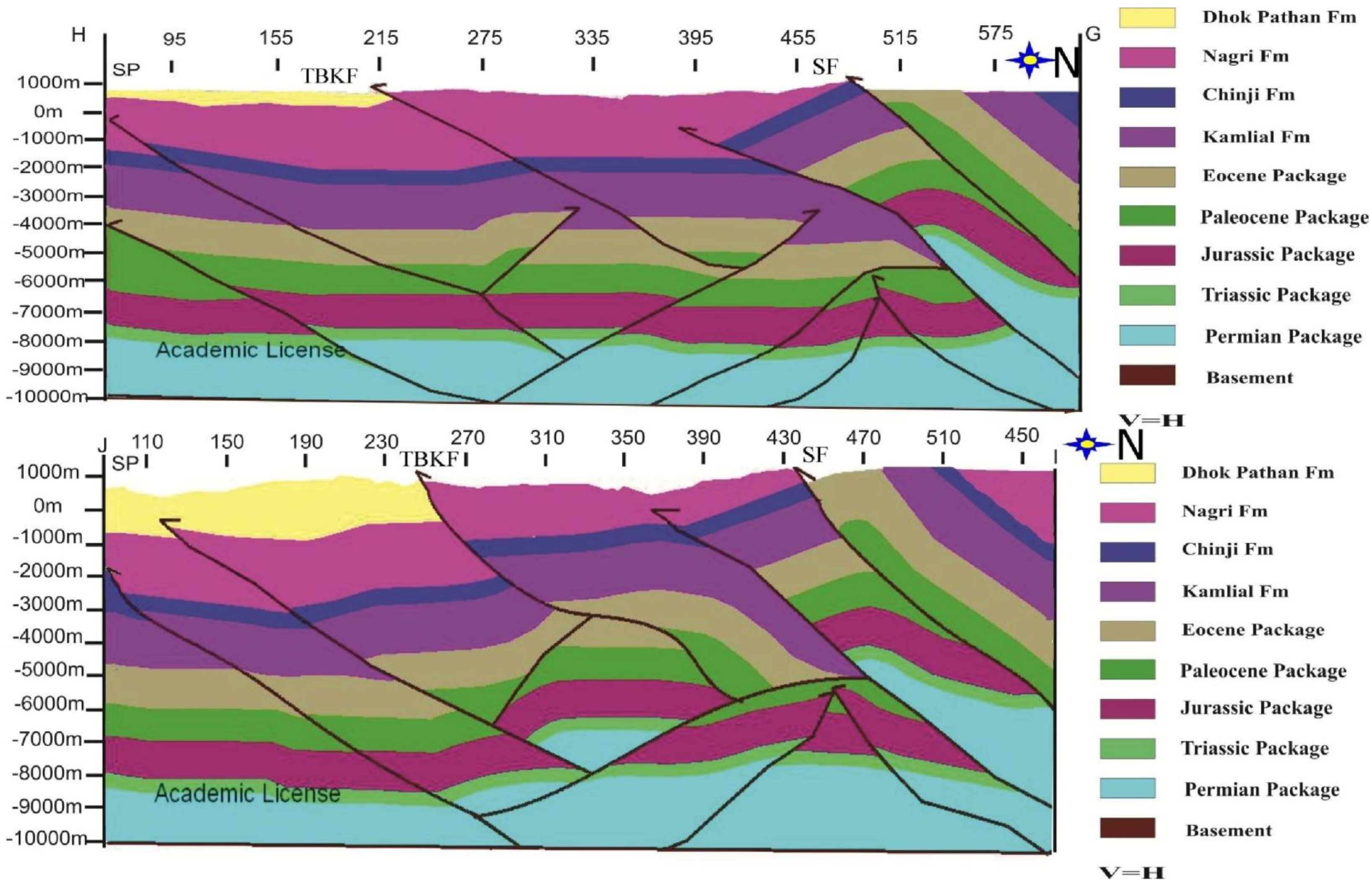

Figure 5.3. Cross section GH and IJprepared along seismic line NK-05 and 11.

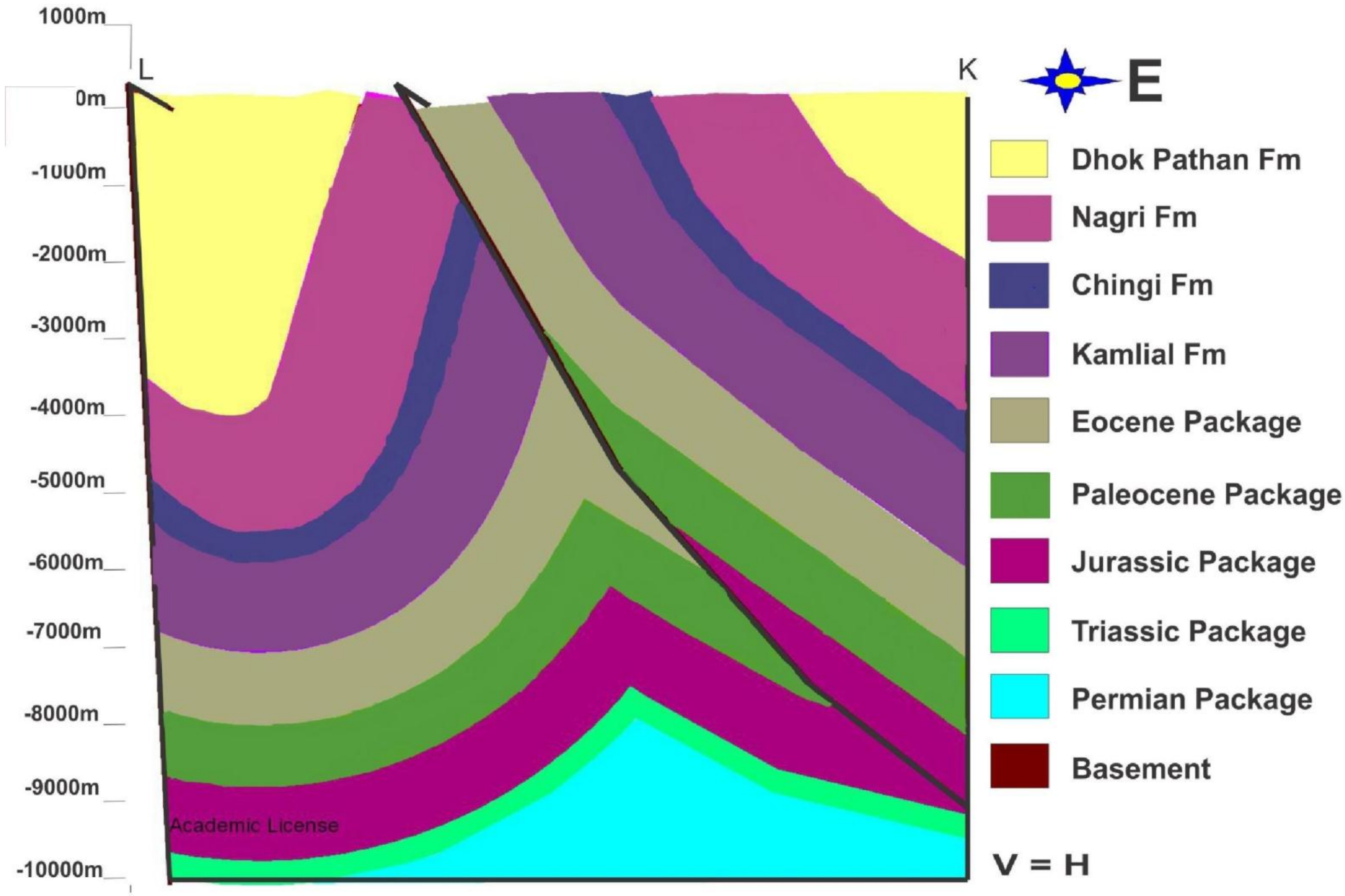

Figure 5.4. Cross section KL.

CHAPTER 6

DISCUSSION AND CONCLUSIONS

Discussion

Geologically Shakardarra is comprised of complex deformational structures, developed and modified by multiple deformational events. The structural models of area show the distribution of structures in 3 dimensional at surface and subsurface. The area is occupied by tight anticlinal and broader synclinal structures. The presence of Eocene Jatta gypsum Formations in the core of anticlinal structures indicate that folds are formed as result of detachment folding on Eocene evaporate detachment horizon. The truncation of folds at its limb by faults narrates that faults are emplaced later in the deformational history of area than folds. The trends of folds axial traces and strikes of faults are ENE to WSW which indicates there development genetically linked to Himalayan induced deformation. The thrust faults are mostly striking ENE-WSW and dipping towards north. The cross sections show that these faults are emanating from basal detachment located at sedimentary crystalline interface. The back thrust exposed at surface are EW in strike and dip toward south. The cross section shows that these back thrust are emanating from forethrust at much shallower depths as compared to fore thrust. The development of back thrust has preserved the critical taper for initiation of fore thrust in south of it. In the central portion of area south dipping blind thrust had uplifted the stratigraphic sequence northward in subsurface. TBKF and CF originate from these blind back thrusts cut upsection to the surface. The reservoirs formation of Jurassic age are structurally uplifted and transected by these faults forming the structures favorable for exploration of hydrocarbon. The faulting in the central formation of study area is developed to achieve the critical taper for initiation of Surghar range frontal thrust in south of shakardarra. The structural geology of area in central portion is comprised of pop-up and triangle zone geometries in subsurface. The change in orientation of the Shakardarra fault, Tolabangikhail fault and Chorlaki fault from E-W to N-S in the eastern portion of area is strongly influenced by right lateral movement of Kalabagh fault present in south east of this area. Dominant flexure/bends in the strikes of Surghar range thrust in west of Kalabagh fault and Shakardarra fault in east represents that the early formed thrusts are rotated along the vertical axis of rotation related to

Kalabagh strike slip fault. It is evident from observation on satellite imagery that Darga syncline right segment and Darga syncline left segment before the development of Kalabagh fault were part of a single synclinal structures containing DhokPathan Formation in the core. The deformation related to Kalabagh strike slip fault had truncated this synclinal structure and changed the orientation and dips of Nagri Formation to vertical near the rotated fault plane of Chorlaki fault and Tolabangikhail faultshown in figure 6.1.

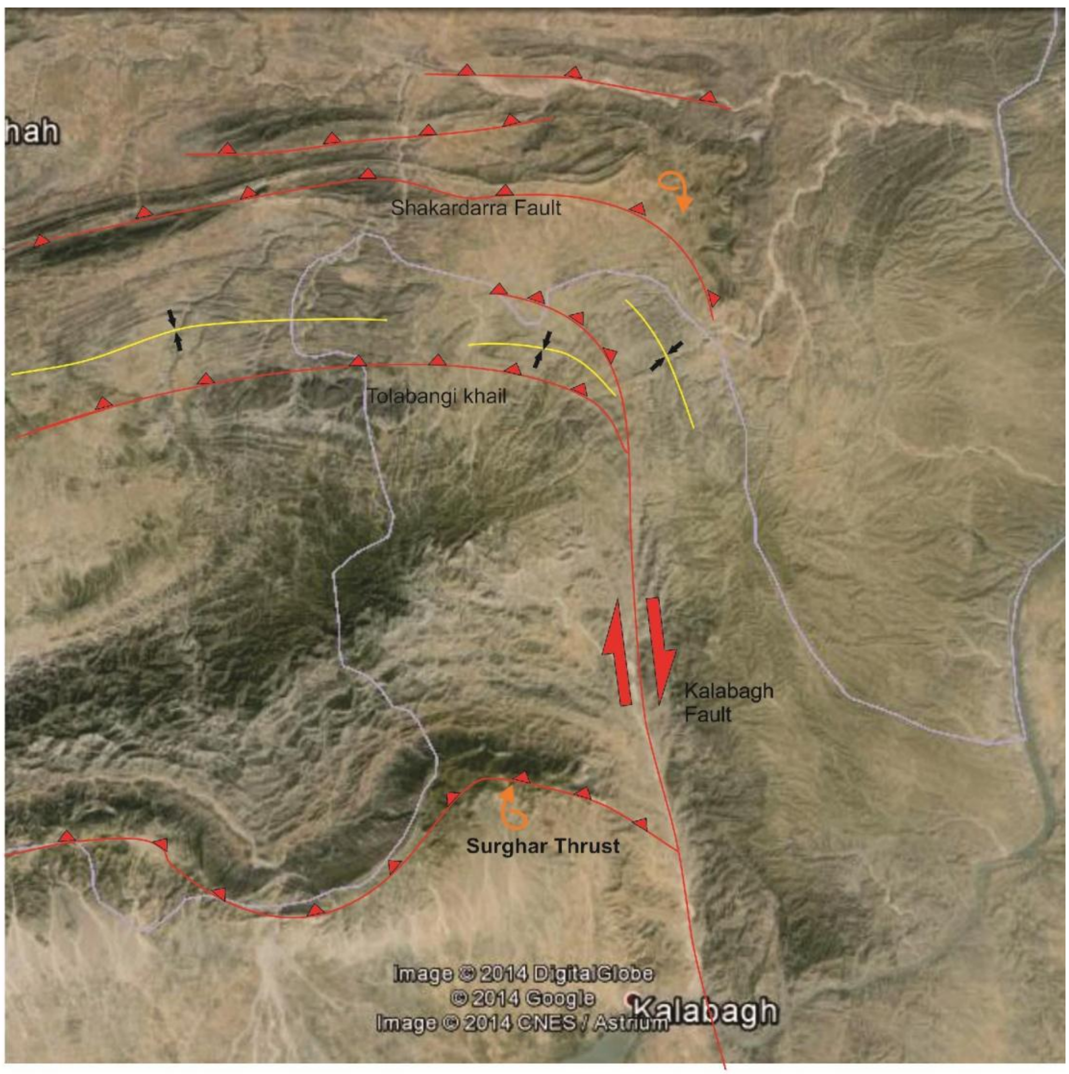

Figure 6.1. Faults orientation changing from ENE –WSW to N-S.

The previous model of Shakardarra (abbasi 1991) had showed the presence of lateral ramp and duplication in Precambrian to Mesozoic strata. The model was purely based on structural geology. However in this research the 3D model developed by integration of structural geology and seismic nullifies the presence of lateral ramps at Hukni and presence of duplexes in the subsurfaceshown in figure 6.2 and 6.3. The research suggests that area is evolved sequentially in three episodes of deformation. In first phase of deformation folding is developed on Eocene evaporate horizons as detachment folds. In second phase of deformation thrusting from basal detachment had truncated the folded structures and elevated the whole stratigraphic sequence. In third phase of deformation early formed thrust faults are rotated in eastern and western parts by the influence of Kalabagh strike slip fault as shown in figure 6.4.

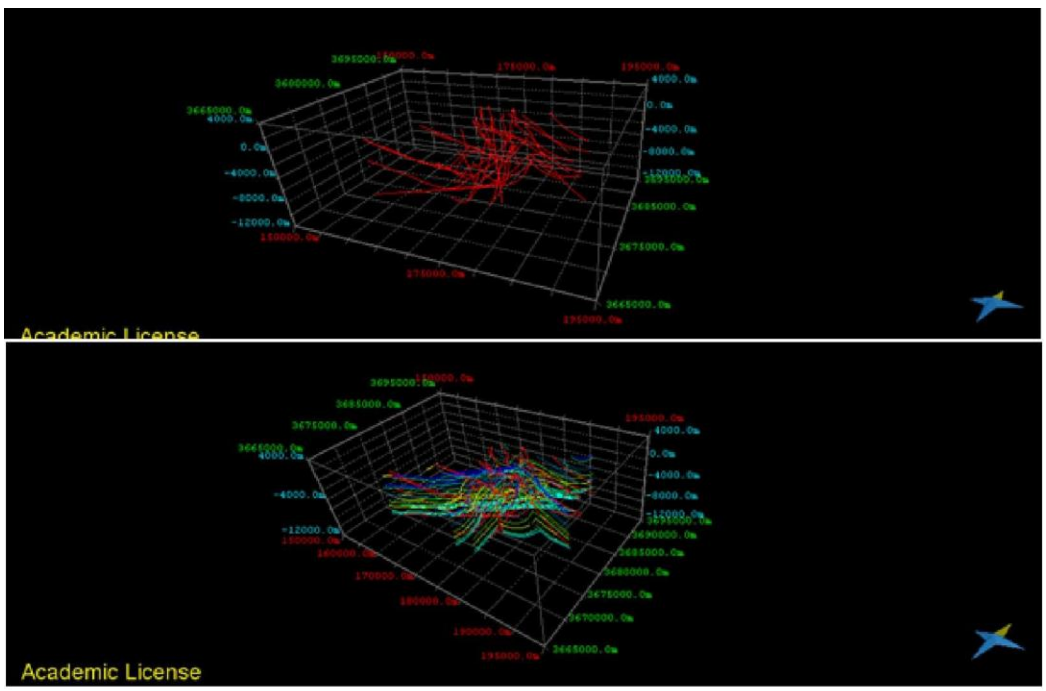

Figure 6.2. 3D model showing the faults and reflectors polylines.

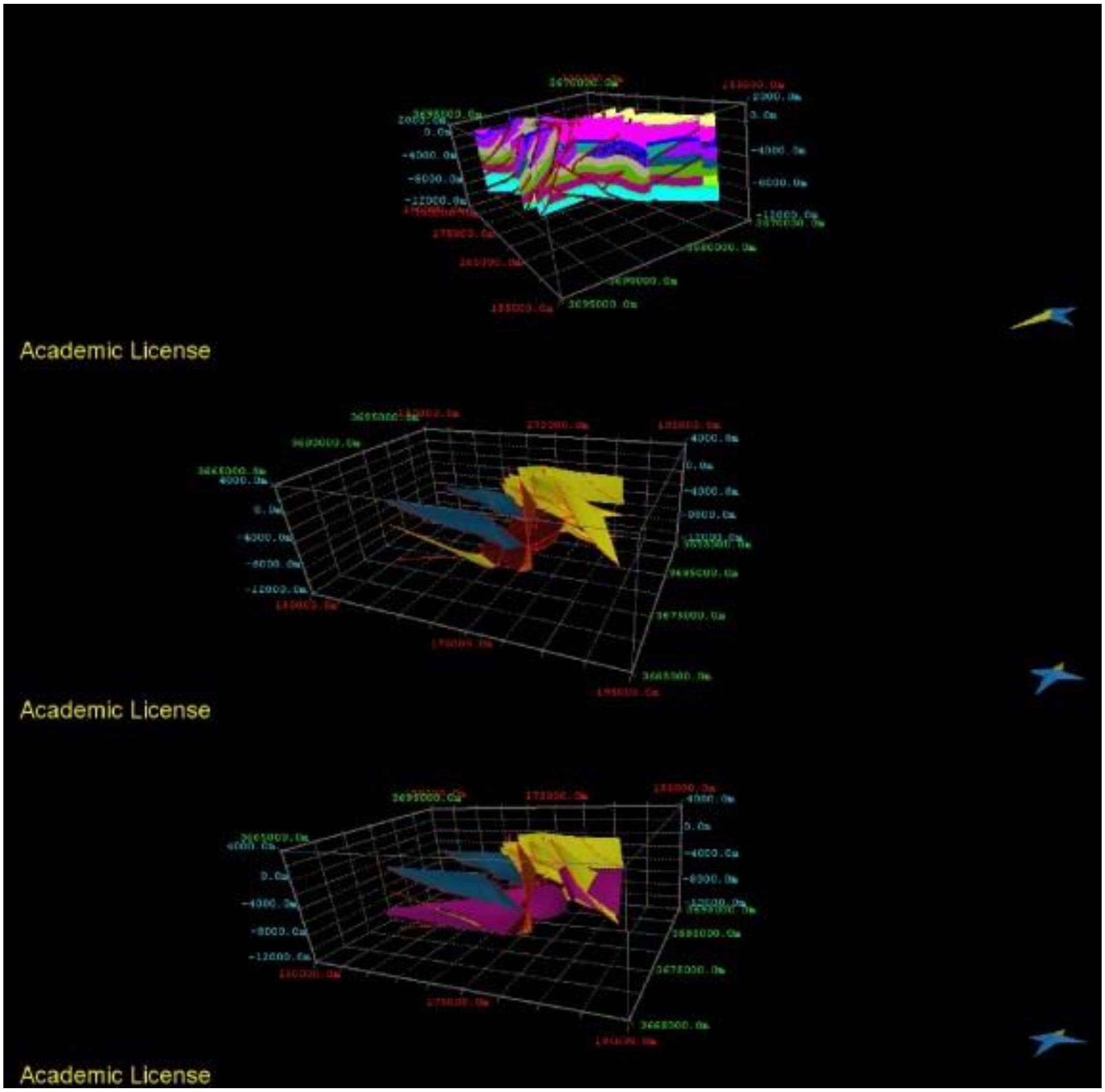

Figure 6.3. 3D model showing the reservoir surface and integration of 2d with 3d.

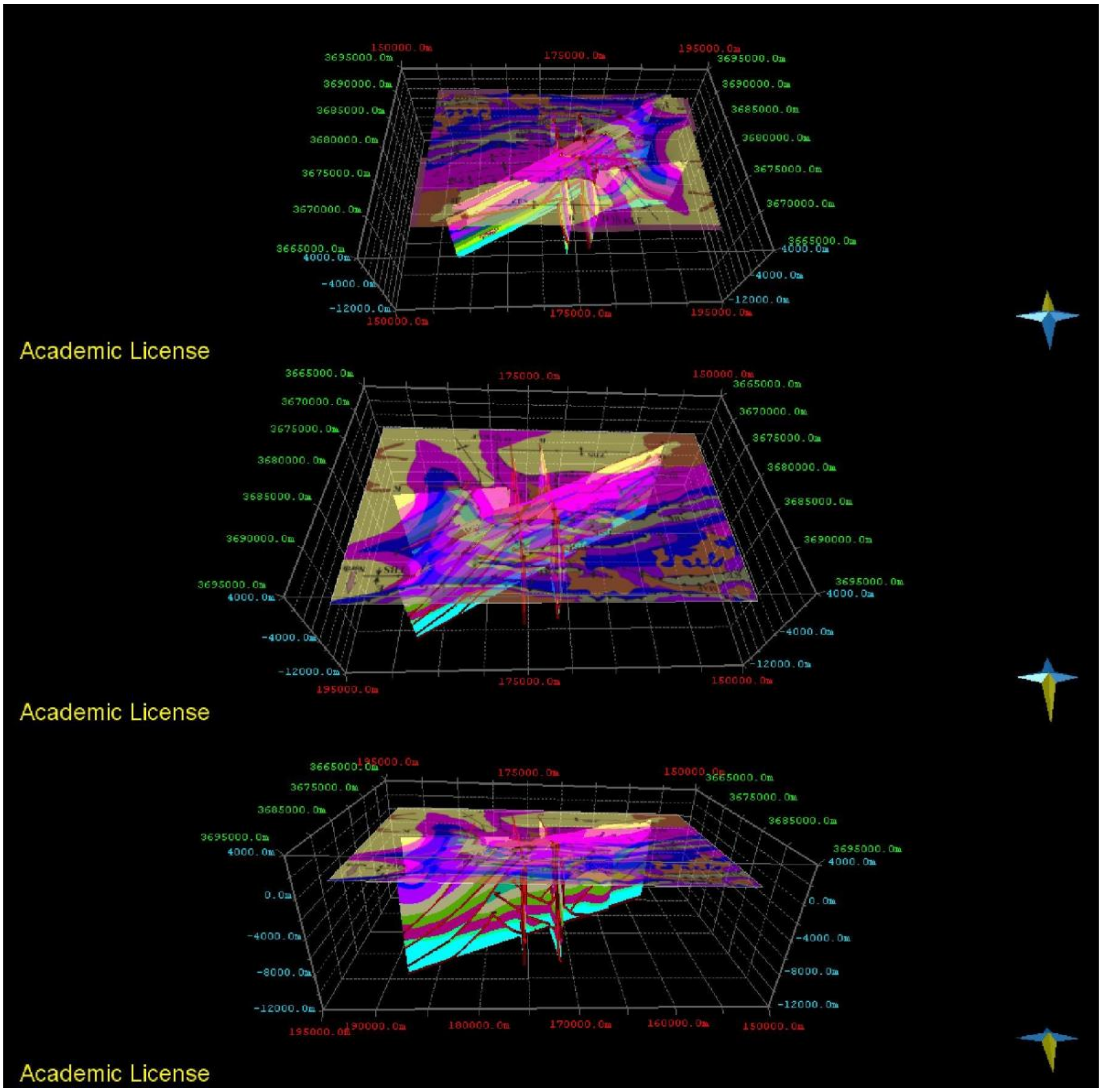

Figure 6.4. 3D model showing cross sections with the overlay of geological map.

Conclusions

Based on this research current research following conclusions is drawn.

(1). Geologically the Shakardarra is comprised of complex deformational structures developed and modified by different deformational mechanisms.

(2). Two distinctive detachment horizons are present in the subsurface at sedimentary crystalline interface and Eocene evaporates sequence.

(3). The area is comprised of broad synclinal and tight anticlinal structures developed as detachment folds on Eocene evaporite sequence.

(4). The general trend of faults and folds is ENE-WSW which shows their genetic link to Himalayan induced deformation.

(5). The truncations of fold limbs by faults indicate that faults are emplaced later in deformational history of area than folds.

(6). The back thrusts in the area are developed to achieve the critical taper for initiation of fore thrust towards south.

(7). The change in strikes of the Shakardarra fault, Surghar range thrust, Tolabangikhel fault and Chorlaki fault indicate that the early formed thrust are rotated along vertical axis by the influence of the Kalabagh strike slip fault.

(8). The area is evolved sequentially in three episodes of deformation:

  (I). Detachment folding along Eocene evaporates.

  (II). Thrust faulting emnating from basal detachment and terminating in surface and subsurface.

  (III). Rotation in orientation of structures by the influence of strike slips faulting.

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