2D Seismic Interpretation Of Sangar Area, Lower Indus Basin, Pakistan

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Certificate

This thesis is submitted by **Mr. Muhammad Mubbashir Ul Zaman and Mr. Adnan Khan** and is accepted in the present form by Department of Earth & Environmental Sciences, Bahria University, Islamabad as the partial fulfillment of the requirement for the degree of **Bachelor of Sciences in Geophysics,** 4 years program (Session 2009 – 2013).

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DEDICTAION

We dedicate this work to our teachers, friends and families, especially our parents, whose patience and love got us where we are, and to the future generation, who will be the guardian of our legacy.

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All praise to Almighty Allah who gave us courage and made us able to completing our thesis work successfully. Then we are thankful to our parents for moral and financial support.

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ABSTRACT

This dissertation contains the study and interpretation of 2D seismic reflection data of selected seismic lines of Sinjhoro area, Lower Indus Basin, Pakistan. The main objective of this research was delineation of subsurface structures favorable for hydrocarbon accumulation. This area is situated in the Sanghar District of Sindh Province and is licensed to Oil and Gas Development Corporation Limited (OGDCL). The seismic data for this dissertation was provided by the Land Mark Resources (LMKR) by the permission of Directorate General of Petroleum Concessions (DGPC). . The names of lines obtained are: (856-SGR-54, 856-SGR-55, 856-SGR-63, 856-SGR-67). Three prominent reflectors were marked on the basis of their reflection character. Two-way time (TWT) was read from the seismic sections and average velocities were used to create TWT and Depth Contour maps.s

CHAPTER 1
INTRODUCTION

1.1 Introduction

The study area is located near city of Tando Alam in Sanghar district, Sindh Province. Sanghar District is one of the largest districts in the Sindh province of Pakistan. Bounded by India on the east, it is located in the centre of Sindh. The district capital, Sanghar, is itself a small city roughly 56 km east-south-east of the city of Nawabshah and the same distance north of Mirpur Khas.

This field was discovered by OGDCL in Sinjhoro Exploration Lease. The Sinjhoro Exploration Lease (E.L.) is situated between 26^o 0’ 0” N – 26^o 15’ 0” N and 68^o 49’ 12” E – 69^o 9’ 0” E in the Sanghar District of Sindh. It is present in the lower Indus Basin. It covers an area of 1283.48 sq km and runs east-west to a length of 55 km. The cities of Jhakro and Shahdadpur are nearest to it. Location map of the study area is shown in figure 1.1.

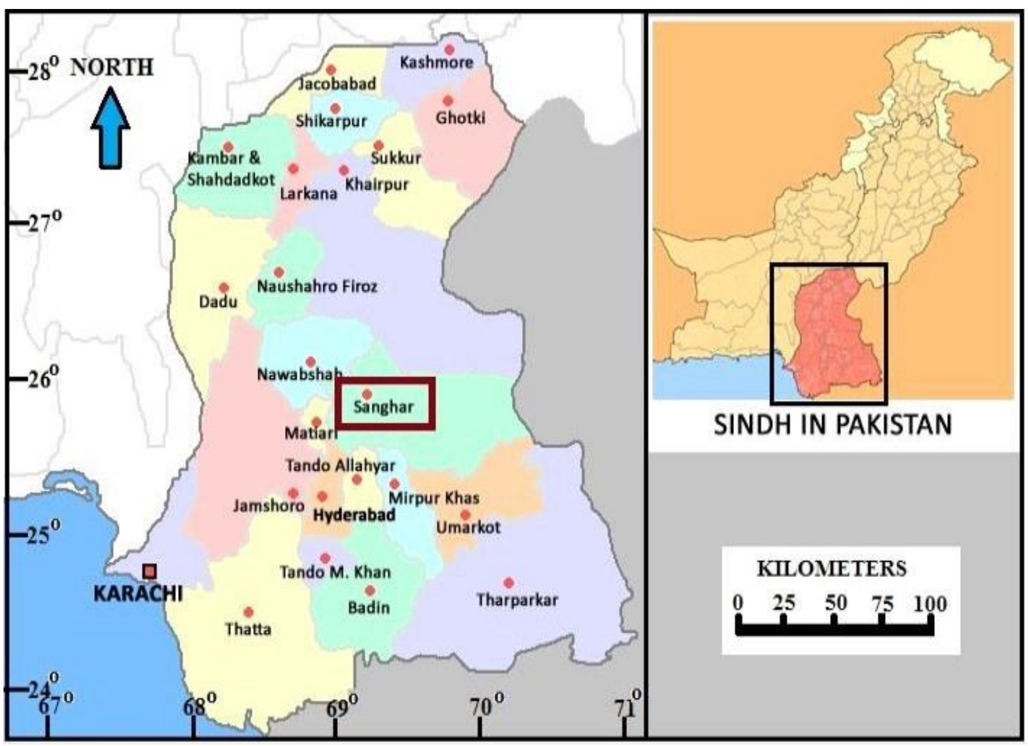

Figure 1.1. Location map of study area (Geological Survey of Pakistan).

1.2 Exploration history of study area

The history of oil and gas exploration in Sindh dates back to 1893 when first well Sukkur-1 was drilled by the Government of Bombay. However, it was not until 1957 when first gas discovery was made at Khairpur by the British Oil Company. The first giant Mari gas field was also discovered in the same year. Exploration activities were accelerated in Pakistan in 1950s after the giant Sui and Mari gas fields. However, failure to discover oil fields discouraged exploration and it declined sharply in the late fifties (Khan et al., 2009).

To revive exploration the Government of Pakistan established Oil and Gas Development Corporation Limited (OGDCL) in 1961. After great efforts, OGDCL made its first success in 1966, when first gas field Sari was discovered in the province of Sindh. However, the thrust of exploration remained in the Potwar area as Sindh was considered to be gas prone area. Limited exploration efforts were therefore diverted to this region. During 1947-1980 a total number of 104 exploration wells were drilled in the country including 35 in Sindh. In the 1970s, OGDCL updated its technology and re-evaluated the potential prospects. However, exploratory drilling had not accelerated until 1981, the year in which first oil field was discovered in the Lower Indus Basin (Badin Sindh) by Union Taxas Pakistan Inc., thus negating the old concept that Sindh was a gas prone region. (Khan et al., 2009).

Following this discovery exploration activity increased significantly in the country, particularly in Sindh. From 1981 to December 1994, a total of 198 exploration wells were drilled in the country out of which 142 were drilled in Sindh. Till December 1994, 100 oil and gas fields have been discovered in Pakistan including 64 oil and gas fields in Sindh alone (oil 37 and gas 27). OGDCL, the major oil company of Pakistan is quite active in petroleum exploration in Sindh province since first oil discovery was made by PETRONAS in 1981. Up to December, 1994 OGDCL has drilled 65 exploration and 38 development wells. Out of 65 exploration wells 23 oil and gas discoveries were made. Presently, OGDCL's 10 oil fields in Sind province are producing 13,500 barrels per day. This crude is transported to Karachi by bouzers for refining purpose. The Sind’s share of oil production will further increase as OGDCL is installing four jet pumps in its Tando

Alam Complex while the recently discovered Mithrao gas condensate will also add significantly to the production of Hydrocarbon in Sindh (Khan et al., 2009).

1.3 Seismic Data

To study the area, 4 seismic lines were selected. The data was acquired by OGDCL. Line 856-SGR-55,856-SGR-63 and 856-SGR-67 are strike lines trending S-N and 856-SGR-54 is dip line trending W-E. Figure 1.2 shows base map of the study area.

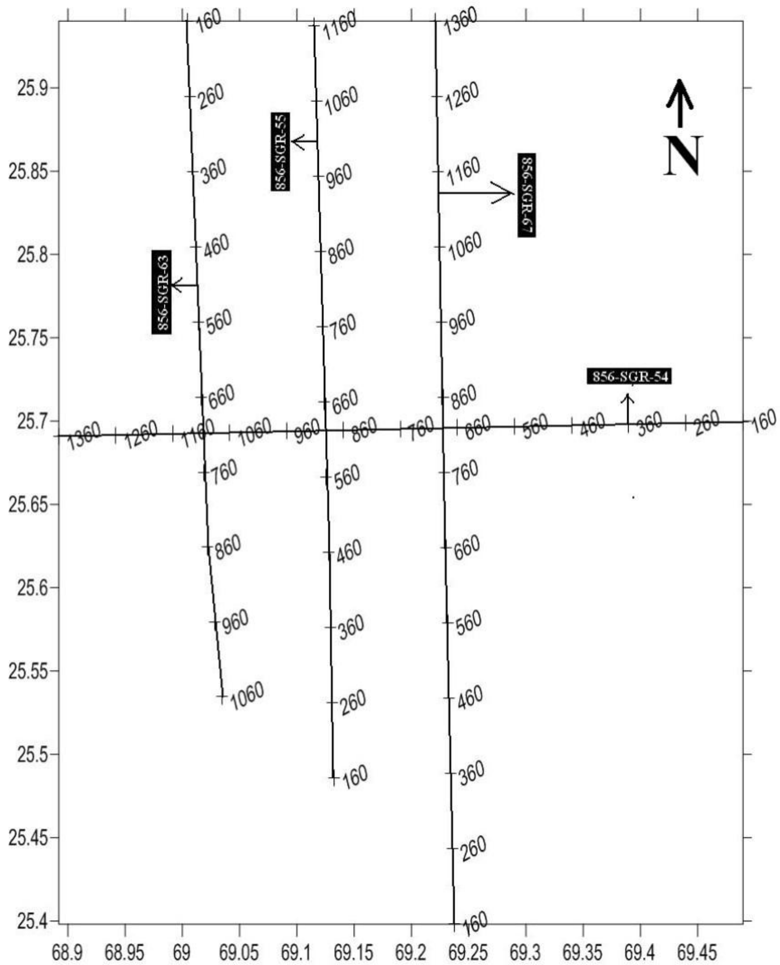

Figure 1.2. Base map of the study area.

1.4 Objective of the research project

The aim of the study was structural interpretation of sanghar area using 2D seismic Data.

CHAPTER 2

REGIONAL GEOLOGICAL FRAMEWORK

2.1 Tectonics

Pakistan possesses the northwestern boundary of the Indian lithospheric plate. The under-thrusting of Indian Plate beneath the Eurasian Plate is producing compressional thick-skinned tectonic features since Eocene time on the northern and northwestern fringes of the Indian Plate (Fig 2.1). The continued under thrusting of the Indian Plate since Cretaceous produced the spectacular mountain ranges of the Himalaya and a chain of foreland fold-and-thrust belts as thick sheets of sediments thrusted over the Indian Craton (Kemal et al.,1997).

In northern Pakistan, the Himalayan trend is divided into four major subdivisions, (Fig 2.1). Karakoram ranges and Hindukush lie in the north of the Main Karakoram Thrust (MKT). South of the Main Karakoram Thrust (MKT) and north of Main Mantle Thrust (MMT) lies the Kohistan-Ladakh block (LeFort, 1975). Low ranges of Swat, Hazara, and Kashmir that are analogous to the Lesser Himalayas of India lie between the Main Mantle Thrust (MMT) and the Main Boundary Thrust (MBT). The outlying Potwar Plateau, bounded on the south by the Salt Range Thrust (SRT), represents the marginal foreland fold-and-thrust belt of Indo-Pakistan subcontinent, equivalent to the Sub-Himalayas in India (Pennock et al, 1989).

2.2 Sedimentary basins

Basin is an area characterized by regional subsidence and in which sediments are preserved for the longer periods of time. The container fill or content, which is the accumulation of sediments resting on the basement, is called a sedimentary cover. The gradual settling of the basin is called subsidence. The point of maximum sedimentary accumulation is called the depocenter. The depocenter may not correspond to the zone of maximum subsidence (Kazmi and Jan, 1997).

2.3 Basins of Pakistan

Pakistan is comprised of following Basins these includes;

(1) Indus Basin

  (a) Upper Indus Basin.

  (b) Lower Indus Basin.

  (c) Central Indus Basin

  (d) Southern Indus Basin.

(2) Balochistan Basin.

(3) Kakar Khorasan Basin (Kadri, 1995).

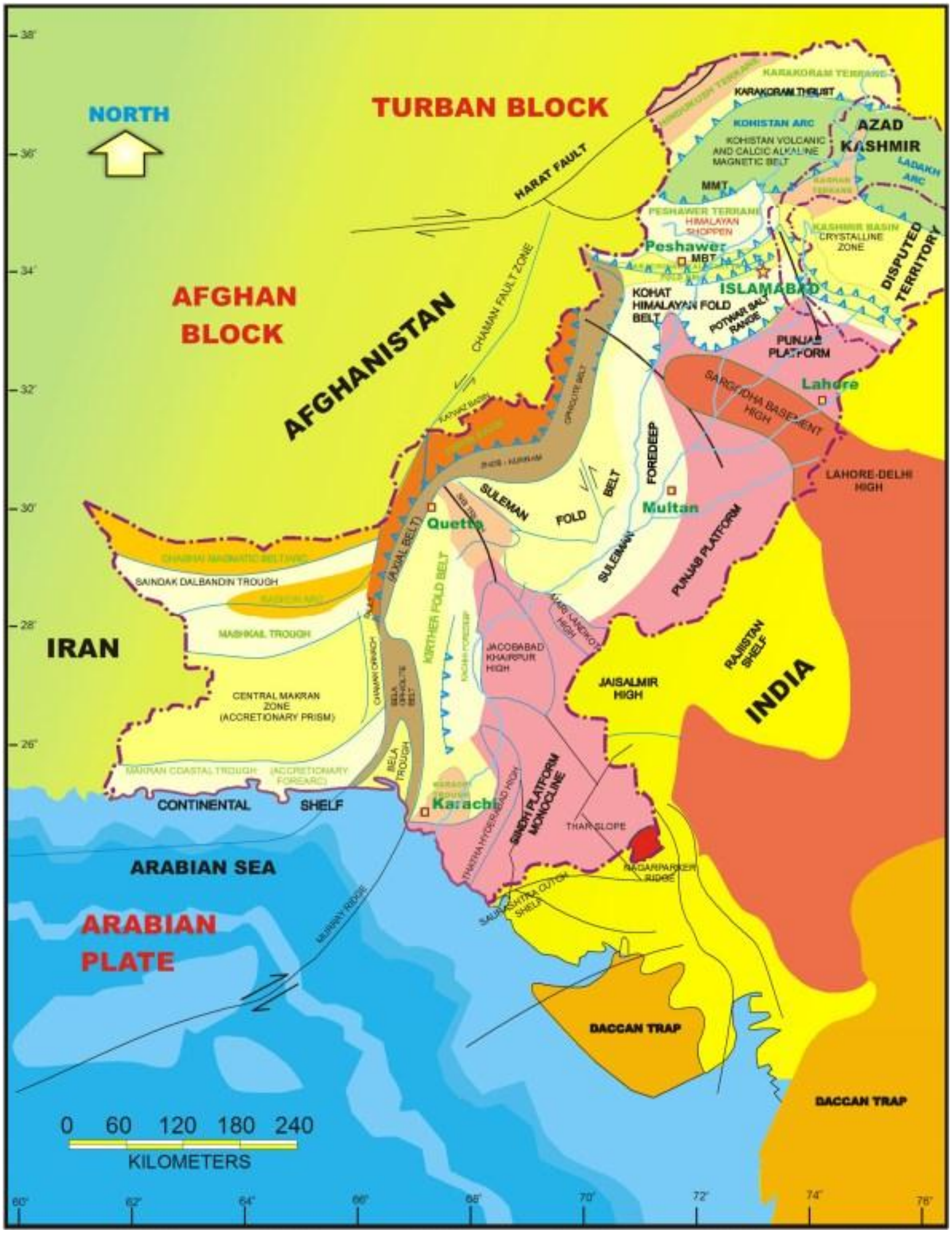

Fig 2.1. Regional tectonic setting of Pakistan (Khan et al., 1986; Gee, 1989).

2.3.1 Southern Indus Basin

2.3.1.1 Regional structural style

The Southern Indus Basin covers an area from approximately 26^{o} 45' N to the India-Pakistan border and coastline in the south. To the west it is bounded by the Kirthar Fold Belt and to the east by the Nabisar slope which continuous eastward into India. The southern Indus Basin is oil prone area with numerous oil and gas producing fields (Kadri 1995). Structural settings of Southern Indus Basin is shown in fig 2.2.

(a) Thar Platform

Thar Platform is a gently sloping monocline analogous to Punjab Platform controlled by basement topography. It is bounded by the Indian Shield in the east, and merges into Kirthar and Karachi Trough in the west and is bounded in the north by Mari Bhugti Inner Folded Zone (Kadri 1995).

(b) Karachi Trough

Karachi Trough is an embayment opening up into the Arabian Sea. It contains a large number of narrow chains like anticlines, some of which contains gas fields, (Sari, Hundi and Kothar). The Early, Middle and Late Cretaceous rocks are well preserved in this area. (Kadri 1995).

(c) Kirthar Foredeep

Kirthar Foredeep trends north-south, from the correlation of Mari, Khairpur and Mazarani wells it appears that the Upper cretaceous would be missing in the area. Paleocene seems to be very well developed in the Depression, like Sulaiman depression, is the area of great potential for the maturation of source rocks (Kadri 1995).

(d)Kirthar Fold Belt

Kirthar Fold Belt north-south trending tectonic feature is similar to Sulaiman Fold Belt. Rocks from Triassic to Recent were deposited in this region. The configuration of the Kirthar fold belt also marks the closing of Oligocene-Miocene seas. The western part of the Kirthar Fold Belt adjoining the Baluchistan Basin, which marks the western edge of the Indus Basin, is severely disturbed (Kadri 1995).

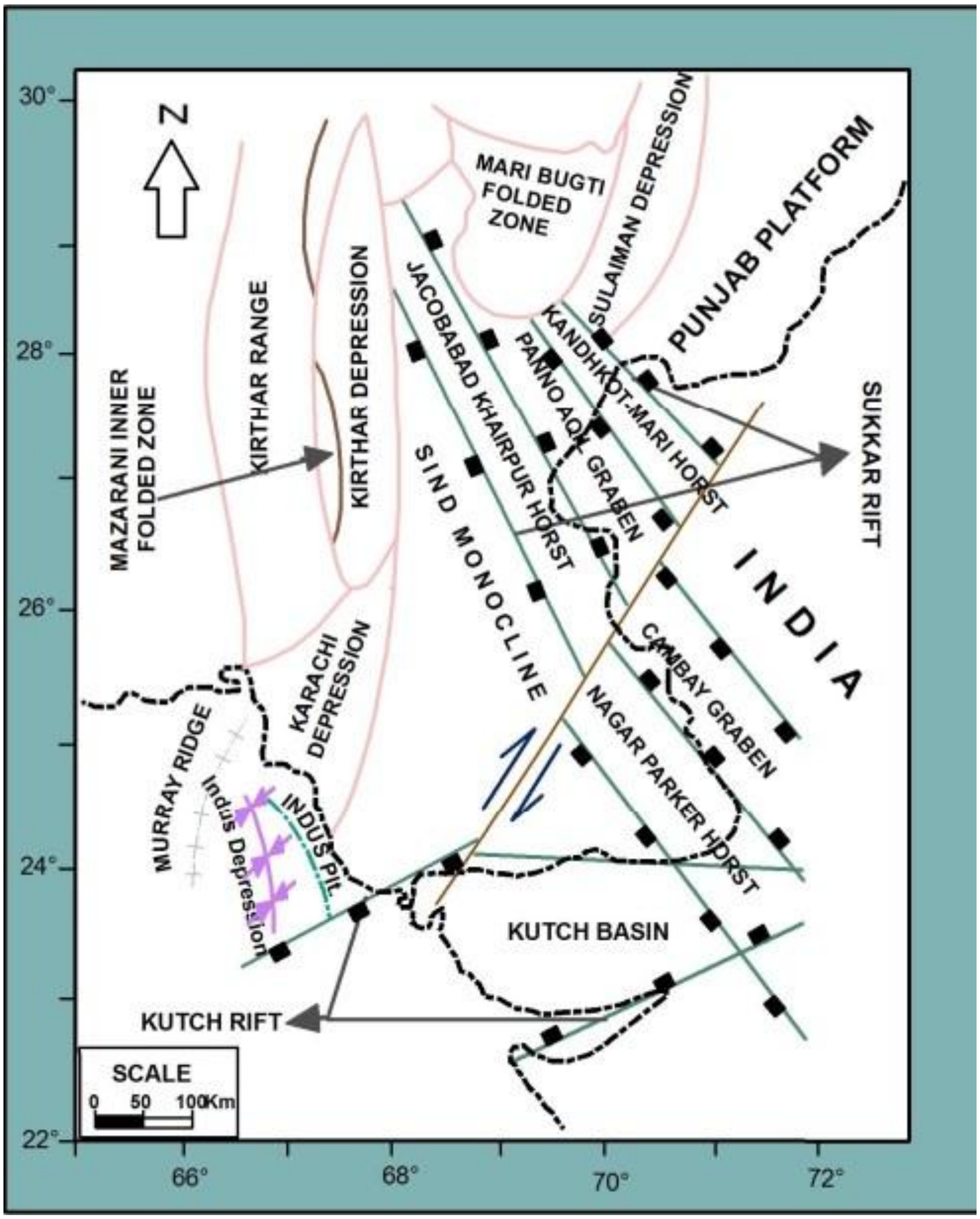

Figure 2.2. Structural setting of Southern Indus Basin (Raza et al., 1990)

(e) Offshore Indus

Offshore Indus is the part of passive continental margin, sedimentation started from cretaceous time, however, deltaic and submarine fan sedimentation has occurred since middle Oligocene time (Kadri., 1995).

2.4 Geology and tectonics of Sinjhoro Block

Sinjhoro E.L is a part of Thar Slope Platform area of Southern Indus Basin. It is bounded in the east by Indian Shield and in the west by Kirthar and Karachi Trough and in the north by Mari-Bugti Inner Folded Zone. During the drift of the Indian plate towards the North-North East, which started in the Triassic, sedimentation took place along the leading edge of the plate in a marginal sag basin. Although several sedimentary cycles can be recognized within this phase, no major tectonic activity occurred until in the Cretaceous. However, later during the Eocene, the first orogenic pulse exercised its influence on the sedimentation by that time, the paleogeography changed completely with the emergence of a volcanic island arc, north west of present day Pakistan (Yeats and Hussain, 1987).

Full-scale collision in the Oligocene resulted in the second orogenic pulse and caused the uplift of many areas in the east and south. The marine sediments became restricted to a narrow but rapidly subsiding trough in the Kirthar area. Towards the end of the Paleocene, the Indus Basin was filled with sediments and must have resembled a vast flood plain with braided stream, the only elevation being the hills of the folded belts (Jaswal et al., 1997).

2.5 Structural settings

The entire southern Indus basin exhibits extensional tectonics and as a consequence, Normal faults are generated showing Horst and Graben structure with former being of great exploratory importance. Offshore Indus is divided into Platform and Depression along a Hinge Line in close proximity and parallel to 67°E Longitude.

2.6 Regional stratigraphy

The Sinjhoro lies within the southern sedimentary basin whose geology has been extensively studied, mapped and its stratigraphic units are well established. The structure has surface geological expression and can be defined on aerial photographs.

The prognosed stratigraphic succession and lithologies were based upon subsurface data and regional stratigraphic information. Most of the Pliocene to Infra-Cambrian succession was well known regionally (Shah et al., 1977).

2.7 Stratigraphy of study area

Stratigraphy of study area comprises of the rocks ranging from Sembar formation to Siwaliks. An unconformity exists between the Alluvium and Laki and another unconformity exists between Khadro and Parh Formations. Although little variation in thickness was noticed, more or less the encountered stratigraphic sequences remained the same as anticipated. Bore hole Stratigraphy is shown in Table 2.1.

2.8 Petroleum geology

2.8.1 Source Rocks

The Lower Cretaceous shale of Sembar Formation is proven source for oil and gas discovered in the Lower Indus Basin because of its organic richness, oil prone kerogen type and thermal maturity. The lower part of Lower Goru Formation is moderately rich in organic shale having fair to good hydrocarbon bearing potential.

2.8.2 Reservoir rocks

The Basal and Massive Sands of Lower Goru Formation are the main zones of interest in this area.

2.8.3 Cap rocks

Thick sequence of shale and marl of the Upper Goru Formation as well as shale within the Lower Goru Formation serves as cap rock for the underlying sandstone reservoirs.

Table 2.1. Bore hole Stratigraphy of study area.

AGE	**FORMATION**	**FORMATION TOPS (m)**			**LITHOLOGY**
		Wellsite	**E.Log**	**Thickness**	
POST EOCENE	ALLUVIUM	Surface	Surface	+617	Sandstone with subordinate clay/claystone and rare conglomerate.
UNCONFORMITY					
EOCENE	LAKI	618	617	563	Limestone with interbeds of marl and shale.
PALEOCENE	RANIKOT	1178	1180	326	Sandstone interbeded with shale and thin beds of Limestone and clay/claystone.
PALEOCENE	KHADRO	1508	1506	73	Sandstone with interbeded clay/claystone and thin beds of basalt.
UNCONFORMITY					
CRETACEOUS	PARH	1579	1579	153	Limestone and chalk.
CRETACEOUS	UPPER GORU	1785	1732	210	Marl with minor shale and limestone.
EARLY CRETACEOUS	LOWER GORU	1942	1942	+1064.5	Shale with subordinate sandstone, marl, siltstone and rare limestone.
	UP. SHALE & SAND		1942	885	Shale with sandstone, siltstone, marl and rare limestone.
	BASAL SANDS		2827	33	Sandstone with subordinate shale.
	TALHAR SHALE		2860	76	Shale with minor traces of sandstone and siltstone.
	MASSIVE SANDS		2936	+70.5	Sandstone with subordinate shale.
TOTAL DEPTH		3000	3006.5	Depth reference is K.B.E i.e. 29.81m AMSL.	

CHAPTER 3

SEISMIC DATA ACQUISITION AND PROCESSING

3.1 Seismic data acquisition

To carry out a seismic survey in an area, the first step is the acquisition of seismic data. It is the procedure through which the seismic reflection data is obtained to image the sub surface and is then followed by seismic data processing and finally interpretation. It is the seismic method that is used for locating hydrocarbon deposits on land, under the sea and in the transition zone (the interface between sea and land). Over the years, there have been significant improvements in the acquisition techniques but the basic principle has remained the same (Shah et al., 1977)..

3.1.1. Basic principle

An acoustic energy source like dynamite, vibroseis or air gun is used in acquisition. The energy from the source is sent into the earth whereby it is reflected back by different layers in the subsurface. The energy from the source is then recorded by geophones or hydrophones in case of marine surveying. The recorded signal is then output to a storage medium usually a magnetic tape (Kearey and Brooks, 1996).

Different types and configurations of receivers are used depending on local environmental conditions and the underground geological features that are to be imaged. The layout of the receivers is also designed to minimize the effect of noise that can otherwise mask the seismic signal. So long as appropriate receiver configurations are used, special computer processing techniques can be applied to the recorded data to remove noise and enhance the seismic signal (Shah et al., 1977).

3.1.2 Energy sources

A seismic source is a device that generates seismic energy used to perform both reflection and refraction seismic surveys. Seismic sources can provide single pulses or continuous sweeps of energy that generate seismic waves, which travel through a medium such as water or layers of rocks. The most common method applied in generating seismic waves is exploding dynamite in the shot holes. There are, however, other methods, which have been introduced as alternative seismic sources. Energy sources are characterized in to two groups:

(a) Impulsive energy sources

(b) Non Impulsive energy sources

An impulsive energy source makes use of explosives which are detonated to produce energy. Most common energy source in this category is Dynamite. Dynamite is exploded inside a drilled hole at a depth ranging from a few meters to several tens of meters. (Shah et al., 1977).

A non impulsive source, on the other hand, does not use explosive detonation mechanism. They produce seismic energy by vibratory or other mechanisms. They are either used in marine survey or in urban or populated areas where it is not safe to detonate explosives. A typical example is Vibroseis. (Shah et al., 1977).

In the given lines 856-SGR-54, 856-SGR-55, 856-SGR-63 and 856-SGR-67 impulsive source has been used.

3.1.3 Spread geometry

The spread used for the acquisition of seismic data on the given lines is symmetric split spread. For a 2D-seismic survey, all source and receiver points must lie in a straight line; this is called straight line shooting. Another type of shooting is called crooked line shooting, in which the receivers do not lie in a straight line and it is only done when straight line shooting is impossible due to some construction etc.

Split spread means that the geophone groups are kept on both the sides of the source point. Here the near offset is 125 m and the far offset is 2575 m as shown in Figure 3.1.

Figure 3.1. Spread geometry.

TR 1 TR48 Shot TR49 TR96

|------------- 2575 m -----------------|----- 125 m -----|------ 125 m -----|------------ 3075 m -------------|

Table 3.1. Acquisition parameters.

ACQUISITION PARAMETERS		
RECORDING DATA	Recorded by	OGDCL
	Field Party	S.P. 6
	Instrument	SN-338-HR
	Format	SEG B
	No. of Channels	96
	Sample Rate	2ms
SOURCE	Source	Dynamite
	Pattern	(9*2*4.5)
	S.P Interval	50M
RECIEVER	Receiver	Geophone
	Geophone Type	L-10
	Geophone Interval	2.08 M
	Geophone Frequency	20 Hz
	Group base	47.84 M
	Geophone Code	Linear
	Group interval	50

3.2 Seismic data processing

Once seismic data has been acquired on field, the second step is the processing of data. The computational analysis of recorded data to create a subsurface image and estimate the distribution of properties is called data processing. Data Processing involves sequence of operations, which are carried out according to a pre-defined program to extract useful information from a set of raw data (Al-Sadi, 1980). The main purpose of processing is to convert seismic data recorded in the field into a coherent cross section, indicating significant geological horizons into the earth subsurface, related to hydrocarbon detection and seismic stratigraphy (Dobrin and Savit, 1988).

The processing sequence involves corrections and adjustments, which increase the signal-to-noise ratio, correct the data for various physical processes that obscure the desired geological information of seismic data (Yilmaz, 2001).

Table 3.2. processing parameters used in the given seismic lines.

Demultiplex (resample to 2ms)
Geometry Description and Application
Spherical Divergence Correction
Deconvolution
CMP sort
Velocity analysis
Normal moveout
Datum Correction
Mute
Stack
Miser (Window 24 ms)
Constant Velocity Analysis
Stack
Finite difference Migration
Filter
Gain (RMS)
RNA

CHAPTER 4

SEISMIC INTERPRETATION

4.1 Introduction

Seismic interpretation is the transformation of seismic reflection data into a structural and stratigraphic picture through processing, contouring of subsurface horizons in time and in depth by applying suitable velocities. The seismic reflection interpretation usually consists of calculating the positions, identifying geologically the concealed interfaces or sharp transition zones from seismic pulses returned to the ground surface by reflection. The influence of varying geological conditions is eliminated along profile to transform the irregular travel time into acceptable subsurface model. This is very important for confident estimation of depth and geometry of bedrock or target horizon (Dobrin and Savit, 1976).

The major aim of seismic reflection surveying is to reveal as clearly as possible the structure of the subsurface. Geological meaning of seismic reflection is simply an indication of an acoustic boundary were we want to know that whether this boundary makes a stratigraphic contact with any other boundary. To distinguish the features that are not marked by sharp boundaries. Geologists ordinarily group the sequence of sedimentary rocks into units called 'Formations'. These formations can be described in terms of age, thickness and lithology of the constituent layer. To distinguish different formations on the basis of the seismic reflections is an important question in interpreting seismic data that may be structural, stratigraphic or lithological (Coffeen, 1984).

There are two main approaches for the interpretation of seismic sections

(a) Structural interpretation

(b) Stratigraphic interpretation

4.1.1 Structural interpretation

It is the study of reflector geometry on the basis of the reflection time. The main application of the structural analysis of seismic section is in the search for structural traps containing hydrocarbons. Most structural interpretation uses two way reflection times rather than depth. Time structural maps are constructed to display the geometry of selected reflection events. Seismic sections are analyzed to delineate the structural traps like folds, faults and anticlines. In this modern era of science and technology, software suits provide a great help in analyzing the seismic data both structurally and stratigraphically. Software helps the interpreter by automatically detecting the fault zones and then marking them on the whole project area. But for this the seismic data should be of high resolution.

For this particular project, emphasised was on the structural interpretation .due to the unavailability of these digital copies of the seismic lines, horizon-marking and time-reading was done manually.

4.1.2 Stratigraphic interpretation

Stratigraphic analysis involves the subdivision of seismic sections into sequence of reflections that are interpreted as a seismic expression of genetically related sedimentary sequences.

According to Dobrin and Savit, 1976 throughout the history of reflection method, its performance in locating hydrocarbons in stratigraphic traps has been much less favorable then in finding structurally entrapped oil and gas.

Stratigraphic oil traps can result from reefs, pinch outs or other features associated with erosional truncations, facies, transition and sand lenses associated with buried channel, lacks are similar sources. Different software provide help in stratigraphic analysis as well by overlaying different seismic attributes on seismic sections to detect pinch outs, truncations etc.

4.2 Interpretation of seismic lines of study area

Hard copies of four seismic lines were obtained from Landmark Resources (LMKR) for this project. These lines were

(1) 856-SGR-54

(2) 856-SGR-55

(3) 856-SGR-63

(4) 856-SGR-67

4.2.1 Identification of horizon

The first step, when starting the interpretation process is to judge the reflections and unconformities, if present, on seismic sections. Those reflectors are selected which are real, show good character and continuity and can be followed throughout area.

Reflectors are marked on the basis of dominant reflection coefficient, which displays that the area of prospecting has been subjected to tectonic and stratigraphic changes. Since the VSP data was not available for correlating the formations present in the area, the previous well data in time frame to assign the ages is used. The previous studies have confirmed on the time section horizons are marked by picking the continuous strain of wavelets running across the section. Confusion arise in marking the continuity because the wavelets are the traces tend to mix up or the sequence might break due to subsurface structural changes or abrupt litholigical changes or the most common problem faced is the presence of different type of noises, such noises cause the distortion of the signal. Therefore in order to decide that whether the sequence continues towards the upper horizon or the lower, a broader view of interpreter, knowledge about the area and considerable experience would help in marking a correct picture.

Four reflectors were marked in the seismic sections of the study area, which were designated as Horizon A (probable Parh Formation), Horizon B (probable Goru Formation), Horizon C (probable Cretaceous Sands) and Horizon D (probable Chiltan Limestone) and then this information is shifted to other lines by tying the seismic sections.

4.2.2 Identification of faults

The next step in the seismic interpretation is identification of faults. Faults are the broken reflectors in the seismic section, which continues after slight distortion in the pattern of the horizon (Campbell, 1965). The detection of faults on seismic section can be quite easy under favorable circumstances. The study is the part of the extensional regime. Therefore normal faults forming the host and graben are present.

In seismic sections that were interpreted no major fault was observed rather there were some minor faults present which were marked. Figures (4.1, 4.2, 4.3 and 4.4) show interpreted seismic sections of seismic lines 856-SGR-54, 856-SGR-55, 856-SGR-63 and 856-SGR-67 respectively.

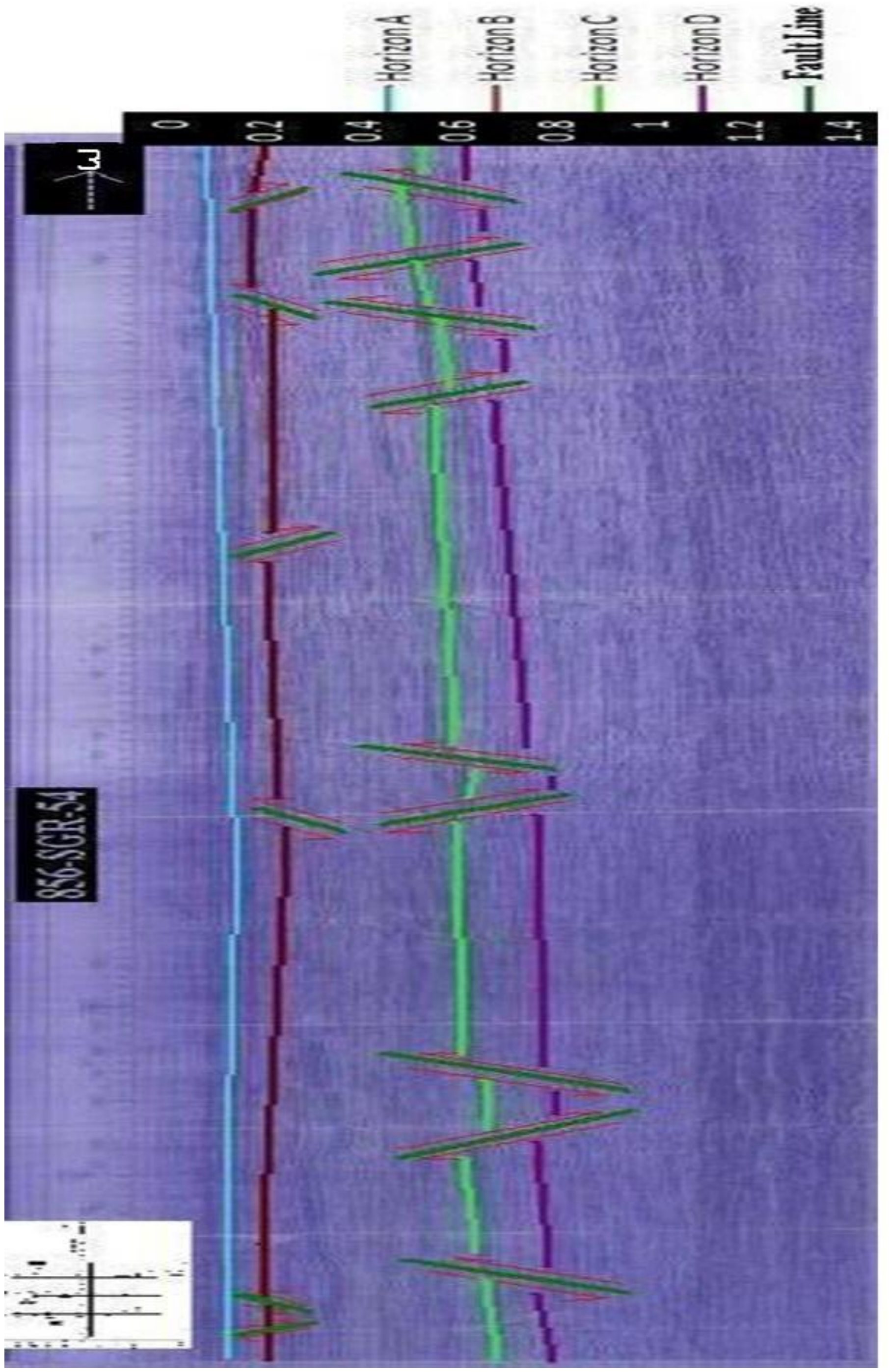

Figure 4.1. Interpretation of Seismic line 856-SGR-54

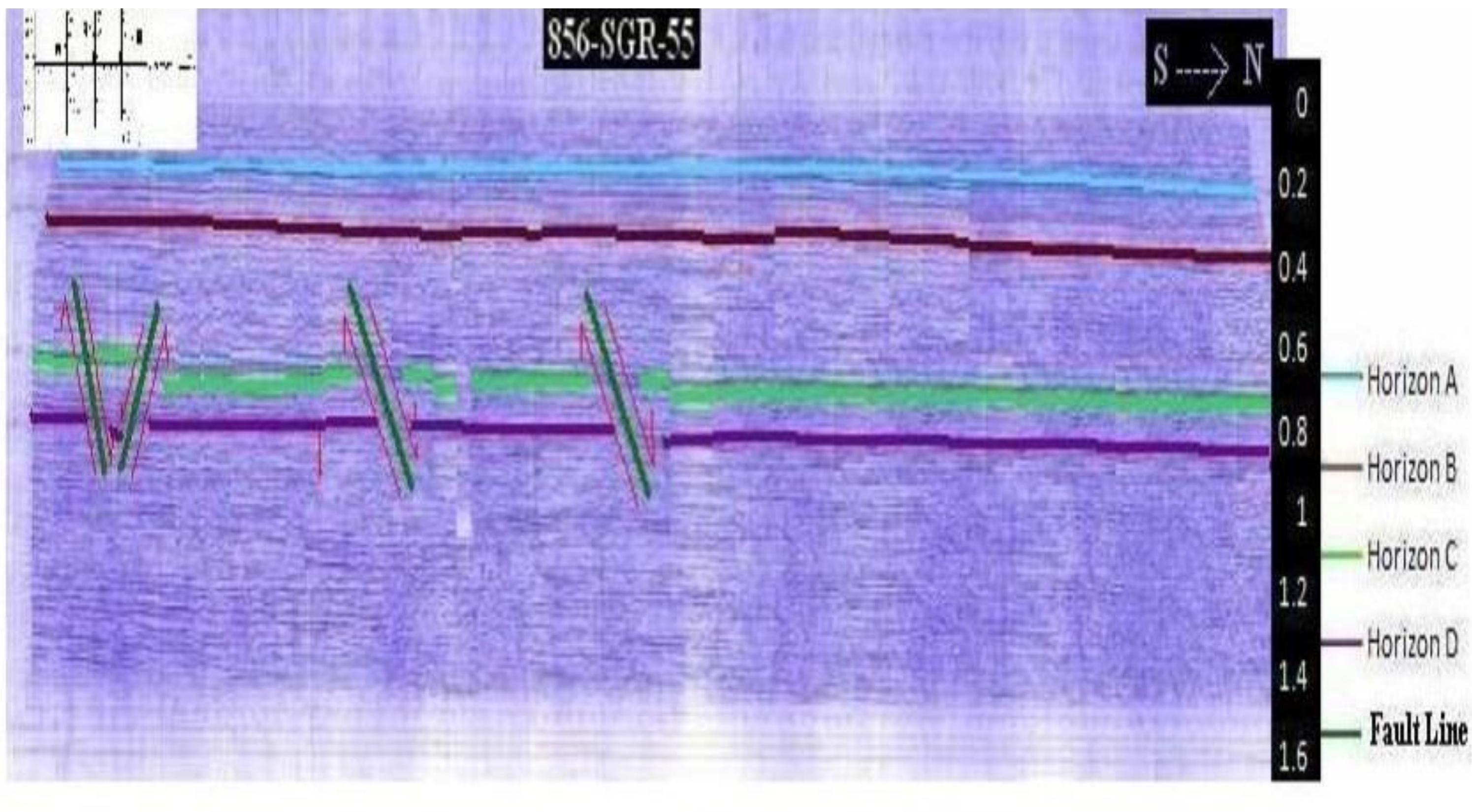

Figure 4.2. Interpretation of Seismic line 856-SGR-55

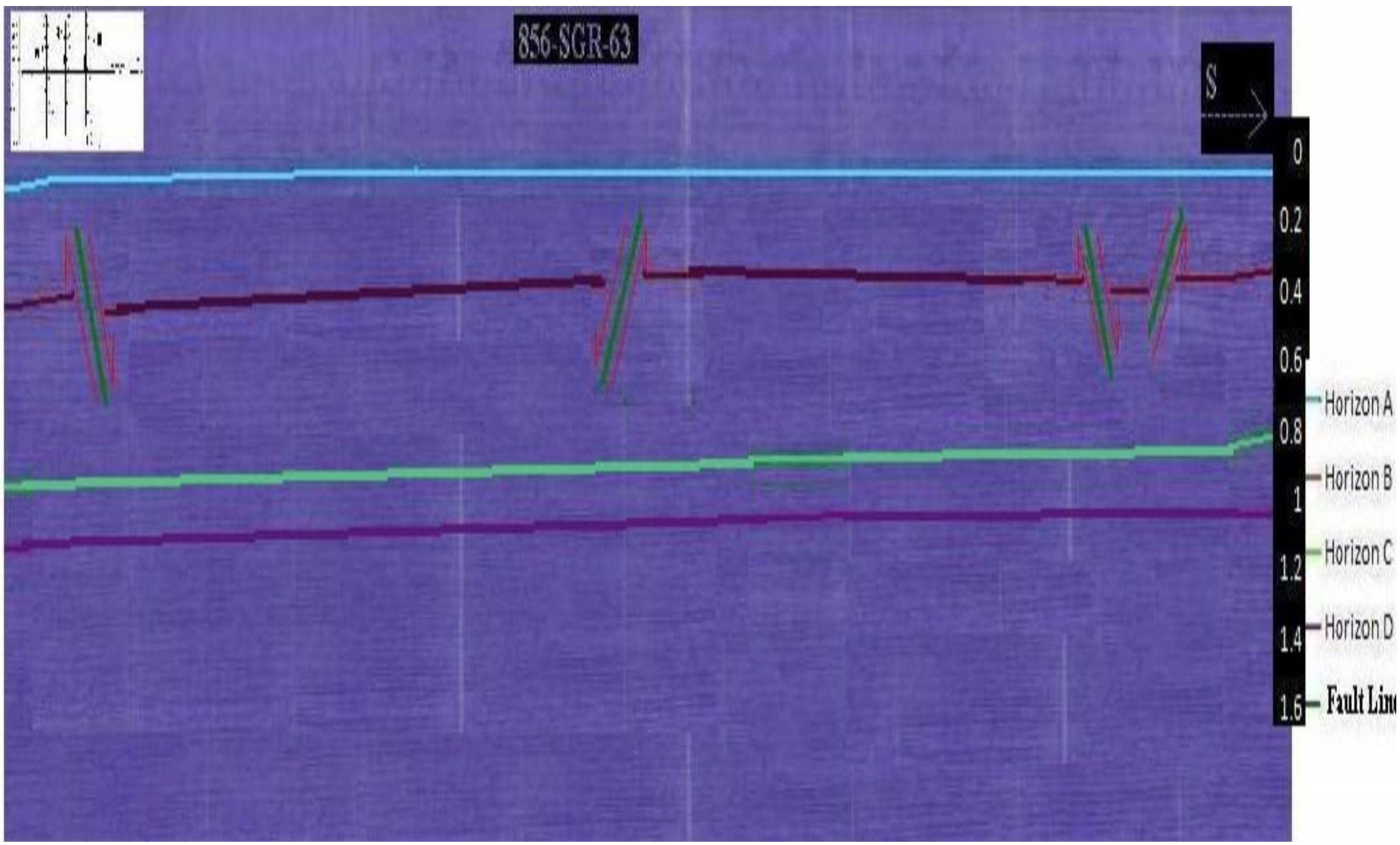

Figure 4.3. Interpretation of Seismic line 856-SGR-63.

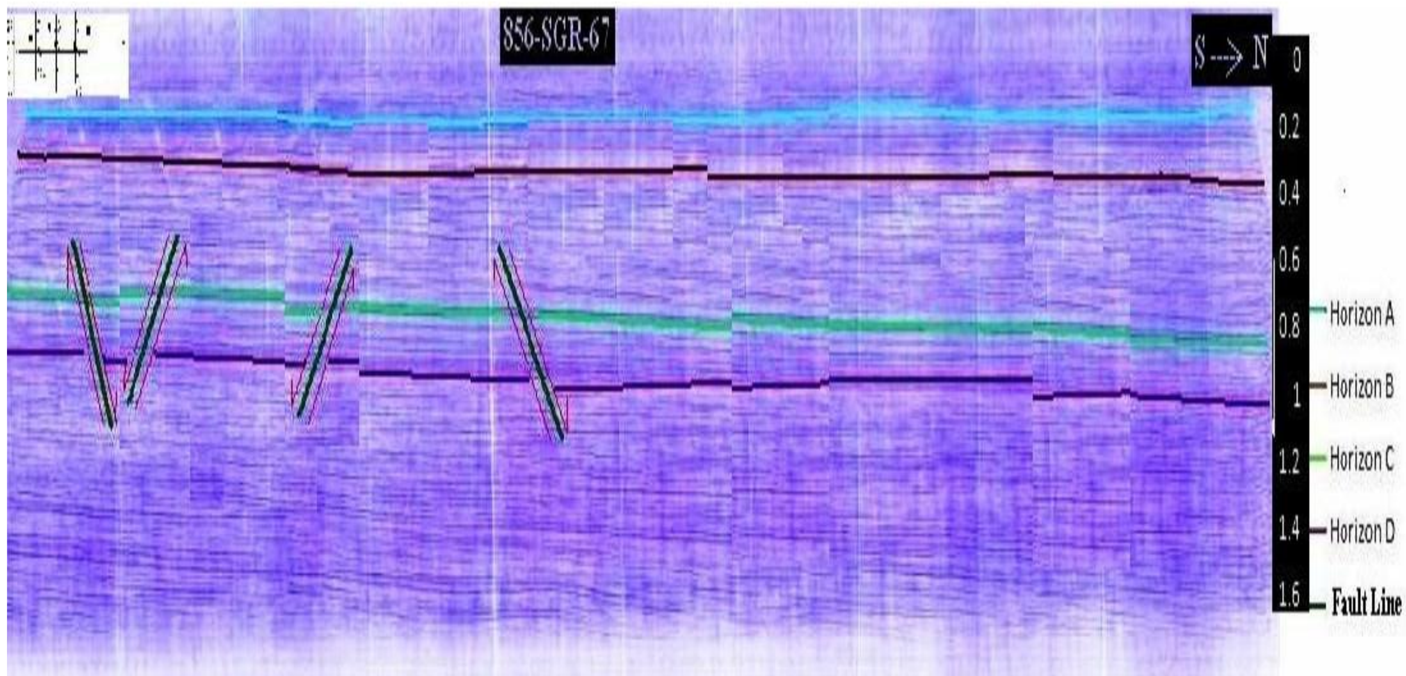

Figure 4.4. Interpretation of Seismic line 856-SGR-67.

4.3 Seismic time section

Time sections are the Figures which show us the two-way travel time curves. Time sections are generated by plotting shot points (SP) against two-way travel time. Figures (4.5. 4.6, 4.7 and 4.8) are showing the time sections of seismic lines 856-SGR-54, 856-SGR-55, 856-SGR-63 and 856-SGR-67 respectively.

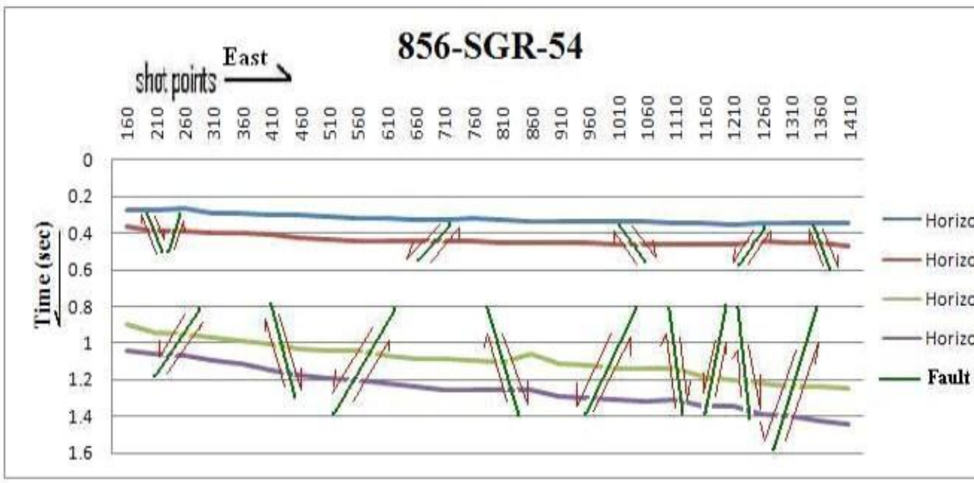

Figure 4.5. Time section of line 856-SGR-54.

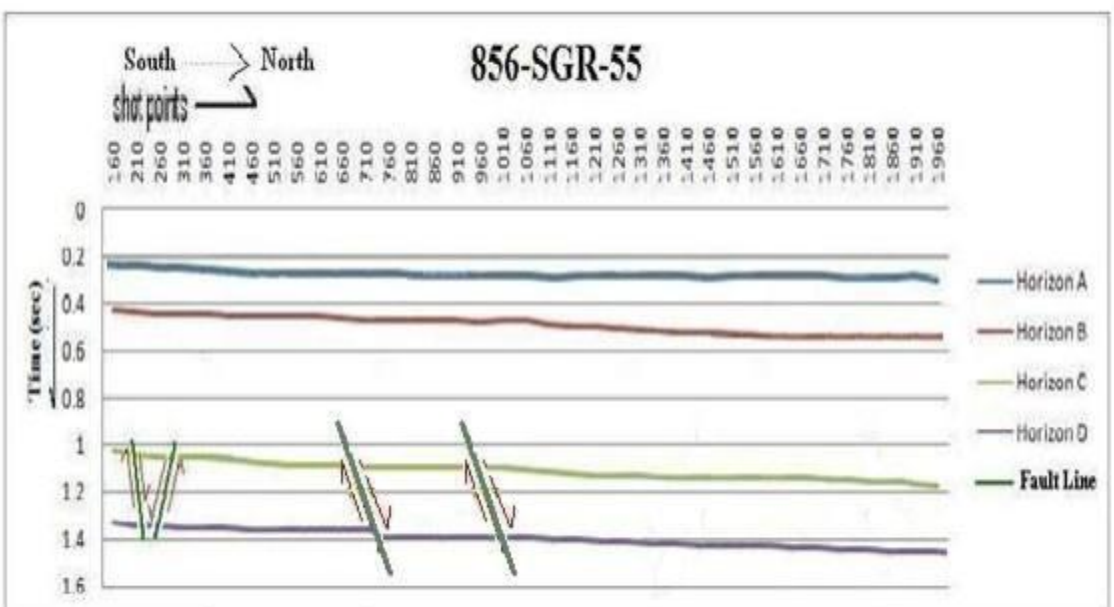

Figure 4.6. Time section of line 856-SGR-55.

Figure 4.7. Time section of line 856-SGR-63.

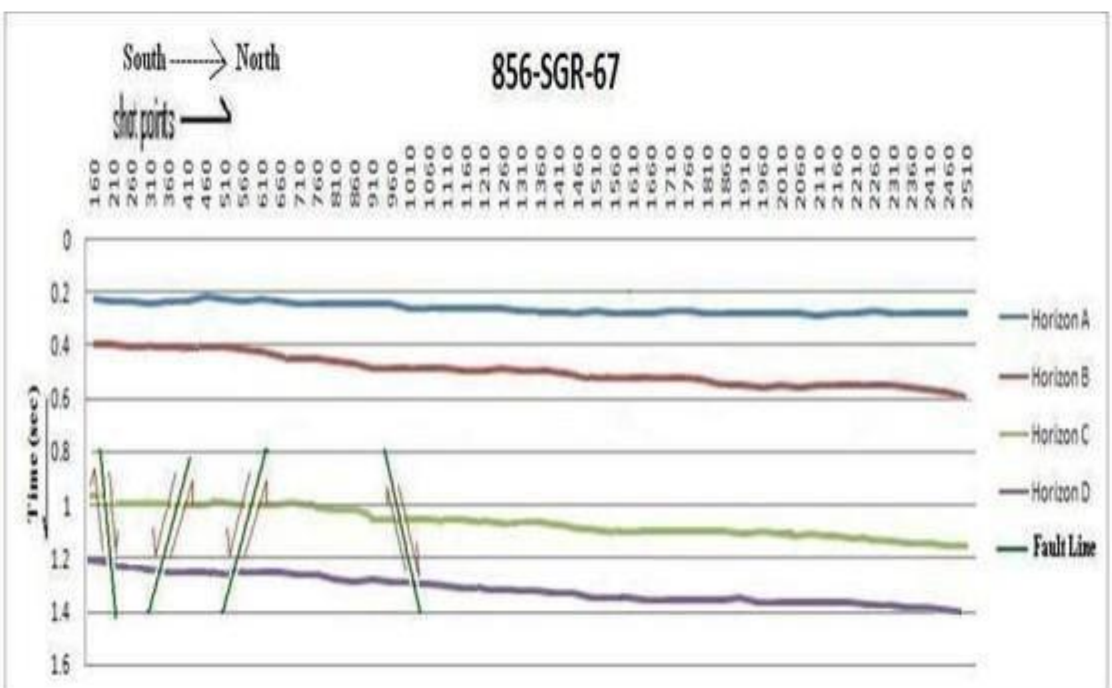

Figure 4.8. Time section of line 856-SGR-67.

4.4 Method of preparing depth section

The depth section provides the configuration of reflectors in similar way as it is in the time section. To determine the depth, the initial step is to read times of each reflector from seismic section. Using the appropriate velocity values and time, the depth of each reflector is calculated as follows:

$$\textbf{Depth} = (V \times T/2)$$

Where,

V= velocity of respective reflector (m/s)

T= two way travel time of each reflector (sec)

4.5 Depth section

Generally the depth section gives the configuration of reflectors in the same way as the time section. Remove the kinks for the horizons as much as possible in order to obtain the smoother horizons (Khan et al., 2010). Depth sections are generated by plotting shot points (SP) against depth. Figures (4.9, 4.10, 4.11 and 4.12) are showing the depth sections of seismic lines 856-SGR-54, 856-SGR-55, 856-SGR-63 and 856-SGR-67 respectively.

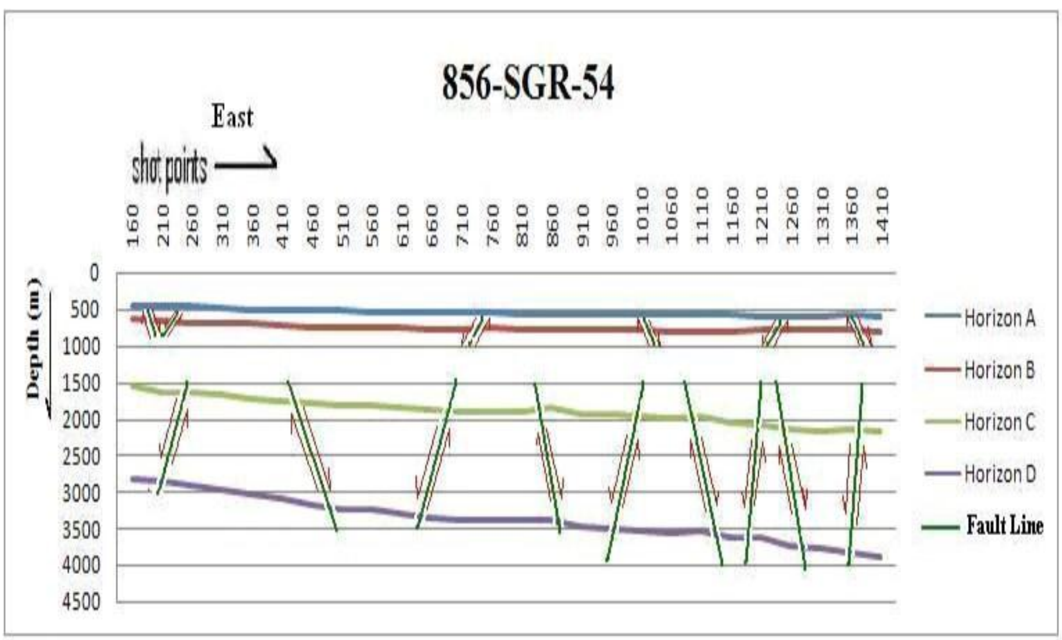

Figure 4.9. Depth section of line 856-SGR-54.

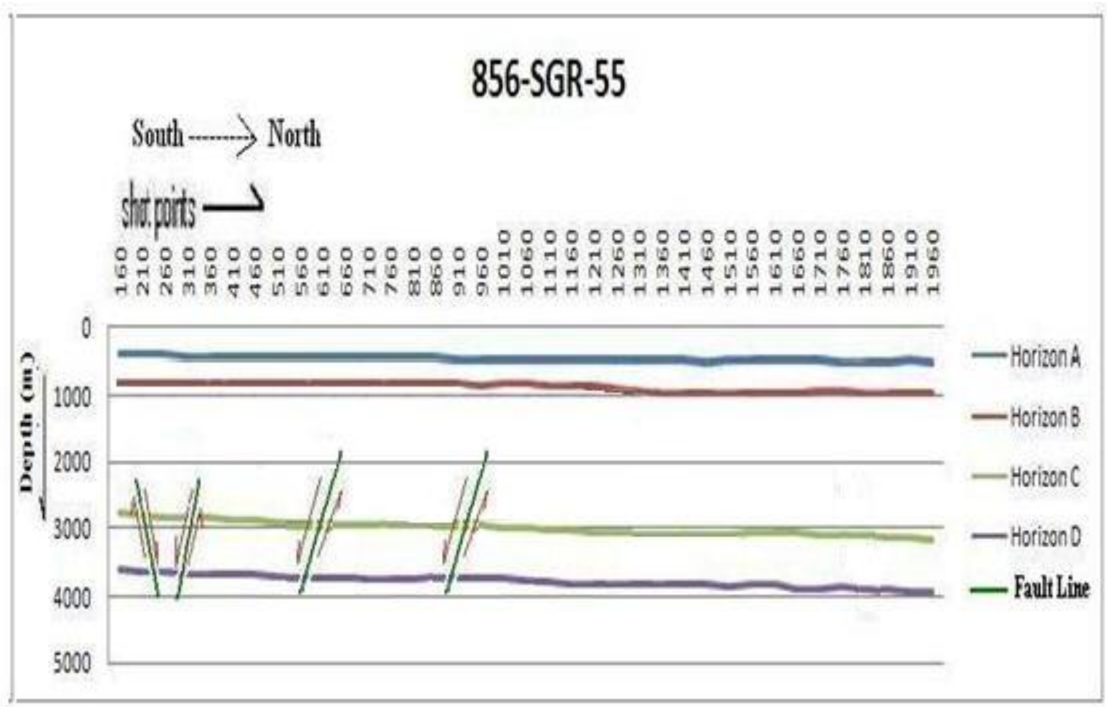

Figure 4.10. Depth section of line 856-SGR-55.

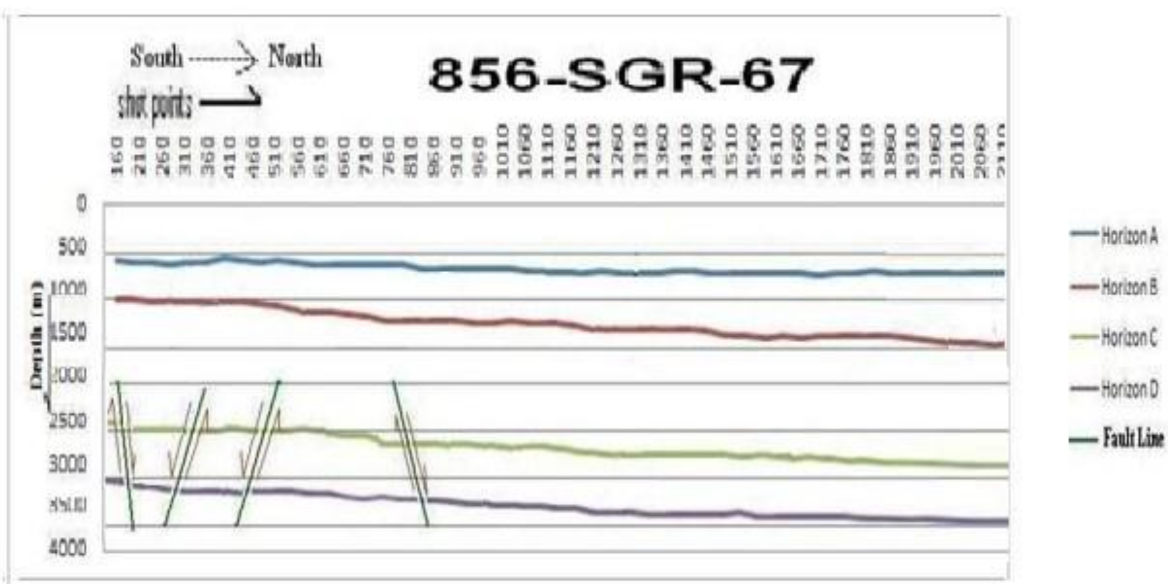

Figure 4.11. Depth section of line 856-SGR-67.

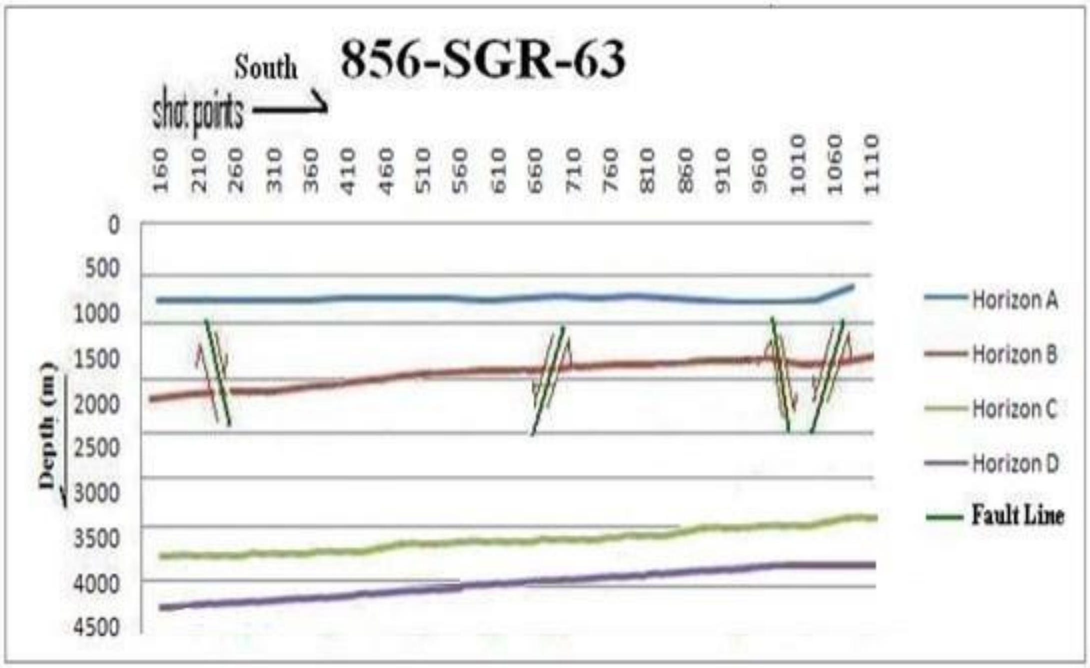

Figure 4.12. Depth section of line 856-SGR-63

4.6 Time contour map

To make a time contour map it is necessary that more than one seismic sections of the same area must be interpreted. All 4 seismic lines (856-SGR-54, 856-SGR-55, 856-SGR-63 and 856-SGR-67) are interpreted and the time contour maps for Horizon A, Horizon B,Horizon C and Horizon D are generated.

The time contour map is made by the following procedure

(1) Transfer the time reading from seismic time section to their respective seismic lines on the base map after specific interval.

(2) Join the points of equal values on the seismic lines to construct iso-contour lines.

Figures (4.13, 4.14, 4.15 and 4.16) represent time contour maps for Horizon A, Horizon B, Horizon C and Horizon D respectively.

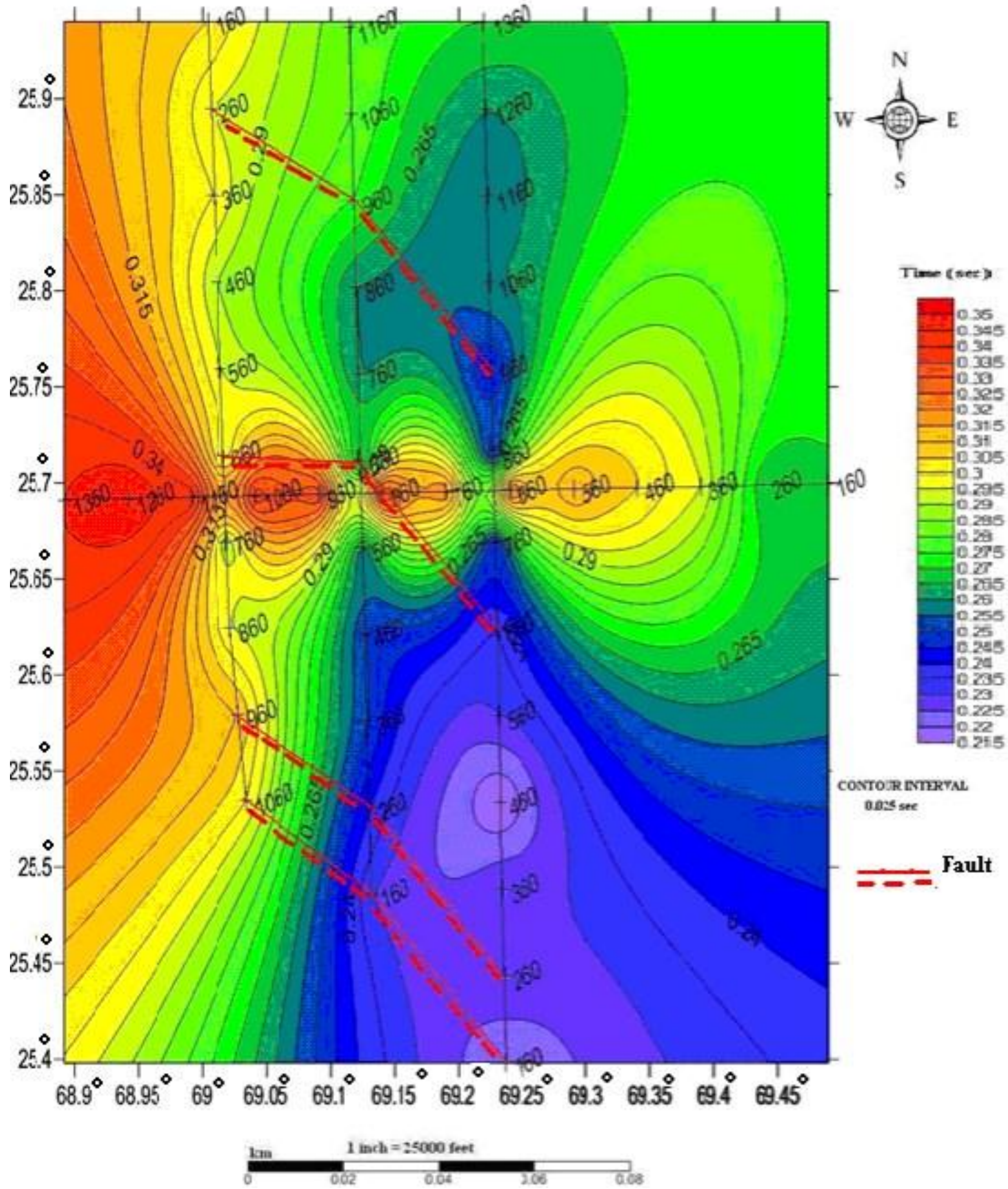

Figure 4.13. Time contour map of Horizon A

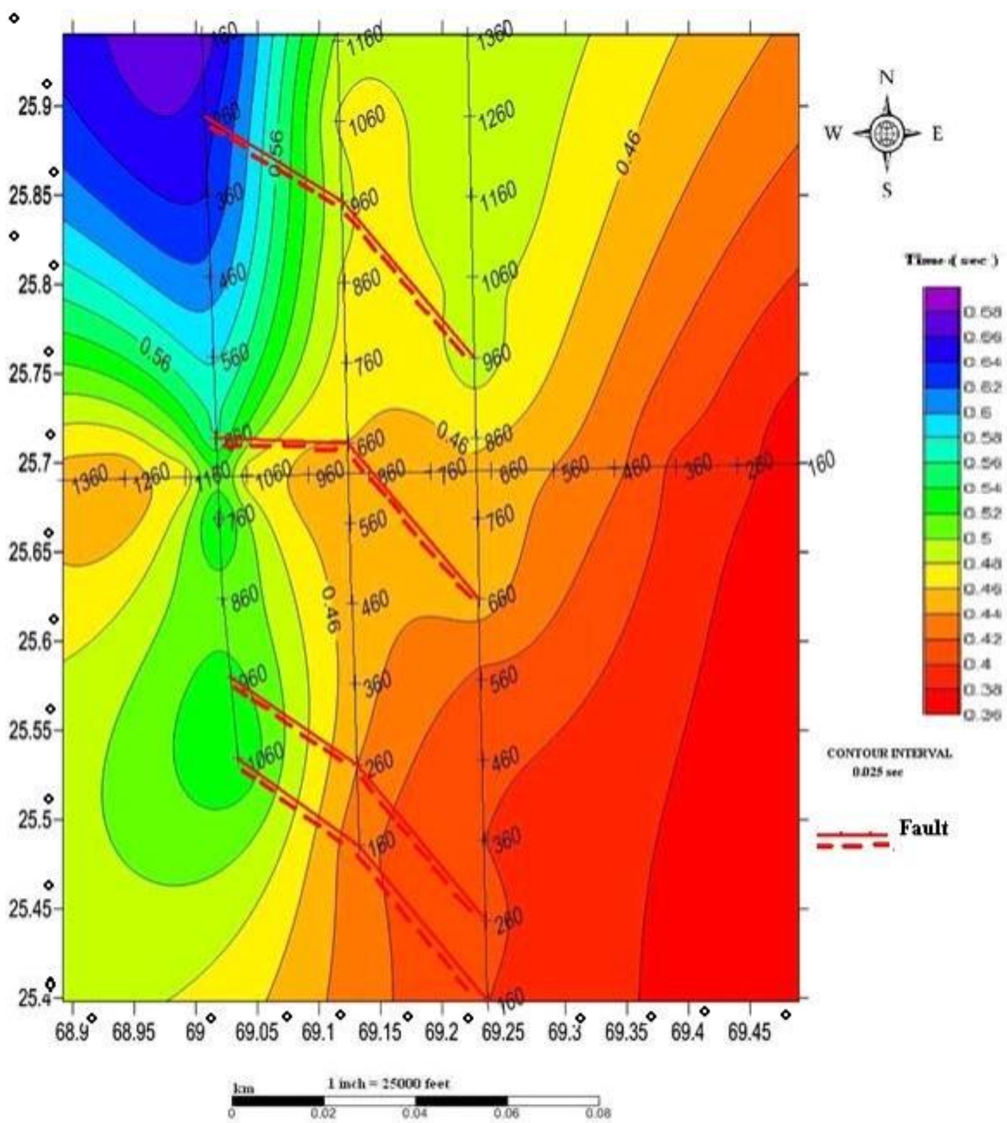

Figure 4.14. Time contour map of Horizan B

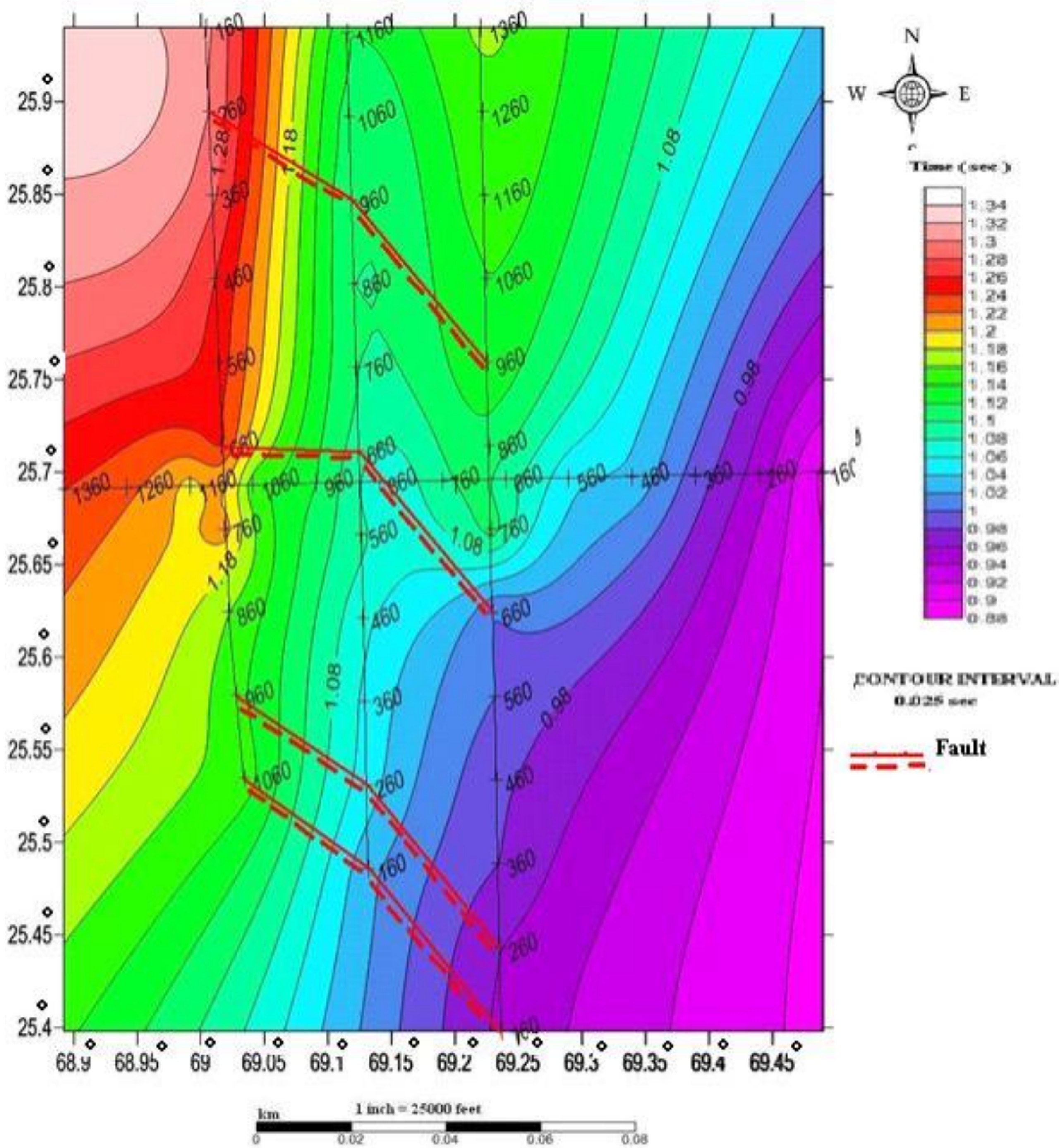

Figure 4.15. Time contour map of Horizon C

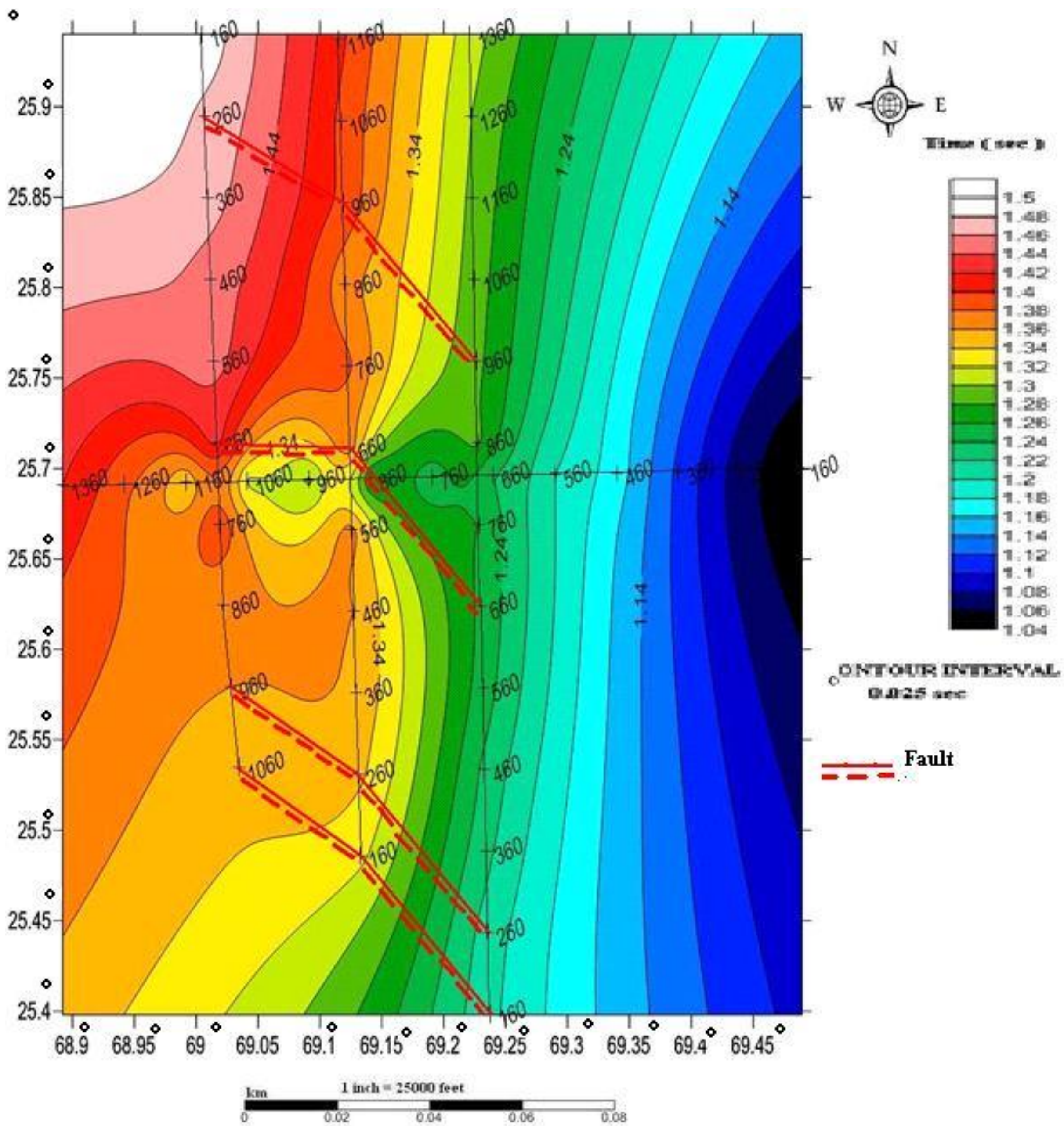

Figure 4.16. Time contour map of Horizon D

4.7 Depth Contour Map

The depth of the Horizon A , Horizon B , Horizon C and Horizon D on the base map are contoured to make depth contour maps which are shown in Figures (4.17, 4.18, 4.19 and 4.20) respectively. The contours show the exact locations of the structures present in the area.

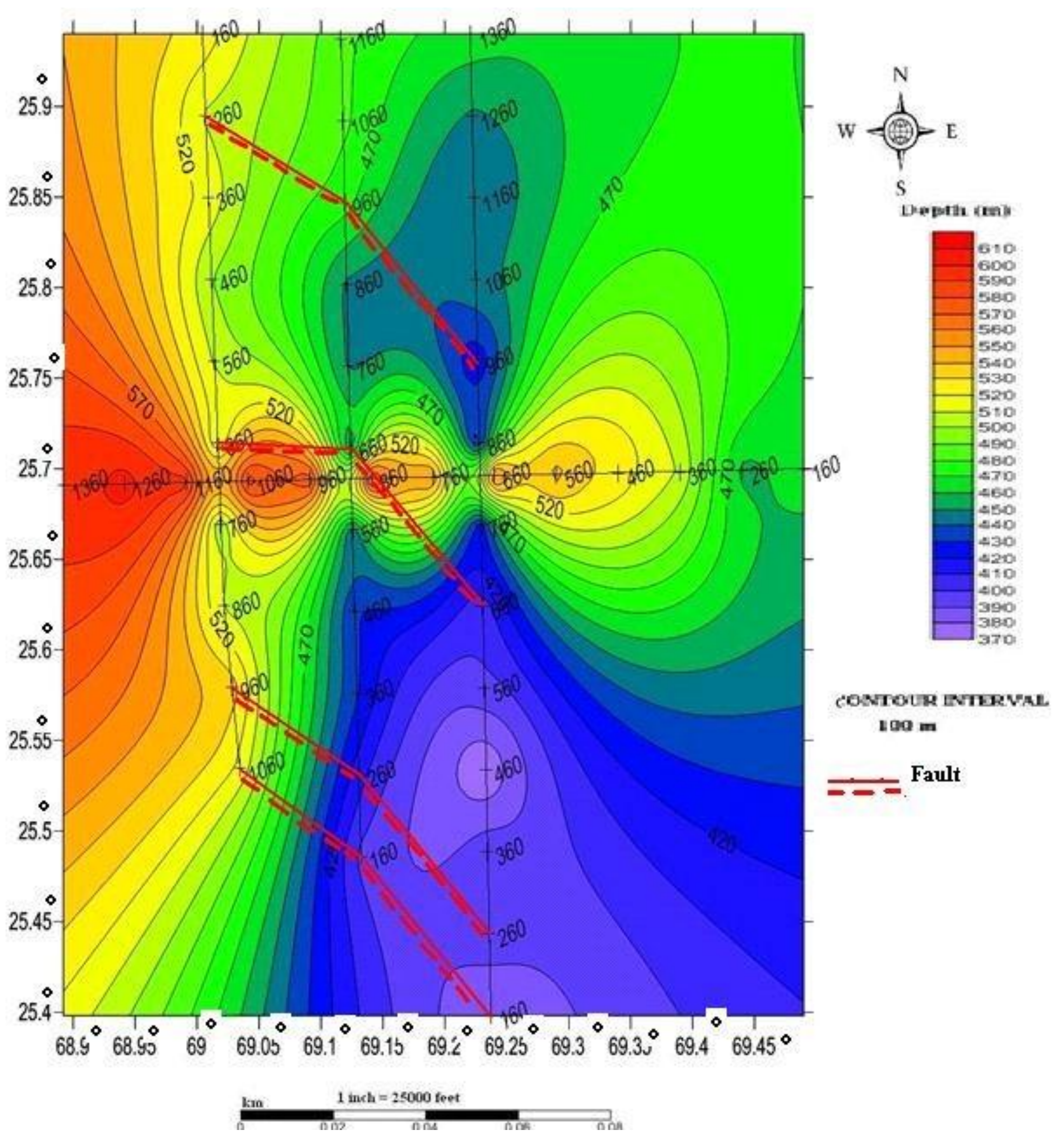

Figure 4.17. Depth contour map of Horizon A

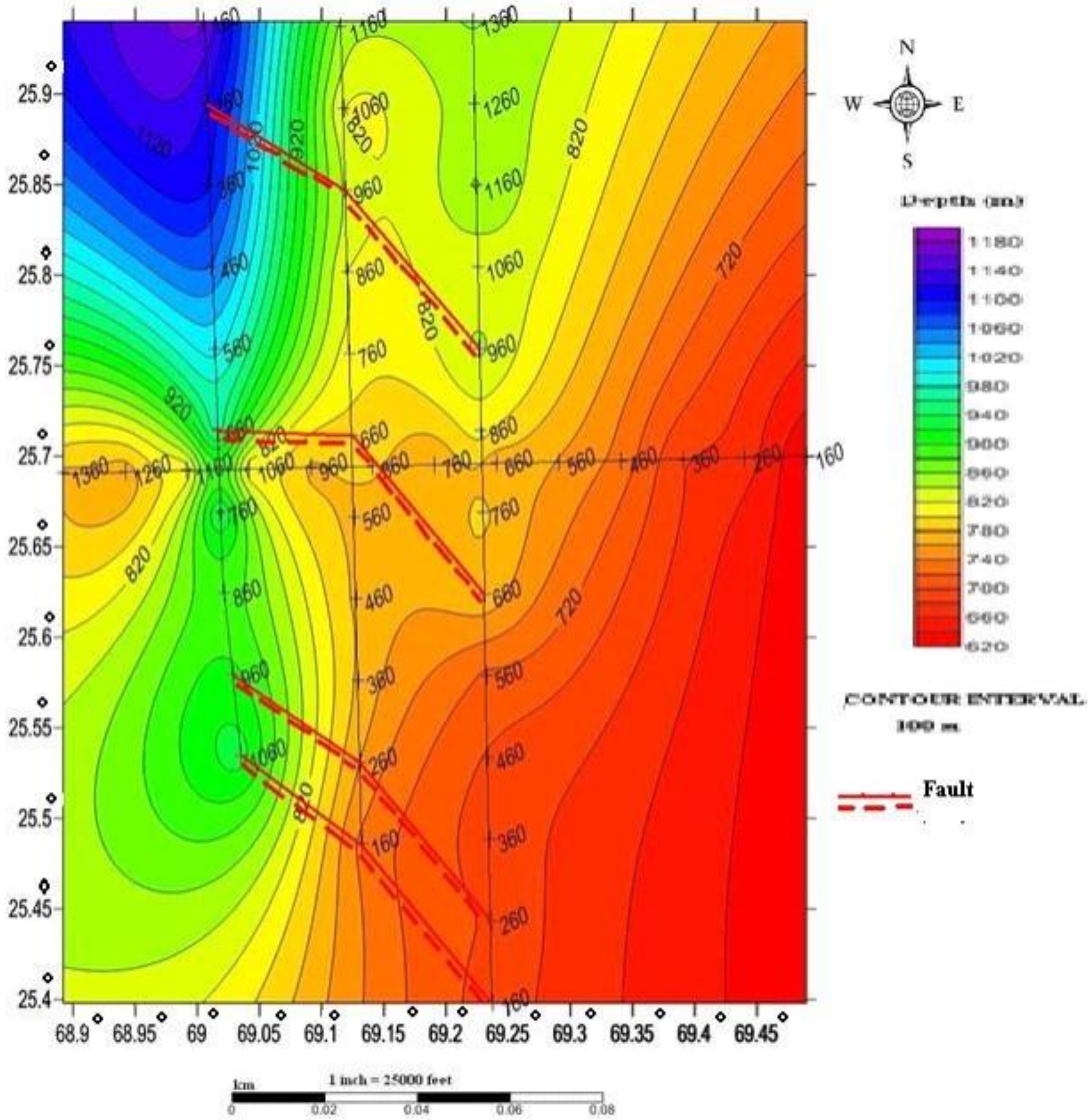

Figure 4.18. Depth contour map of Horizon B.

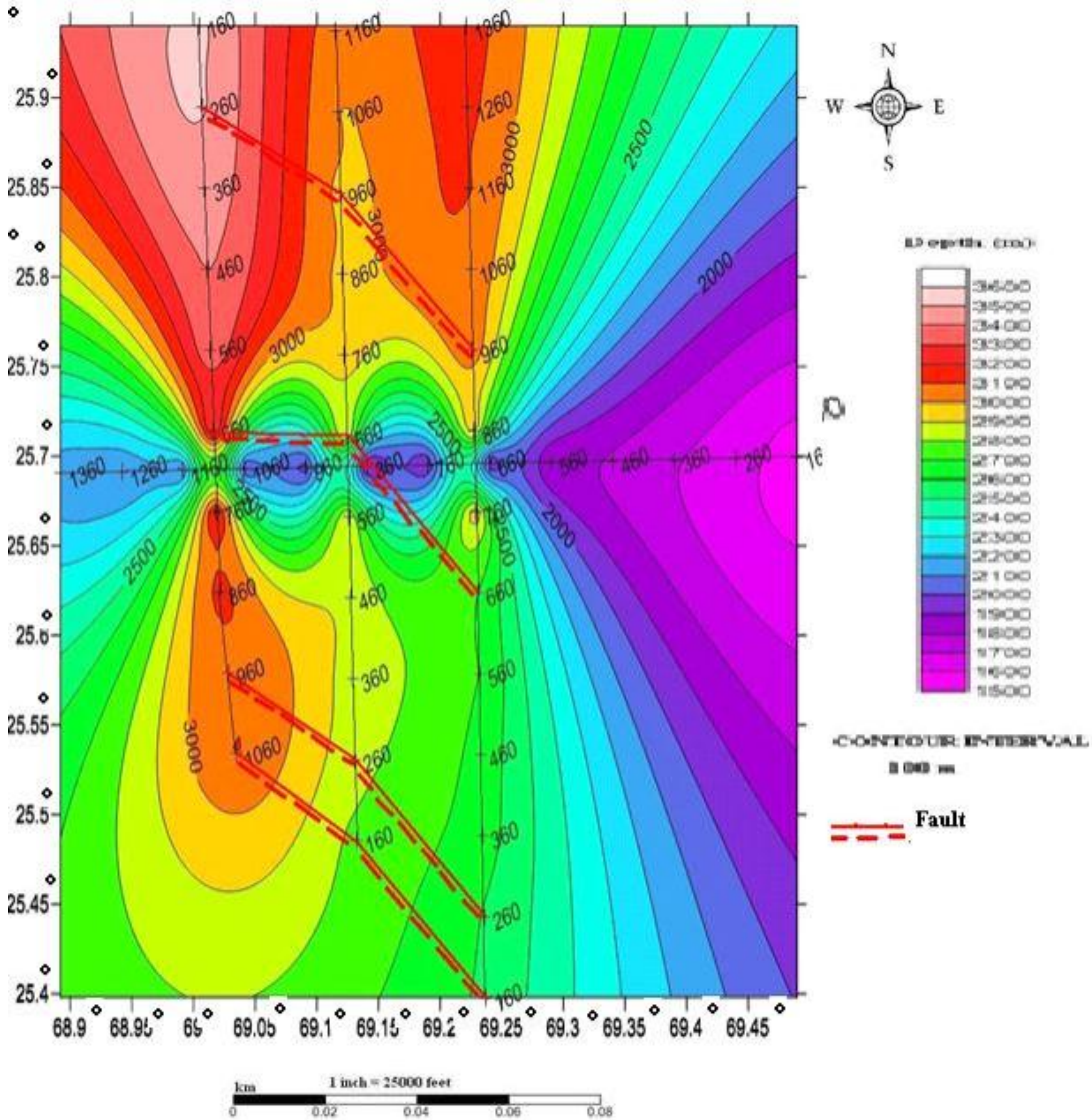

Figure 4.19. Depth contour map of horizon C

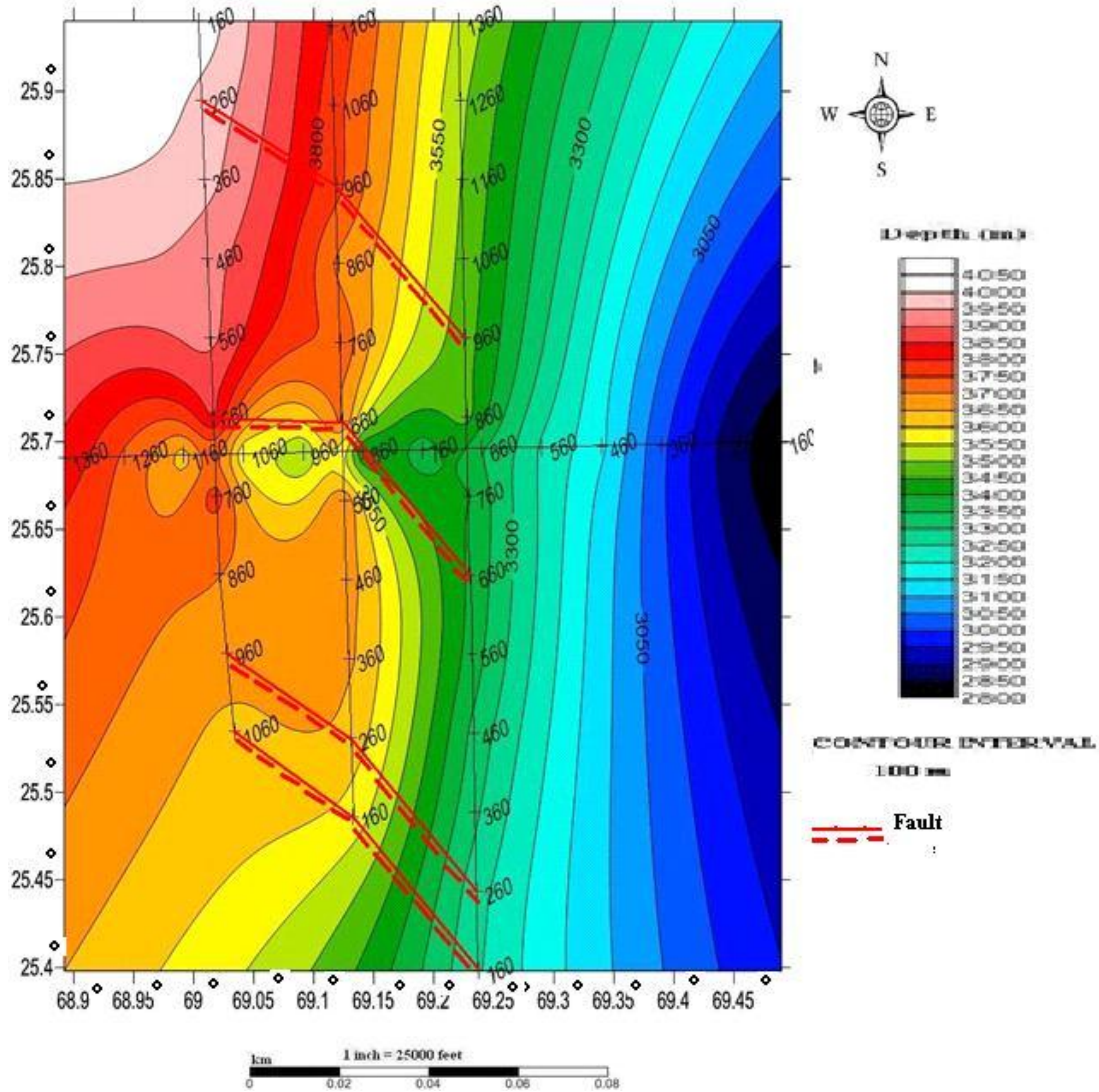

Figure 4.20. Depth contour map of Horizon D

CONCLUSIONS

(1) Extensional regime in this area is confirmed, showing normal faulting.

(2) Horst and graben structure are formed in the area.

(3) Structural pattern is east-west trending.

(4) The dominant normal faulting in our study is the likelihood of extensional regime.

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