2D Seismic Interpretation of Tajjal/Kadanwari Area, Lower Indus Basin Integrated with Petro physics Analysis

By

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CERTIFICATE OF APPROVAL

This dissertation by **AMBER NAEEM ABBASI** d/o **MUHAMMAD NAEEM ABBASI** is accepted in its present form by the Department of Earth Sciences, Quaid-i-Azam University Islamabad as it satisfies the requirement for the award of degree of **BS.hons Geophysics.**

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DEDICATION

My whole work is dedicated to my Parents, Teachers, Friends and Siblings especially to my Brother **FAISAL NAEEM ABBASI** whose valuable ideas, motivation and encouragement made me able to touch this stage.

Acknowledgement

All praises for **Allah Almighty**, the most beneficent and the most merciful; first of all, I am thankful to Allah Almighty, who is the Lord of the worlds, who gave me strength, ability and opportunity to seek knowledge, His blessings enabled me to complete this research work. I offer my gratitude to last prophet **Muhammad (PBUH).**

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I am indebted to my loving parents and brothers who encouraged and motivate me to face the challenges of life during the course of my academic career. I am also highly indebted to my friends: Haider Ali Khan, Zubia Rasheed, Hajra Rasheed,, Muneeb-ur-Rehman, Usman Nadeem Farooqi, Tayyab Hamid, Hamza Hamid and Oun ur Rab for their encouragment and support.

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ABSTRACT

The objective of the Research work is to evaluate potential leads and prospects in Tajjal Area, Kandanwari Gas Field, Lower Indus Basin, Pakistan by interpreting Seismic Sections for structural and stratigraphy study, by using Forward Modeling and Preparation of Fault Model. Rock physics and Petrophysics analysis of kadanwari area using Well Data is the secondary objective of Rearch.

Attribute analysis are also done in this research using seismic and well data.

Petrophysical studies Lower Goru Formation include the determination of the Total Porosity and Effective Porosity, Calculation of Shale Volume, Water Saturation, hydrocarbon Saturation and Moveable Hydrocarbons. The result shows the presence of clean Sandstone and Gas Sands with high porosity in the productive zones. Many Plots and Cross Plots are made for the Lithology identification.

CONTENTS

CHAPTER # 01

INTRODUCTION

1.1 Introduction to the Study Area:

Geographically Tajjal Gas field is located about 120 Kms south east of Sukkur in Sindh Province of Pakistan. Geologically Tajjal Gas Field (Gambat Block) lies in Lower Indus Basin -a proven Geological Province in the Islamic Republic of Pakistan. Indus basin is the part of Indus-Gangas lowland, a vast depression which has filed with the layers of marine and continental sediments over Preacambrian to Recant time. On the basis of different geological features the basin is further classified in Upper Indus basin, Central Indus basin, and Southern Indus basin. Our area is important for its gas fields mainly KADANWARI, SAWAN and MIANO etc. the geological and geographical boundary of Tajjal area is mention in fig

a) Geographical Location of Tajjal Area:

- **Longitude of the area is 69° 03 12" E**
- **Lattitude of the area is 26° 53 45 N**

Figure 1.1 Location Map of The area (www.google-earth.com)

b) Geological Boundary of Tajjal Area:

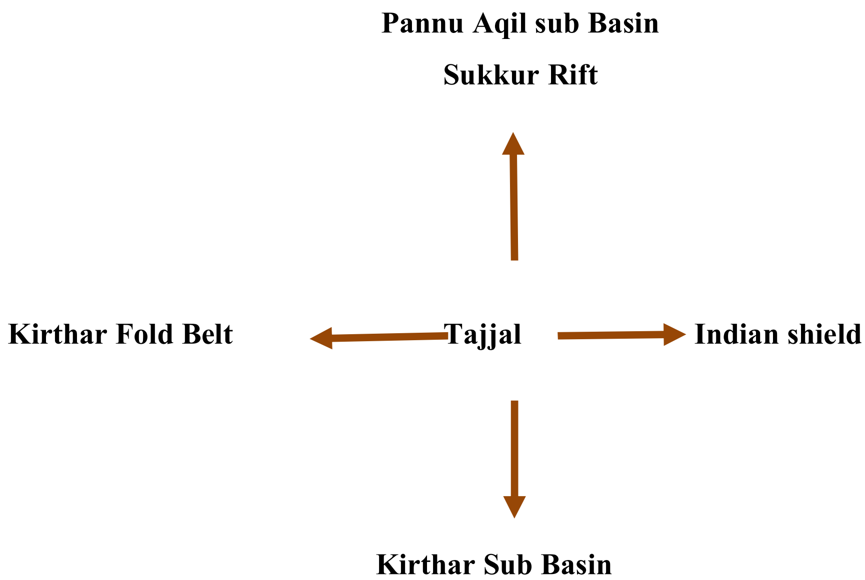


Fig 1.2 geological boundary of Tajjal Area

c) Geographical boundary of Tajjal Area:

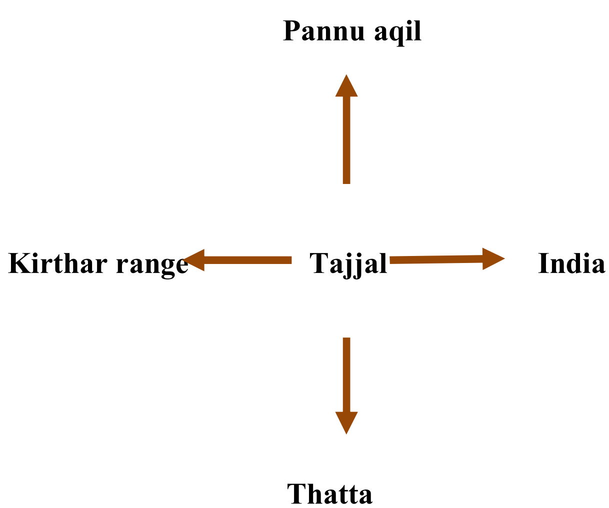


Fig 1.3 geographical boundary of Tajjal Area

1.2) Exploration History of the Study Area:

On July 21, 1987 the Petroleum Concession Agreement for Tajjal Block was awarded to a consortium comprising of LASMO (which was afterwards acquired by Eni AEP-Agip Exploration & Production).

Kadanwari gas field was discovered in 1989 and brought on stream in May 1995. The field was discovered by the K-1 well, which was drilled in Sep 1989. Interpretation of seismic data acquired by ENI Pakistan in November 1989 was used in SEG-Y format for Structural and Stratigraphical Interpretation. Since the study area is part of the Lower Indus Basin which is an extensional regime resulting extensive Horst and Graben Geometry that may be considered as probable hydrocarbon bearing zones. The area is known for the existence of stratigraphic, structural and combination of both traps. The organic rich shales within the Sembar Formation are the essential hydrocarbon generating source rock of this region including other parts of the Indus Basin. Sandstones of Lower Goru Formations are the primary reservoirs. Other reservoirs are Eocene to Paleocene carbonates and sandstone. The seismic data used for this research confirmed successfully the geological and stratigraphic set up.

The reservoir section at kadanwari belongs to the lower goru sand while sealing is provided bu the upper goru shaly sequence. The lower goru sands have been divided into further sub units of sand.each company working in the area has its own sub-division; here we are following subdivision which has divided reservoir units into seven sand bearing members, b to h. the main producing sands in the area are e and g but d, and f have also produced in few well.

1.3) Base Map and Integrated Geophysical Data:

2d seismic reflection profile data for study area were acquired by LASMO oil Pakistan ltd. (now ENI). Following seismic lines and well log data is depicted in table.

Table 1.1: seismic lines of study area:

S.No	Line name	Shot points	direction	Line type
1	GTJ89-512	100-378	E-W	Dip
2	GTJ89-516	101-415	E-W	Dip
3	GTJ89-206	100-312	E-W	Dip
4	GTJ89-207	100-312	N-S	Strike

Table 1.2: wells selected for study area

S.NO	Well name	Latitude (x)	Longitude (y)	Total depth(m)	Elevation (kb)	Status
1	Kadanwari-14	027.074444	069.033889	3505.0000	60.6000	Gas
2	Kadanwari-08	027.172705	069.236612	3545.00000	61.82000	Gas

1.4) Base Map:

It is the map that shows all lines under consideration of the area and it also shows the boundary of the block concession. Although two lines are not sufficient to map the structure, an attempt is made to make base map and contouring by combination of adjacent lines.

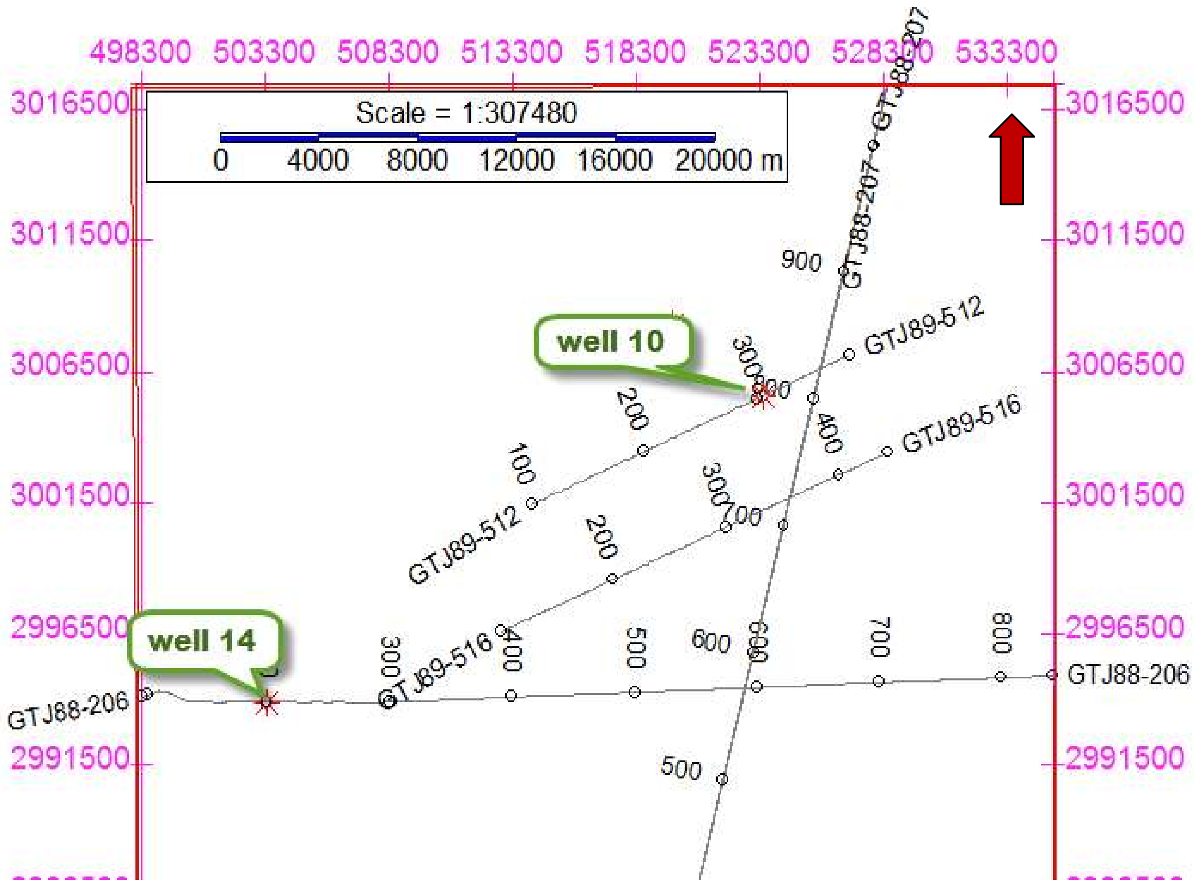


Fig: base map of the area, showing location and orientation of seismic lines

1.5 field parameter:

a) RECORDING PARAMETERS

- INSTRUMENT…………………………….348(no.158)
- RECORD LENGTH………………………..6 SECS
- SAMPLING RATE…………………………4 MSEC
- RECORDING FILTER……………………..out-125 HZ
- TAPE FORMAT…………………………….out
- NOTCH FILTR……………………………..SEG-Y 6250 bpi
- POLARITY………………………………….upward ground

MOVEMENT IS A NEGATIVE

NUMBER ON TAPE

B) SOURCE

- SOURCE……………………………VIBROSEIS
- NUMBER OF VIBRATIONS………3
- NUMBER OF SWEEPS PER VP…..12(4*3)
- SHOT INTERVAL………………….50 mters
- SWEEP FREQUNCY……………….15 to 80 hz
- SWEEP LENGTH………………..…10 secs

C) DETECTORS

- NMBER OF GROUPS………………..120
- GEOPHONE TYPE…………………..sm4 u/b 10 hz
- GEOPHONE PER GROUP……………36
- GROUP INTERVAL…………………..50 m
- GEOPHONE SPACING ……………….1.39 m
- ARRAY LENGTH ………………………48.6 m

LAID SYMMETRICALLY ABOUT STATION

1.6 PROCESSING SEQUENCE

a) DEMULTIPLEX

DEMILTIPLEX, OUTPUT FORMAT-WGC CODE 4

DISPLAY ALL RECORDS

b) PROCESSOR

- DELETE ALL BAD TRACES
- ASSIGN FIELD GEOMETRY AND ELEVATION BASED STATICS TO TRACE HEADER

d) F-K DOMAIN FILTER

ON SHOT DOMAIN

PASS OF SIGNAL LIMIT=11MS/TRACE

e) SORT

SORT TO CDF ORDER

e) DECONVOLUTION

A) GEOMETRIC SPREADING

B)SURFACE CONSISTENT DECONVOLUTION

NUMBER OF WINDOWS

MINIMUM PRDICTIVE LAG4MS

C) WHOLE TACE BALANCE TO 2000 RMS

f) REFRACTION STATICS

VELOCITY CONTROL FROM UPHOLES

AND INTERSECTING LINES

OFFSET USED: 75-625 M

g) RESIDUAL STATICS

WINDOW 100-3200 MS

SHIFT LIMIT24 MS

MODELLED OVER 50 CDP'S

a) **VELOCITY ANALYSIS**

ANALYSIS AT ABOUT 60 CDP INTERVALS

7CDP'S SUMMED PER ANALYSIS

11 CDP'S IN VELOCITY FUNCTION STACK

b) **NMO, MUTE AND STACK**

VELOCITY AS LISTED ON TOPHEADER

LIMITED STRENGHT MUTE- 200% WITH

MUTE APPLIED AFTER NMO:

STACK NOMINALLY 60 FOLD

a) **NOISE ATTENUATION**

ATTENUATION OF RANDOM NOISE

BTY LINEAR PREDICTION

OPERATOR WIDTH TRACES

LENGTH OF WINDOW W500MS

WIDTH OF WINDOWW 75 TRACES

b) **PRE MIGRATION SCALING**

c) **KIRCHOF MIGRATION**

100% STACKING VELOCITIES

a) **TRACE EQUALIZATION**

REFLECTION STRENGHT GAIN RMS=2000

STANDOUT=1.5 FILTER=400 MSEC LONG

a) **PLAYBACK**

PRESENTATION VA/SO

GAIN9DB

DISPLAY POLARITY NORMAL

DATUM MEAN SEA LEVEL

1.7 SOFTWARE PURPOSE:

Software tools used in the thesis workflow have been summarized below along with their functionality.

1. **Kingdom suite**
   - Base map generation
   - Basic interpretation
   - DEM contours
   - Petro physics
   - Rock physics and engineering properties
2. **Kingdom SMT**

   Seismic attributes analysis

1.8 Aims and Objectives:

The objective of the research work is mapping and interpretation of lower goru formation in kadanwari gas field and identification of potential leads in the area.

1.7 Methodology:

To achieve the desired goal, the study was carried out in the following systematic manner:

Seismic interpretation includes:

- Mistie analysis(bulk & interactive)
- Synthetic seismogram genetation
- Synthetic and seismic matiching
- Synthetic display

- Fault interpretation(unassigned fault)
- Reflector marking with well picks
- Horizon interpretation (arbitrary lines)
- fault model (assigned fault)
- time contour maps(contouring & gridding)
- preparation of averaged velocity maps
- depth contours maps(contouring & gridding)
- isochrones maps and isopack maps
- identification of reservoir lithology

petrophysical analysis includes following steps:

1. marking the zone of interest
2. preview input log curves
3. calculation of volume of shale
4. calculation of porosity(total & effective)
5. calculation of water saturation
6. calculation of hydrocarbon saturation
7. cross plots of different kadanwari wells includes,
    - crossplots of depth vs total porosity & effective porosity
    - crossplots of bphi vs rhob
    - crossplots of depth vs water saturation
    - picket plots for resistivity of water
    - crossplots of depth vs hydrocarbon saturation
8. well correlation
9. attribute analysis has been done in this project

CHAPTER # 2:

Regional geology setting and stratigraphy of the area

2.1) Regional geological setting of the study area:

The regional geology of an area plays an important role for precise interpretation of seismic data. Pakistan is geologically divided into three main basins Indus, Baluchistan and kakar khorasan which are further sub-divided into different sub-basins. Our interested basin is lower Indus basin, runs in the dominant trend of north-south is bounded by the Indian craton(nagar parker granite area) to th east, the kohat potwar plateau to the north, fold and thrust belts of the sulaiman and kirthar ranges to the west. (kadri 1995).

Kirthar Foredeep:

Its trends north-south and has a faulted eastern boundary with thar platfoem. It is inferred that the sedimenatation had been continuous in theis depression. This depression is the area of great potential for the maturation for the maturation of source rock (kadri, 1995).

Kirthar Foldbelt:

It is also north-south trending tectonics features. Structures located in the kirthar foldbelt are related to compression and strike-slip movement of the western margin of the indo-pakistan plate. This is the feature where significant crustal shortening occurred against eurasion plate. Intense structural deformation in the kirthar range has resulted in deep seated thrust . stratigraphy form Triassic to recent has been observed from the exposed outcrops while precambrain to Permian may be present in subsurface (kadri 1995).

It is concluded from the above discussion that the region has shown both the compressional and extensional tectonics in association with wrencting. At the western marginal, there is a structural high i.e kirthar foldbelt. Transpressional regime has been establisted in kirthar foldbelt, where positive flower structures and thrusted anticlinal structural are observed. While towards eastern sidem thre lies thar plateform. It depicts transtensional tectonics related to the drifting of indo-pakistan plate. Due to extentional tectonics, horst and graben structures has been formed on a gentle broad monocline.furthermore extensional resultd in the development of negative flower structures (kadri, 1995).

2.2) Tectonics of the Study Area:

The tajjal area is located on khairpur high area. It is actually a basement high and mostly the eastern part that extends to the Indian border obscured by desert sands except in the areas near khairpur and sukkur where Eocene carbonate crop out (Nasir, et al,2007).

The following three key tectonic events are responsible for the structural configuration of the field.

- First in late cretaceous uplift and inversion, the axis of uplift appears to be oriented NE-SW but the degree of the uplift is uncertain.
- The second is right lateral strike slip faulting, which are basement rooted. These hae a general nw-se orientation and exhibit ‘flower structure “ cross section profiles”.
- The thid event is late tertiary t recent uplift/inversion of the khairpur high, and is responsible for stratigraphy and structural traps in the area (nasir, et al, 2007)

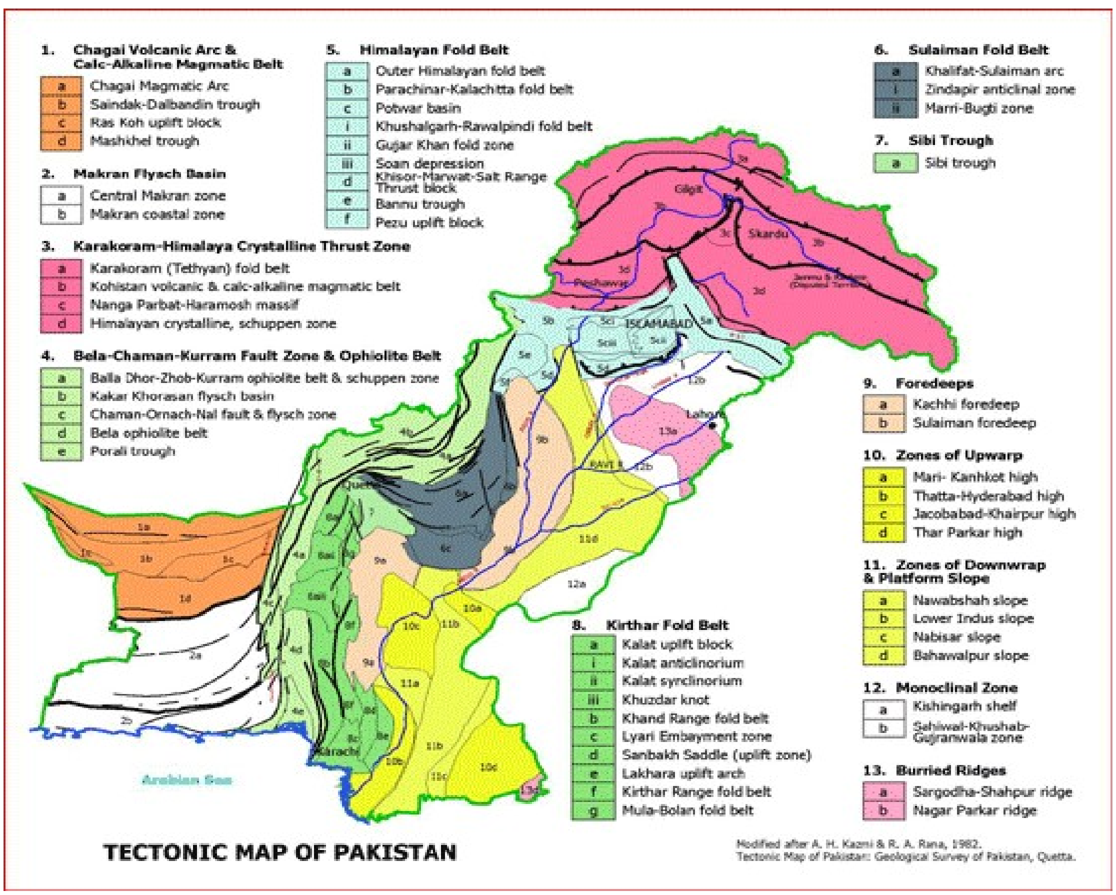


Figure 2.1 Showing tectonic zones of Pakistan (www.OPII.com)

2.2) Stratigraphy of the Area:

Generalize stratigraphy chart is shown in fig. in which the ages of the rocks ranges from Jurassic to tertiary. In tajjal block chiltan limestone of Jurassic age overlies traissic sequence. About 600 m thick shale of sembar formation overlies the chiltan limestone, on the top of sembar formationis lower goru, which is consider as major source rock in the area. Lower goru is further divided into five units such as basa sand overlies sembar formation, lower shale overlies basal sand, middle sand overlies lower shale, upper shale lies between middle and upper sand which is 5^{th} unit of the lower goru . depositinal environment of the upper sand is shallow marine to deltaic and consider as good reservoir in the lowet Indus basin (alam et, al, 2002).

Table 2.1:Straitigraphic succession of kadanwari well-10

Age	Formation	Tops(m)	Thickness(m)
Miocene	Siwalik	7.9	302
Eocene	Kirthar	310	0
	Drazinda	310	100
	Pirkoh	410	55
	Sirki	465	88
	Habib Rahi Member	553	143
	Laki	695	625
	Ghazij Shale	1320	91
	Sui Main Lime stone	1411	0
Paleocene	Ranikot Shale	1411	120
	Ranikot Sand Stone	1531	436
Ceataceous	Upper Goru	1967	1109
	Lower Goru	3076	

Stratigraphically, the shale series of the early cretaceous sember formation and interbedded shale layer of lower goru formation are the main docyment petroleum source rock units in the southern Indus basin. Upper Paleocene marine transgressive shale acts a secondary sourcerock, deeply buried in the western half of the southern Indus basin (zaigham and mallick, 2000). The basal sand of lower goru formation is target formation is target foemation in the area. Massive sand is another interested producing resetvoir from its various sand sheets of multiple thickness, the possibility of reservoir in the lower gory overlain on basal sand could not be ruled out, however that have not yet proved to be such up till now (kadri, 1995). In general, the transgressive shales of the cretaceous (sember) and tertiary (bara, lakhra, laki-ghazij, and kirthar formation) acts as a seal in southern Indus basin (zaigham and mallicks, 2000). Intra-formation shale of lower goru formation provides effective vertical and lateral seal. The shale units also provides cross fault seaf. Fault may also acts a seal. Upper goru shale, lower goru and talhar shale are the primary seal for lower goru reservoir sands (kadri, 1995).

2.10 MAJOR FORMATIONS OF THE AREA (TAJJAL)

Following are the major formations which encounter in the TAJJAL Area.

- ✓ **CHILTON LIMESTONE**

The Chiltan limestone is typically a massive, thick bedded, dark limestone, but shows colour and texture variations within one section and in different areas. The colour varies from black, dark grey, grey, light grey, brownish grey, bluish grey to occasionally white. Pisolitic limestone beds are present locally. The texture varies from fine-grained, sub-lithographic to oolitic, reefoid and shelly. In the Axial Belt, the limestone gives a fetid smell.

The Chiltan limestone is widely distributed in the Sulaiman Kirther Province and Axial belt, forming prominent high mountains like Koh-e-Maran, Koh-e-Siah, Chilian, Murdar Ghar, Takatu, Khalifat and Zardah. The Chiltan limestone, where developed, overlies the Shirinab formation conformably. The upper contact with the Mazar Drik formation is gradational. No fossils are found and on the basis of stratigraphic position age given is Middle Jurassic (Shah, 1977).

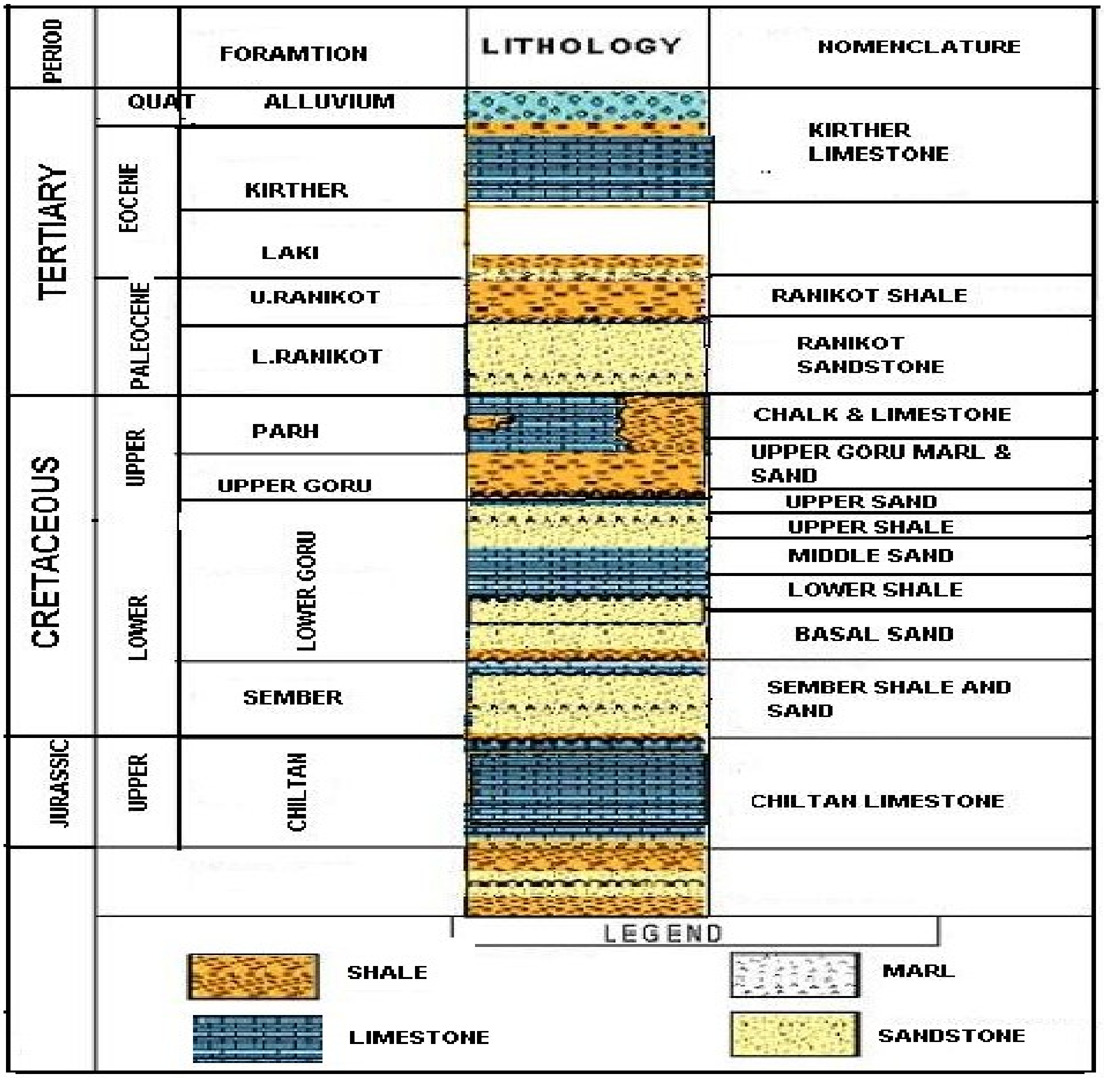


Figure2.3. Showing the generalized Stratigraphic Column of Southern Indus Basin (www.ogdcl.com)

✓ GORU FORMATION

The Goru formation consists of interbedded sandstone, shale and siltstone. The limestone is grained, thin bedded, light to medium grey in colour (Shah, 1977).

On the basis of lithology Goru Formation is divided in two parts

- Lower Goru
- Upper Goru

✓ LOWER GORU

The lower Goru is main reservoir rock within the area. The lower Goru horizon as a general 5 divisions based on predominant lithologies (Gilbert Killing et al).

- The Basal Sand unit
- Lower Shale
- Middle sand unit **(**which has a good reservoir potential**)**
- Upper Shale
- Upper Sand

✓ UPPER GORU

The upper Goru sequence of middle to late cretaceous unformable overlies the lower Goru formation which consists of mainly marl and calcareous claystone occasionally with inerbeds of silt and limestone (Gilbert Killing et al).

The Goru Formation is widely distributed in the Kirther and Sulaiman Province. The lower contact with the Sembar formation is conformable and is very locally reported unconformable by Williams (1959).The upper contact is transitional with the Parh Limestone.The Goru formation may be correlated with the Lumshiwal Formation of the Kohat-Potwar Province. The formation contains foraminifers and bivalves and age given is Early Cretaceous (Shah, 1977).

✓ DUNGAN FORMATION

Williams (1959) defined the formation as Dungan Formation. The formation dominantly consists of nodular to massive limestone with subordinate shale, marl, and sandstone and limestone conglomerate. Limestone is dominant in most of the places and is dark grey to brown and creamy white. The shale is dark blue grey, brown and olive and the shale becomes dominant in the southern Sulaiman Range. The Dungan formation is mainly developed in the Sulaiman Province and parts of the CalcareousZone of the Axial Belt. The formation unconformably overlies the Fort Munro formation in the Quetta and Harnai region and in the north-eastern Sulaiman Province it unconformably overlies the Pab sandstone. while the upper contact with the Ghazij formation is conformable. The formation is richly fossiliferious .The fossils recorded are foraminifers, gastropods, bivalves and algae . Foraminifers are dominant and on the basis of these fossils age given to this formation is Early Eocene age (Shah, 1977).

- ✓ **RANIKOT GROUP**

Blanford (1876) was the first to give the name Ranikot group.Vredenberg (1909a) subdivided the Ranikot group into Lower Ranikot (sandstone) and Upper Ranikot (limestone). One division of Ranikot group suggests that it comprise of three formations which are Khadro formation, consists of olive, yellowish brown sandstone and shale with interbeds of limestone. Keeping ascending stratigraphy order, Above Khadro formation is Bara formation (Lower Ranikot sandstone) consists of variegated sandstone and shale. And the upper one is the Lakhra formation (Upper Ranikot limestone) consists of grey limestone, grey to brown sandstone and shale. Various authors have given it different divisions. Below are explained the three formations as part of the Ranikot group with details (Shah, 1977).

- ✓ **KHADRO FORMATION**

The basal part of the formation is comprised of dark colored limestone with shale, followed by olive, grey to green, soft, ferruginous, medium grained fossiliferous sandstone an olive, grey to brown gypsiferous shale with interbeds of fossiliferous limestone. A number of basaltic lava flows are also present. The volcanics contain dark green and black basalt interbedded with mudstone, clay stone and sandstone. The formation is widely distributed in Kirther fold belt and its thickness varies at different localities..Its lower contact is unconformable with Moro formation and Pab Sandstone, while its upper contact is conformable with Bara and Dungan formations in various parts of Kirther-Sulaiman fold belt.

Khadro formation may be correlated with the lower part of the Rakhshani Formation of Chagai and Ras Koh area. Fossils reported from the formation include Corbula Globigerina pseudobulloides and G. triloculinoides and so many others. And age given to the formation is Early Paleocene (Kazmi and Abbasi, 2008)

- ✓ **BARA FORMATION**

This rock unit consists of soft sandstone, shale and clay, at some places it is richly coloured and variegated with brown and red colours.The sandstone is fine to coarse grained, soft, poorly sorted and cross bedded. Some of the shale are highly carbonaceous and has been developed into high economic coal deposits at Lakhra, Sonda and Thar. Ferruginous nodules and minor volcanic fragments are also found.This formation is widely distributed in Kirther fold belt. The lower contact with the khadro formation is conformable, in the Bara Dome, and in Rahman Dhoro it overlies a 19 m thick sequence of Deccan trap basalt (Gingerich et al. 1979). And the upper contact with the Lakhra formation is conformable, and where the Lakhra formation is missing, it has upper unconformable contact with the Eocene Laki formation. The formation is fossiliferous. it has yielded some bone fragments of crocodiles and turtles and some dicotyledonous leaves, and calcareous algae. So basis on these fossils age given is Middle Paleocene (Kazmi and Abbasi , 2008)

2.3 Petroleum Play in the Study Area:

- **Source Rock : Sember Shale**
- **Reservoir Rock: Basal Sand**
- **Cap Rock : Upper Goru, Marl**

♦ Reservoir Rocks:

the basal sand of lower goru formation is target formation in the area. Massive sand is another interesting producing reservoir from its various sand sheets of multiple thicknessed. The possibility of reservoir in lower goru overlain on basal sand could not be ignored although they have not proved as reservoirs still now (kadri, 1995). Hydrocarbon targets may also exist in the Jurassic chiltan limestone, Paleocene and Eocene formations (zaigham and mallick, 2000).

♦ Seal Rocks:

sember formation, bara-lakhra, laki-ghazij and kithar formations cts as seal in soyuthern Indus basin. Inter-bedded shales of lower goru formation provies effective vertical an lateral seal and act as a primay seals. The upper goru forms the top and lateral seals for the upper sand units of lower goru formation. (kadri, 1995).

♦ Source Rock:

sembar is considered as source rock in the lower and middle Indus basins that has high vertical and lateral extension throughout the basins. Source rock in the study area is of early cretaceous. The lower goru sand provide the accumulation of hydrocarbon while the upper goru shaly formation provide a trap. Normal fault provide as excellent seal to hydrocarbon.

- **Traps:**

all production in the study area is from structural traps. The tilted fault traps in the lower Indus basin are a product of extension related to rifting and the formation of horst and graben structures. The temporal relationships among traps formation among trap formation and hydrocarbon generation, expulsion, migration, an entrapment are variable throughout the Indus basin.

Chapter # 3

Seismic Data Interpretation

3.1 Introduction:

Interpretation is the transformation of seismic data into structural and straitigraphic picture through a series of different steps. Thus threading together all the available together all the available geological and geophysical information including the seismic and then integrating them all in a single picture can only give a picture closer to the reality.During seismic data interpretation, the final processed seismic lines are interpretated in order to construct a geological model of the area which describes area which are favorable for hydrocarbon accumulations. There are two main approaches for the interpretation, namely:

- Structural Analysis
- Straitigraphy Analysis

➢ Structural Analysis:

The main utilization of structural analysis approach is to look for potential structures which can hold and accumulated hydrocarbons. Several structural interpretation techniques utilize two-way reflection times rather depth. The structural traps such as fold, faults and anticlines are of main concern in this concern in this approach(dobrin and savit 1988).The fault analaysis helps in structural analysis. Some seismic contains images that can be interpreted without any difficulty. Discountinuous reflectors clearly indicates fault and undulating reflections reveals folded beds. Most interpretation of structural features are directly marked on seismic time sections (Robinson and coruth 1988).

➢ Stratigraphic Analysis:

The areas favorable for hydrocarbon accumulation are located in the straitigraphic interpretation which is formed by the variation in the deposition of sediments. These traps are marked by pinchouts, unconformity etc(badley, 1985).In the study of given seismic data , the former approach was used, as the area is dominated by normal faults and associated horst, graben structures. Smt kingdom 8.4 was used for the interpretation of digital seismic data.

Some of the parameters used in seismic stratigraphic interpretation are:

- ✓ Reflection configuration
- ✓ Reflection continuity
- ✓ Reflection amplitude
- ✓ Refection frequency
- ✓ Interval velocity
- ✓ External form

➢ Mistie Analysis:

In smt kingdom software there are two types of mistie analysis. Both bulk analysis and interactive analysis were used. In the bulk mistie analysis we can graphically analyze the mistie components of 2d and 3d surveys. In this analysis intersection mistie information is computed and displayed as a bubble map overlay. Bubble size is computed from the obsolute display values.

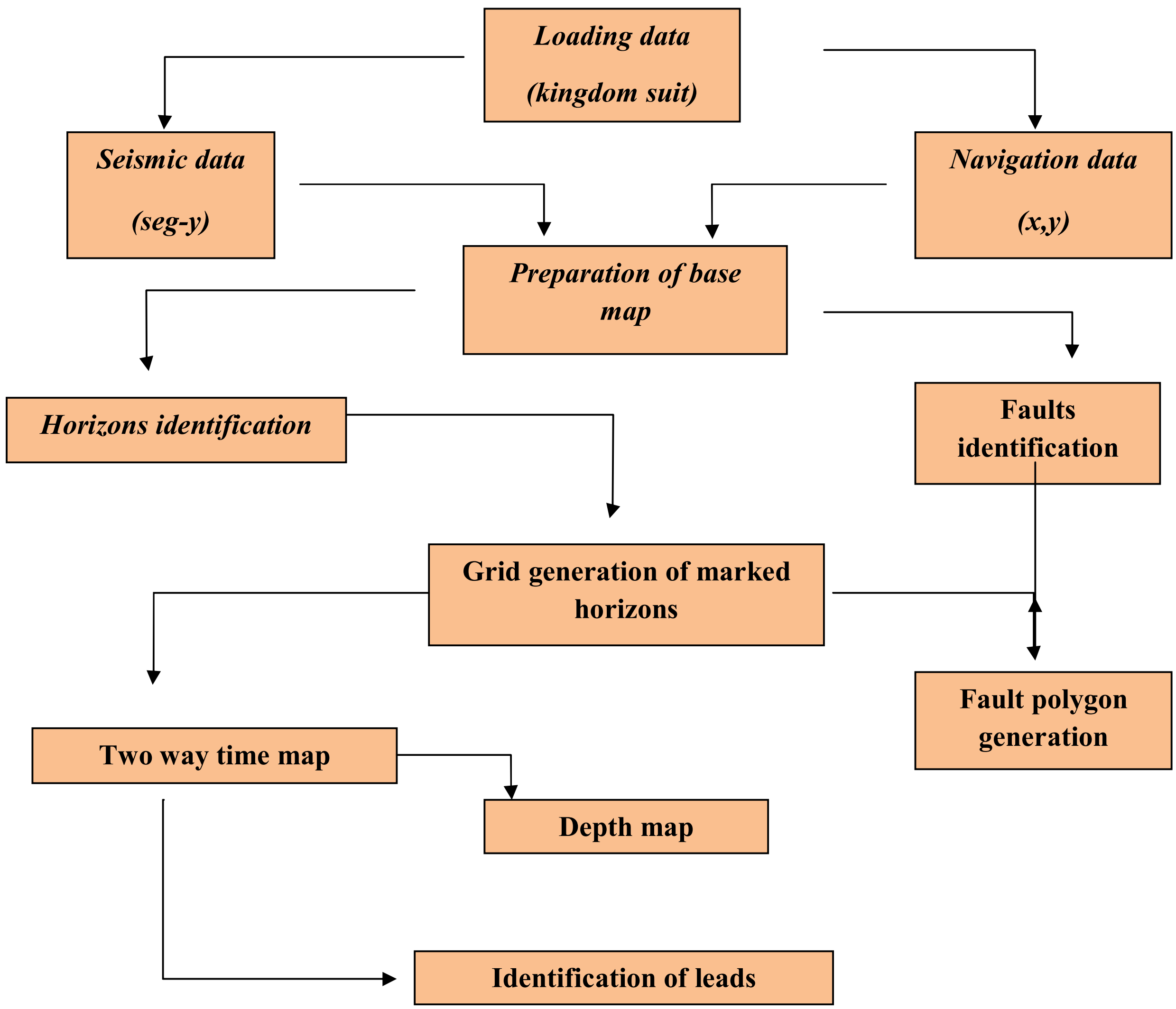
The seismic data have different time values where one seismic line crossed the other seismic line i.e tie points. It is necessary to adjust this difference at tie-point , seismic line tj … was selected as reference line having well kadanwari . in digital seismic data, prominent misties of about 20 to 30 millisencond were observed. Detail of th bulk mistie analysis is shown in the following table.

3.2 Working Procedure:

The following steps were followed for interpretation purpose.

- Preparation of base map
- Generation of synthetic seismogram
- Fault identification and marking
- Horizon marking

All digital maps along with geo-referenced imagery were produced by using kingdom suite. The interpretation was done on kingdom which provides an interactive interface for marking horizons and faults, exporting horizons time, velocity and depth data for contouring and for further analysis such as facies analysis and well columns correlation as shown in fig


Loading data
(kingdom suit)
Seismic data
(seg-y)
Navigation data
(x,y)
Preparation of base map
Horizons identification
Faults identification
Grid generation of marked horizons
Fault polygon generation
Two way time map
Depth map
Identification of leads

Generation of Synthetic Seismogram:

For the generation of synthetic seismogram two way time for each well top is required. Two way time for each well top or reflector is calculated by using depth, sonic log data of well and replacement velocity of the area.we need following information to generate synthetic seismogram.

- Time-depth charts
- Velocity of (Sonic DT log was used)
- Density log(RHOB was used)
- Wavelet (to be convolved)

The purpose of generation of synthetic is to find two way travel time against each depth for marking of horizons. With the help of this synthetic seismogram two horizon were marked on this time. Tie marked seismic with other lines and horizons are marked on these lines. During tie lines mistie shift is applied.

seven seismic lines assigned are interpreted in following sections.

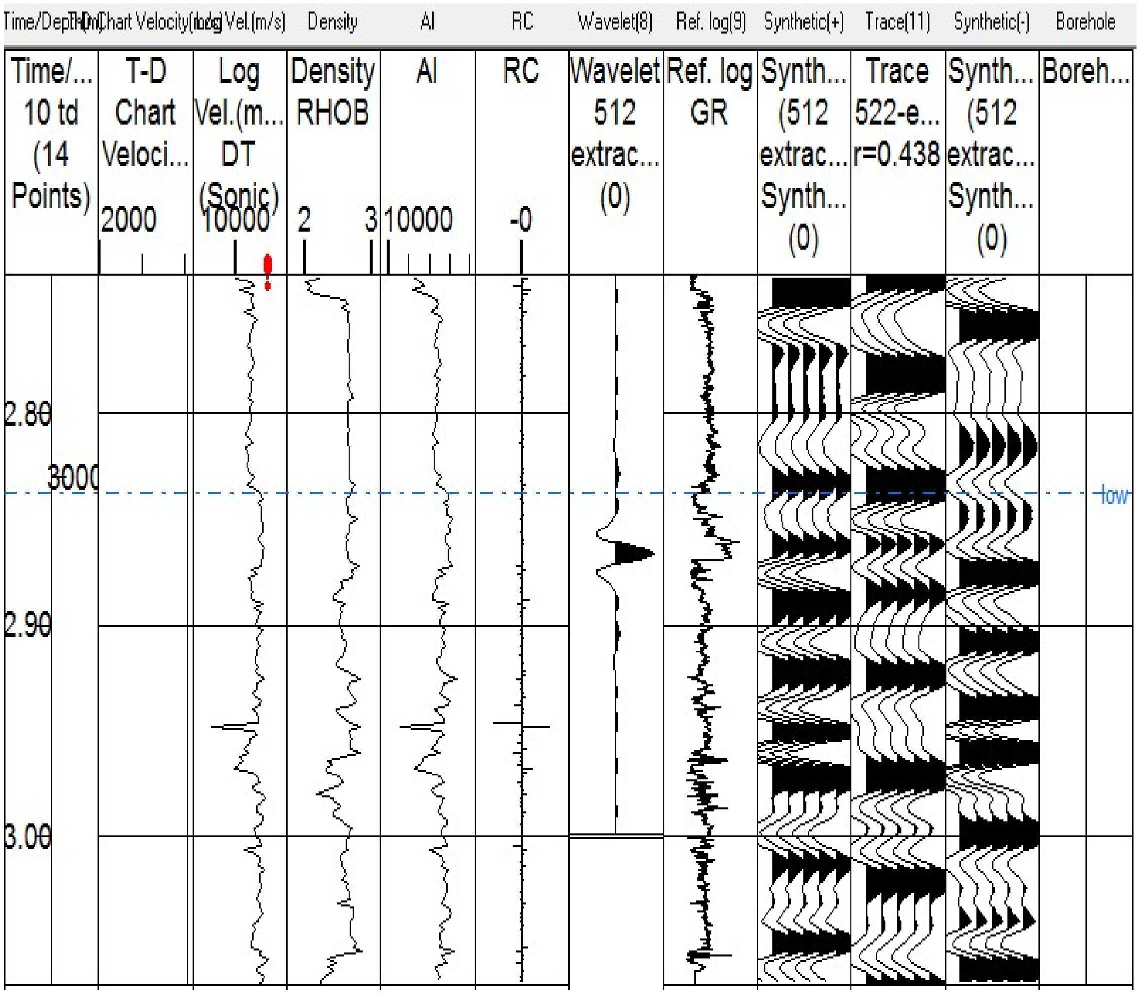


Fig. 3.2: Synthetic seismogram of kadanwari-10

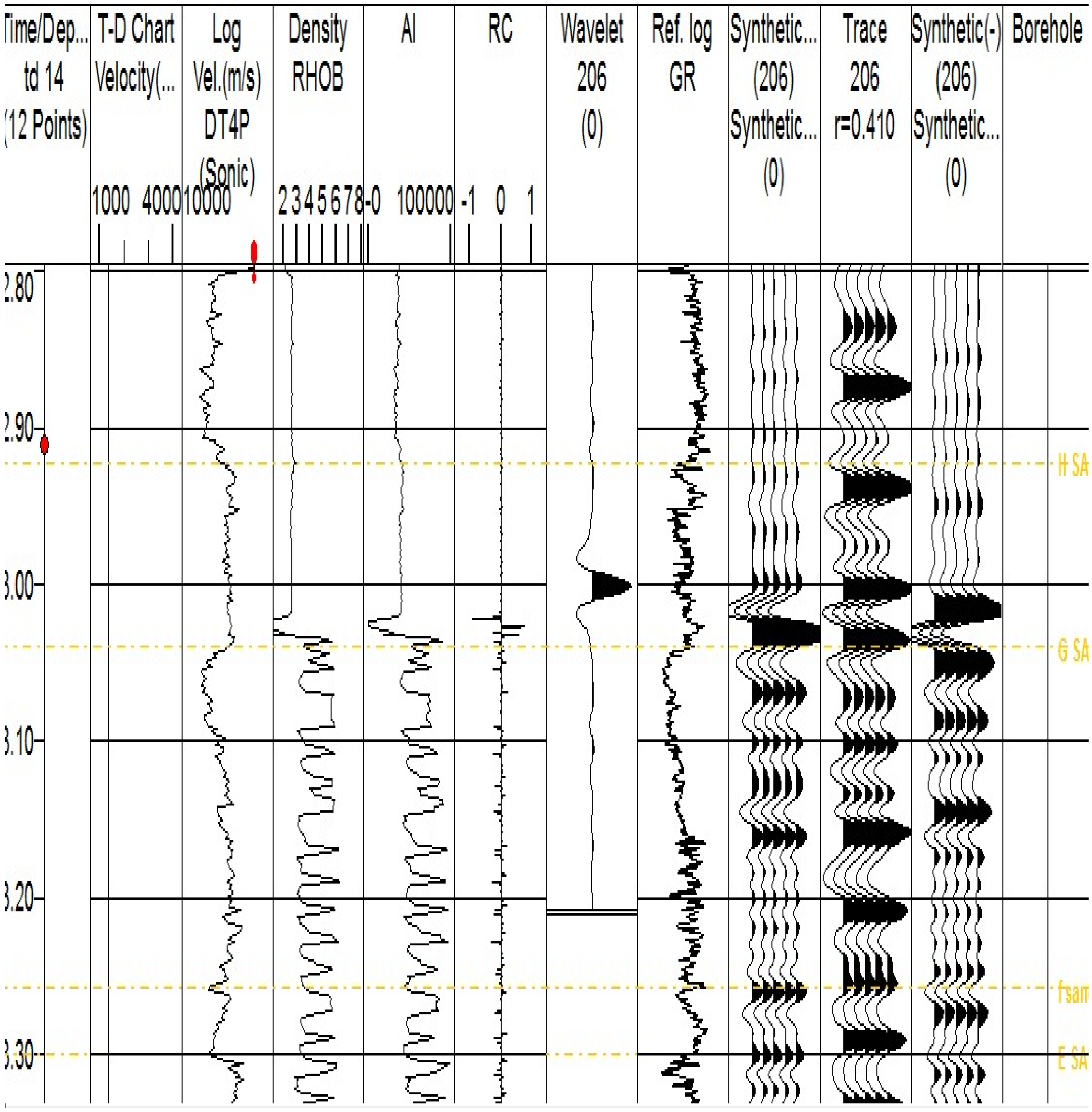


Fig. 3.2: Synthetic seismogram of kadanwari-10

Seismic Horizons:

The main (prominent) reflection that are present on the seismic sections are marked, and then selected those reflection that have good characteristics and continuity, and they can also be traced well over the whole seismic section. There are difficulties continuing the refections at the end of the seismic section and confusions are arrived where reflectors are mixed that may be due to sudden change in lithology , seismic noised, poor data quality or presence of salt in the subsurface at these locations. The seismic data was interpret using kingdom which is used for interpretation.

The seg-y format data of seismic line GTJ89-508 ,GTJ89-512, GTJ89-516, GTJ89-522, GTJ89-206 and GTJ89-207 is loaded by kingdom software for interpretation. After loading data in kingdom software of lines using the interactive tools and application of kingdom software prominent horizons are marked following the trend and continuity of the reflectors. The lines comprises normal faulting which shows a strike slip nature and horst and graben geometry.

Fault Identification and horizon identification:

Following steps should be followed to interpret the faults on the seismic data.

- Geology of the area
- Marking faults on seismic sections
- Correlation of the faults

Fours lines are interpreted on the basis of faults. All faults are N-S oriented, showing marked horizons (lower goru, ranicot and sui main) terminated by normal faults. Faults are represented on the seismic sections (Figures 4.4 and 4.5) as a discontinuous reflection along marked horizons. The subsurface structures are related to normal faults in East and West with small throw (f1,f2,f3,f4,f5,f6,f7 and f8). The pattern of seismic reflections from the strata within the basin suggests that the processes of continental rifting and deposition were contemporaneous. The younger sequence seems to have been affected by minor reactivation of an older fault.

The main prominent reflections that are present on the seismic sections are marked, and then selected those reflectors that have good characteristics and continuity (like lower guru and upper guru), and they can also be traced well over the whole seismic section. There are difficulties in continuing the reflectors at the end of the seismic section and confusions are arrived, reflectors are mixed that may be due to sudden change in lithology, seismic noises, poor data quality and present of salt in the subsurface at these location. The seismic data was interpreted using kingdom, which is used for interpretation.

Seismic time section:

After marking seismic horizons and faults, the time of each reflector was noted at different vibrating points, and then the seismic time section is generated by plotting the two-way travel time of the reflectors and faults on y-axis against the shot point on x-axis. The seismic time section is simple, reproduction of an interpreted seismic section.

Time of each reflector at different vibrating points are noted and then the seismic time section is generated by plotting the two-way travel time of the reflectors and faults on y-axis against the vibrating points on x-axis points.

The time section gives the position and configuration of reflectors in time domain. Positions of the reflections on the time section depend on velocity differences as well as on layer thickness. Five prominent seismic horizons and seven faults are marked all the faults marked are the normal faults forming horst and graben geometry. The maximum and more visual vertical and horizontal separation (heave and throw) occurred due to these. Five faults dip in west direction while other two faults dips in east direction.

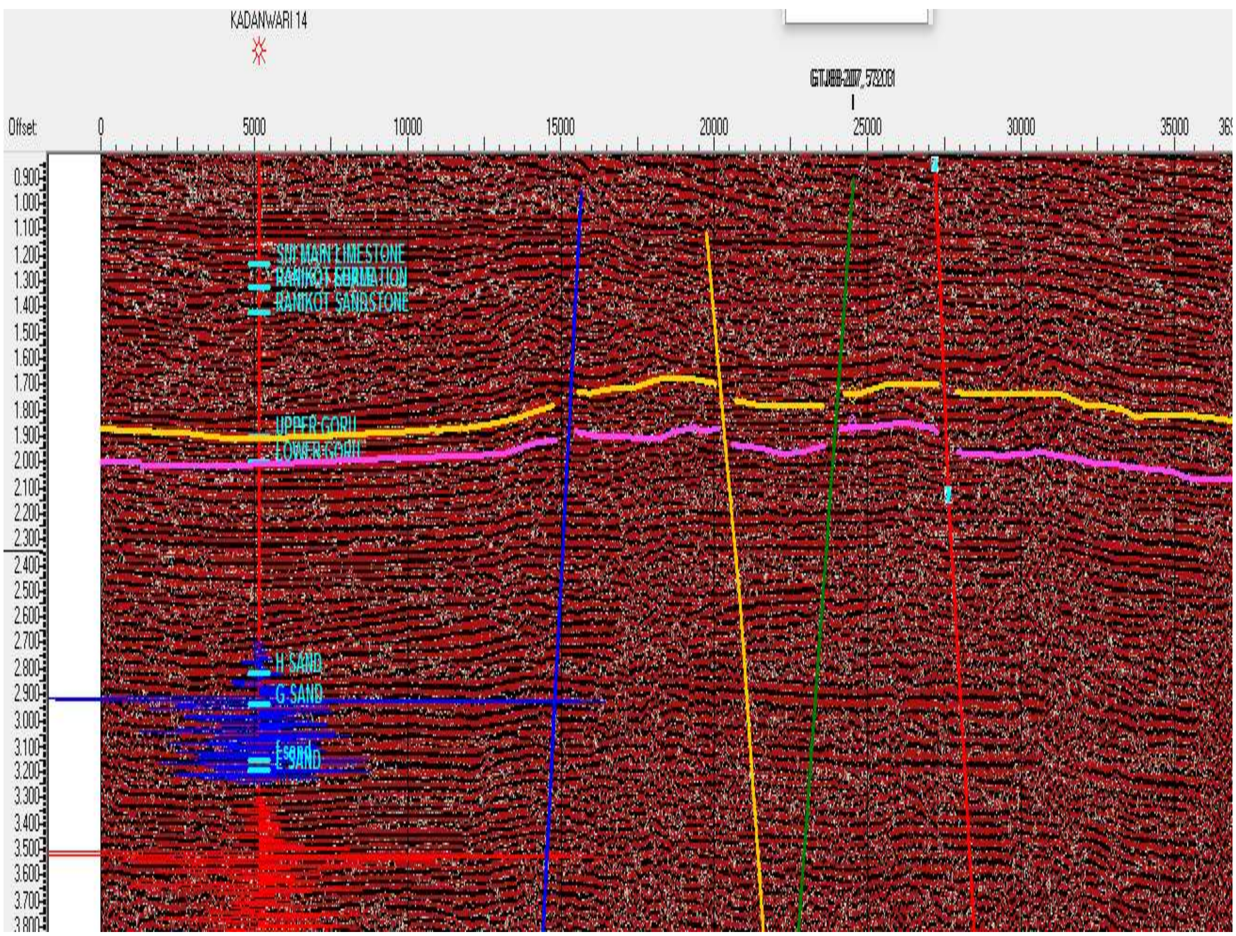


Fig: seismic time section of line GTJ88-206

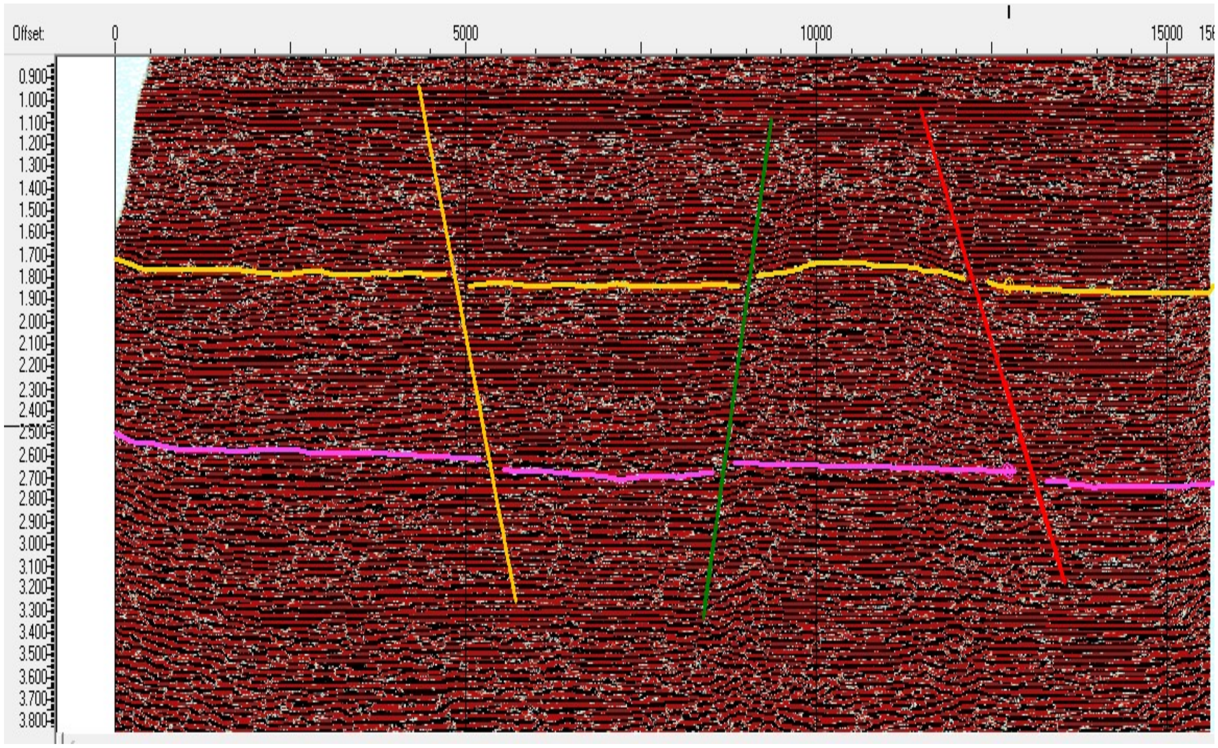


Fig: seismic time section of line GTJ89-516

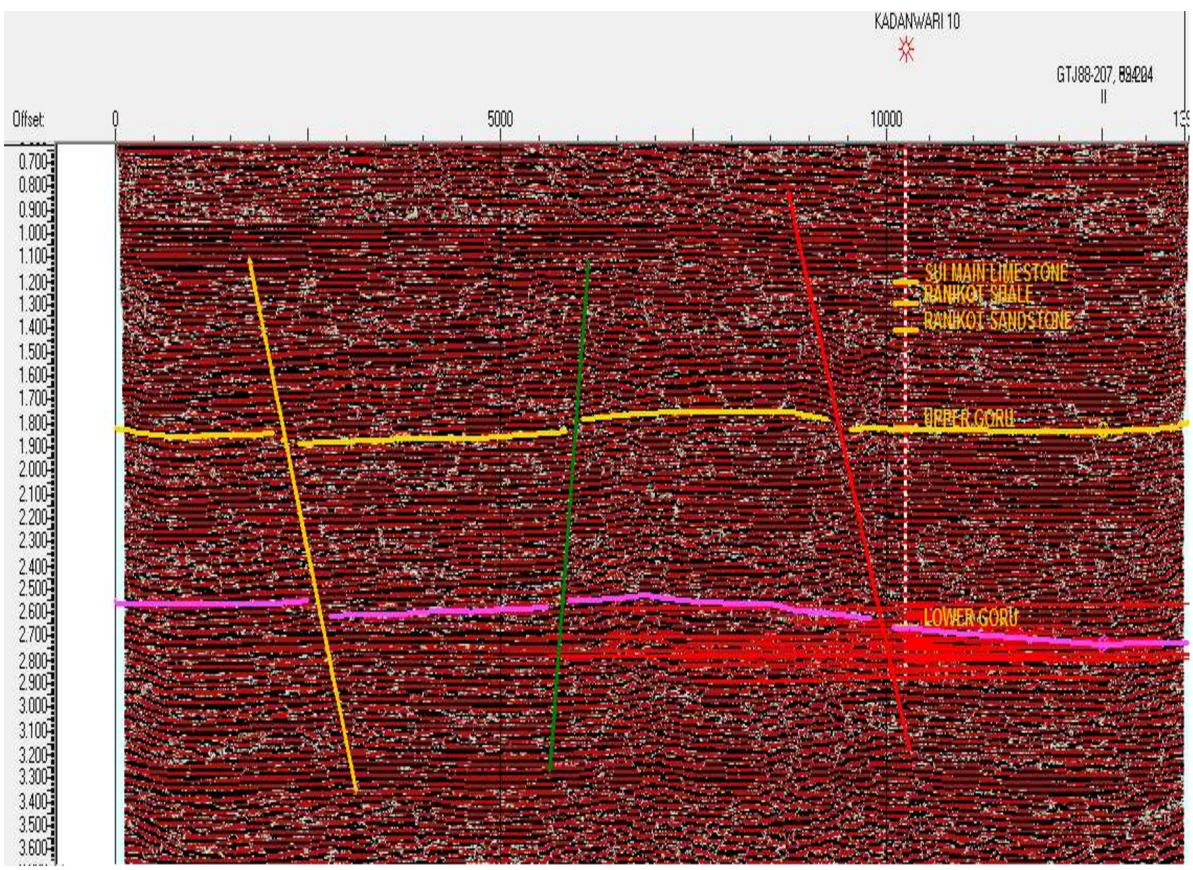


Fig: seismic time section of line GTJ89-512

Fault polygons generation:

Before generation of fault polygons it is necessary to identify the faults and their lateral extent by looking at the available seismic data. If one finds that the same fault is present on all the dip lines, then all points (represented by + sign by default kingdom software) can be manually joined to make a polygon. Construction of fault polygons are very important as far as time and depth contouring of a particular horizon is concerned. Any mapping software needs all faults to be converted in to polygons prior to contouring. The reason is that if a fault is not converted into a polygon, the software doesnot recognize it as a barrier or discontnuitie, thus making any possible closures against faults represent a false picture of the subsurface, formed at lower goru level shows that after construction of faults polygons, the high and low areas on a particular horizons become obvious. More over the associated color bars helps in giving information about the dip direction on the fault polygons if dip symbols are not drawn.

Fault polygon are constructed for all marked horizons and these are oriented in NS.

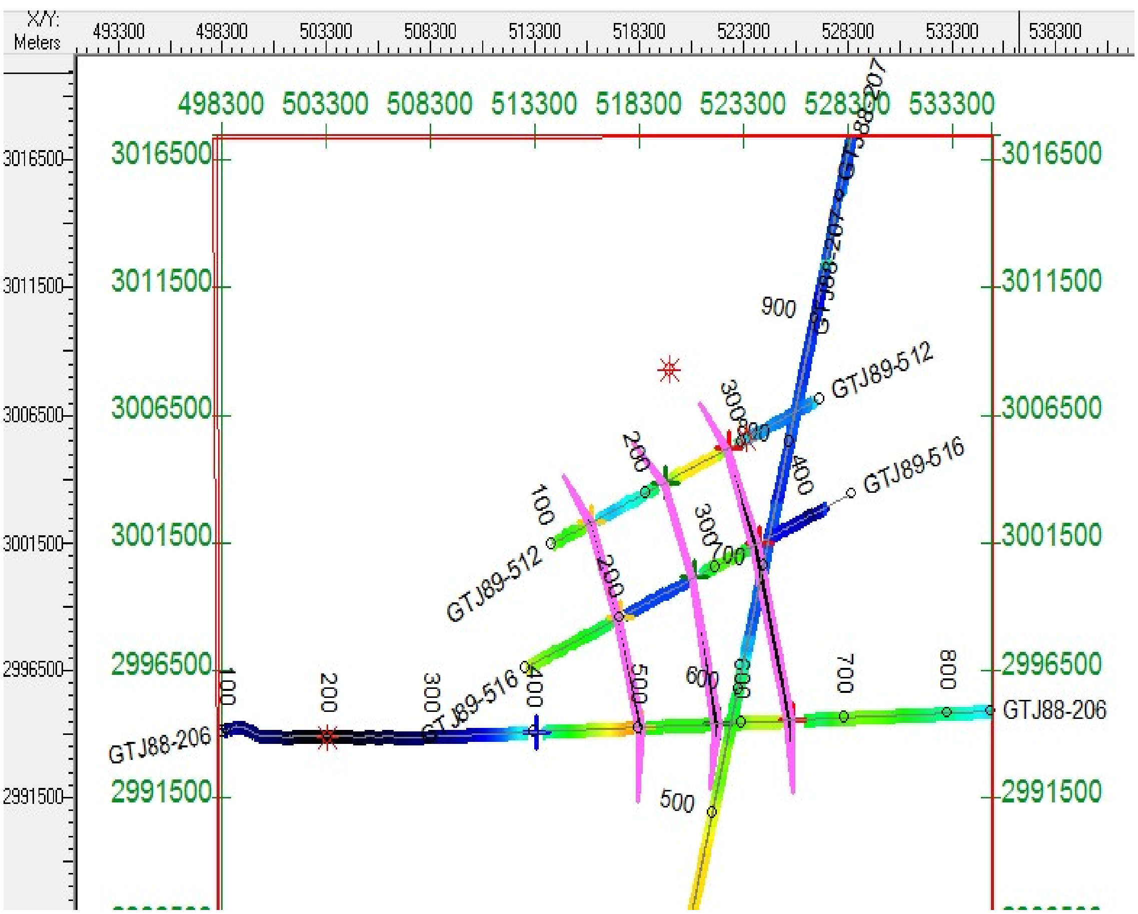


Fig: showing set of fault polygon of an arbitrary prominent horizons marked on seismic section. It is of upper guru.

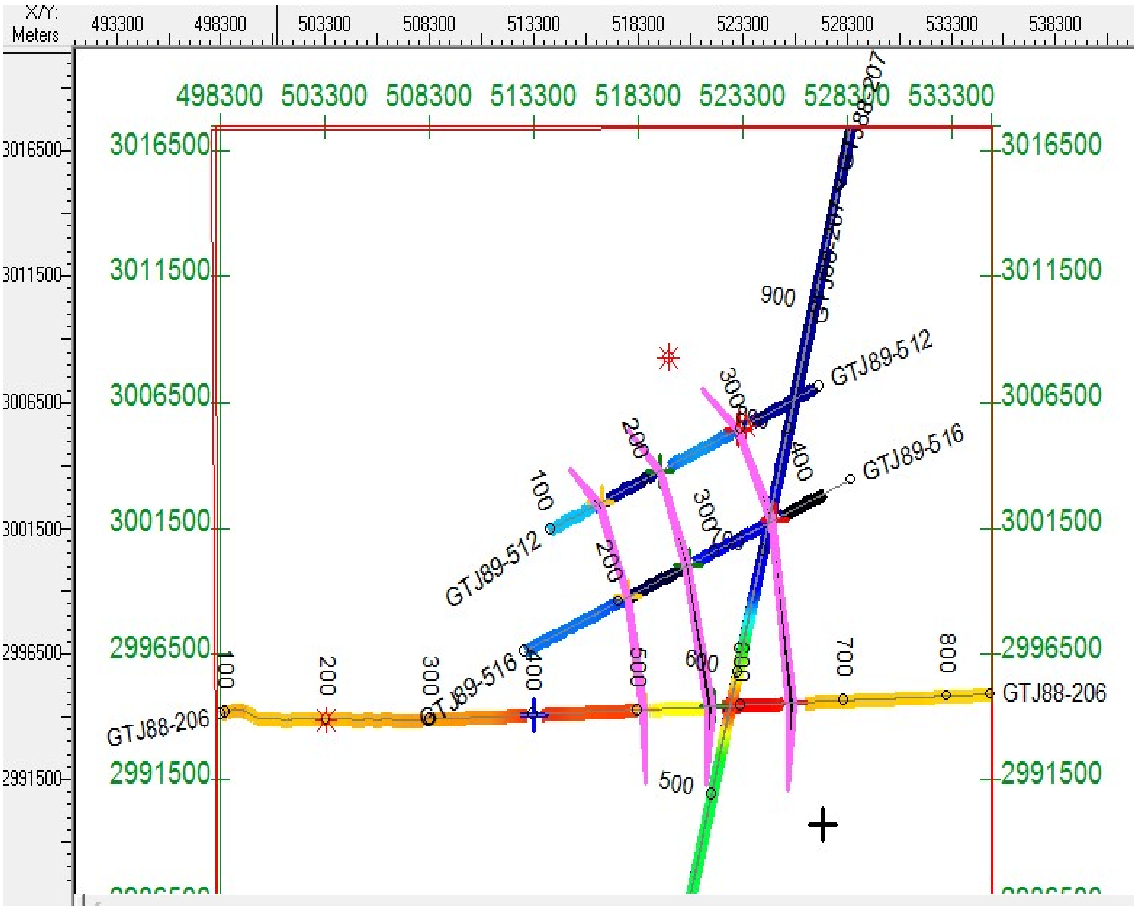


Fig: showing set of fault polygon of an arbitrary prominent horizons marked on seismic section. It is of lower guru.

4.4 CONTOUR MAPS

The final products of all the seismic exploration are the contour maps, time or depth. Mapping is part of the interpretation of the data, the one on which the entire operation depends for its usefulness. The contours are the lines of equal time or depth wandering around the map as dictated by the data (Coffeen, 1986).

Contouring represents the three-dimensional structure on a two dimensional surface. These contour maps reveal the slope of the formation, structural relief of the formation, its dip and any faulting and folding. The interpreted seismic data is contoured for producing seismic maps which provide a three-dimensional picture of the various layers within an area which is circumscribed by intersecting shooting lines. These time and depth contour maps have been generated with the help of Seismic Micro Technology SMT (Kingdom 8.6).

4.4.1 Time Contour Maps of Marked Horizons

Time contour maps at the level of marked horizon i.e. Upper Goru and Lower Goru are shown in Fig. 4.6 and Fig. 4.7. In Fig4.6 time contour map of lower Goru with contour interval of 0.0045 second is shown, In the NE Lower Goru horizon is shallow and the depth.of horizon increases towards west. Closed contours shows structural trap.

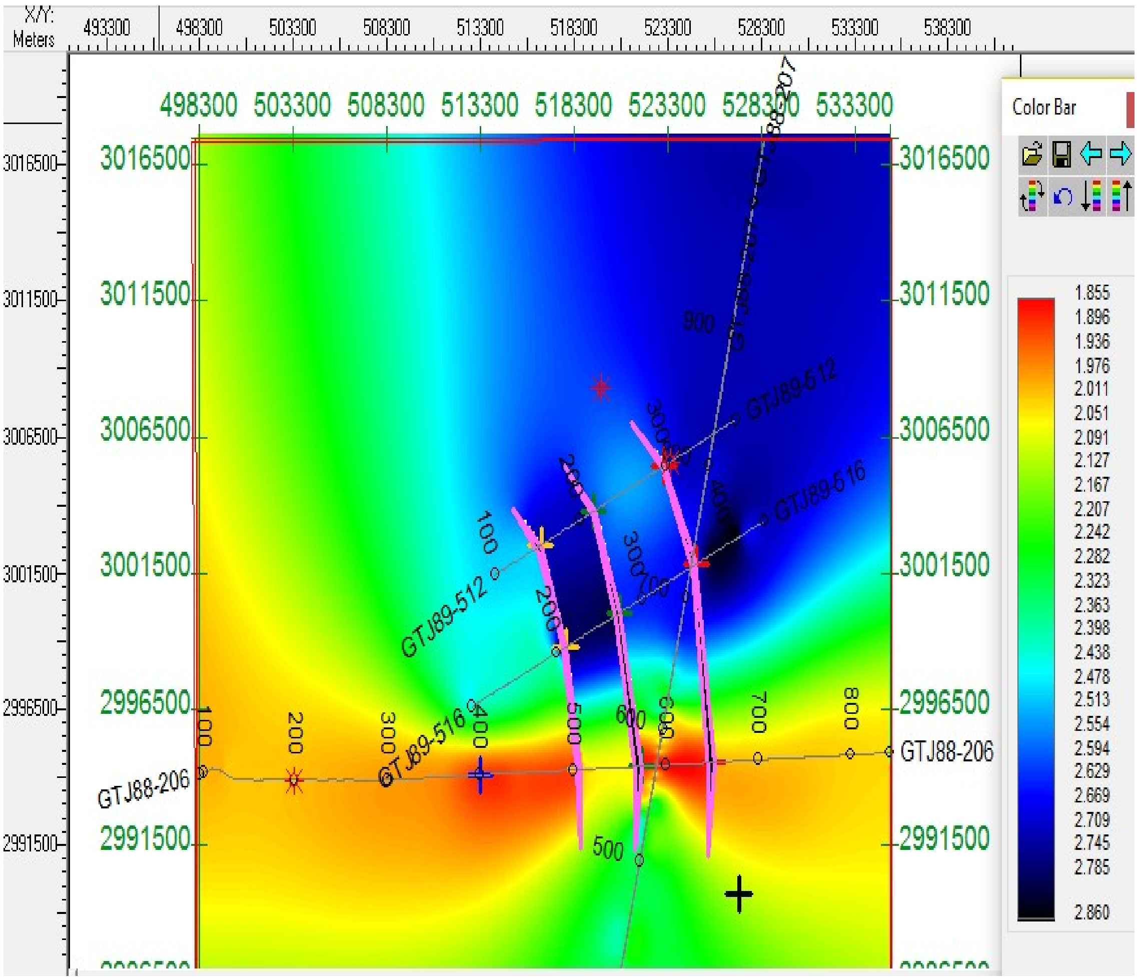


Fig: time section of lower goru formation

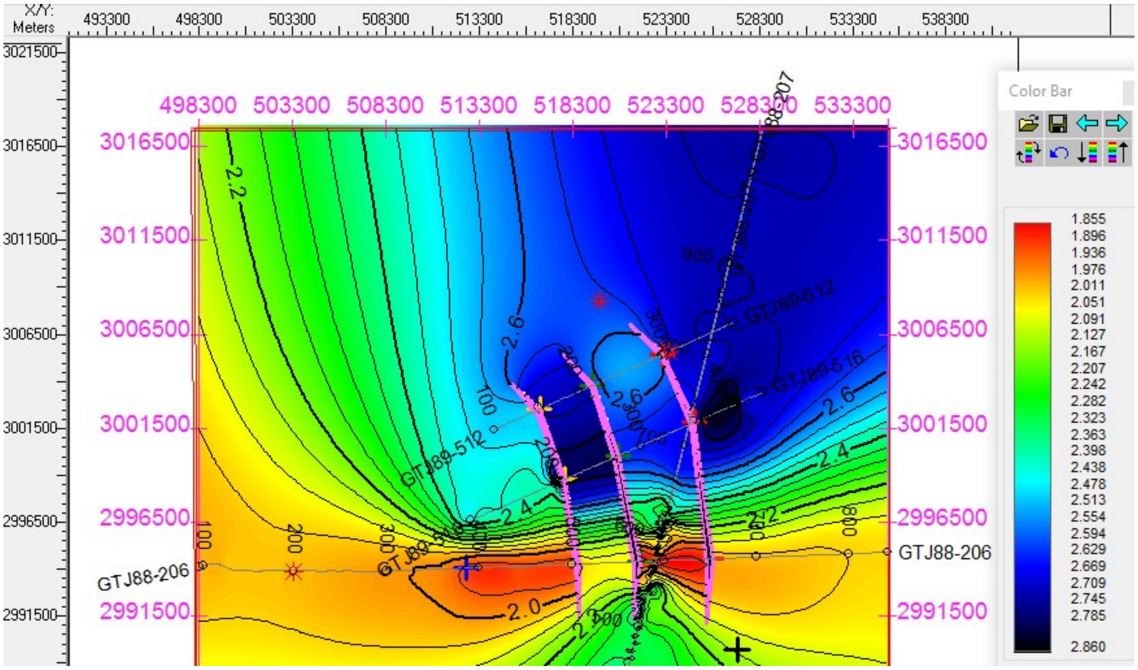


Fig: time contour section of lower goru formation

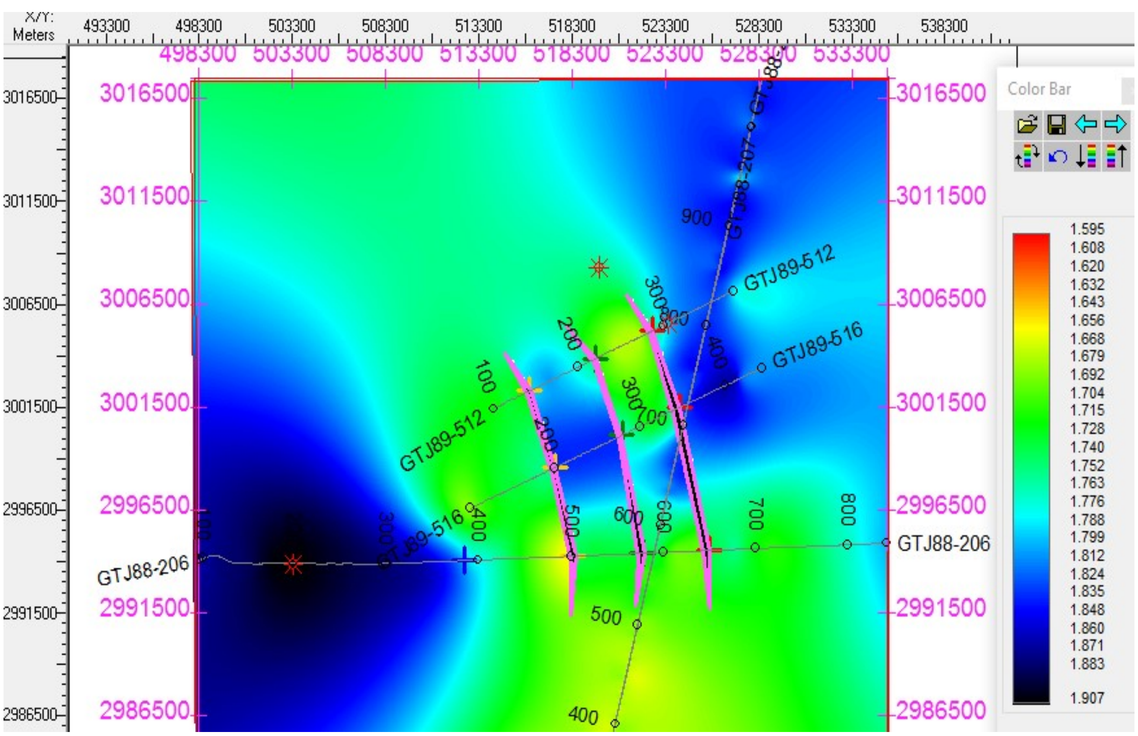


Fig: time section of upper goru formation

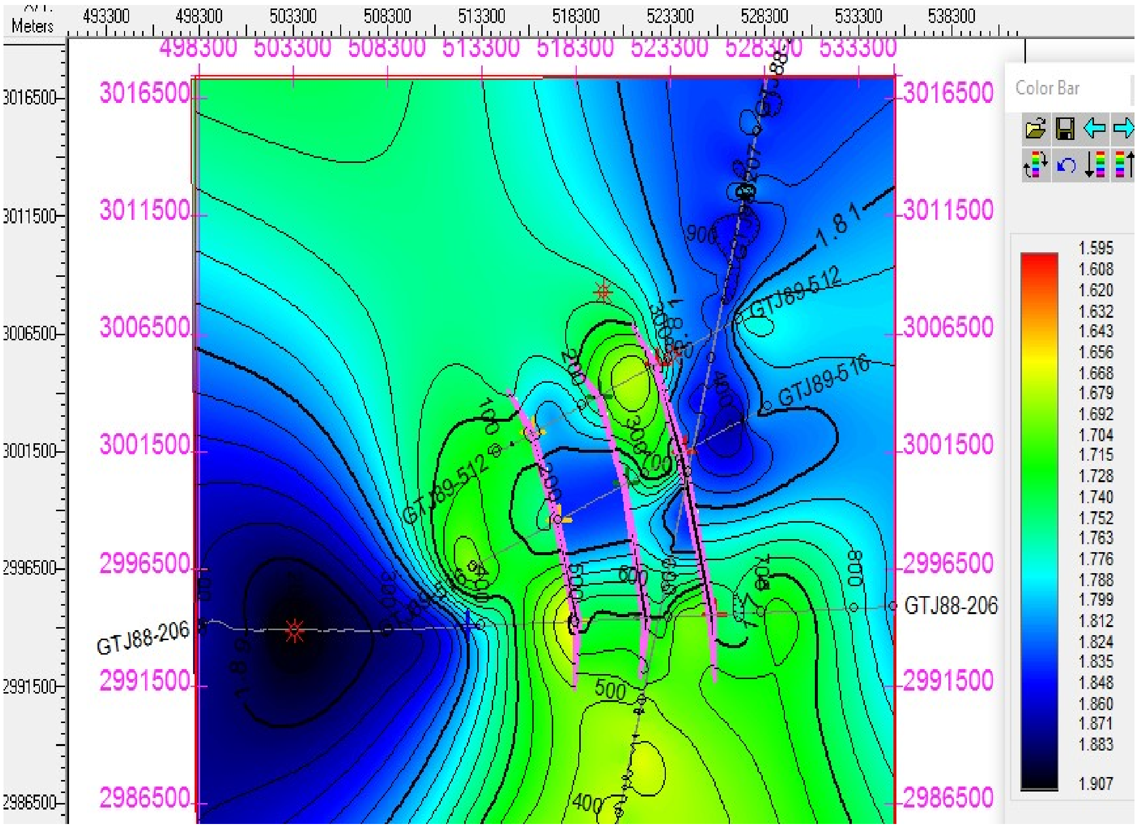


Fig: time contour section of lower goru formation

4.12 SEISMIC DEPTH SECTION

To determine the depth, the first 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:

$$D = \left(\frac{T}{2}\right) * V$$

Where

V = average velocity

T = two way travel time

D = depth

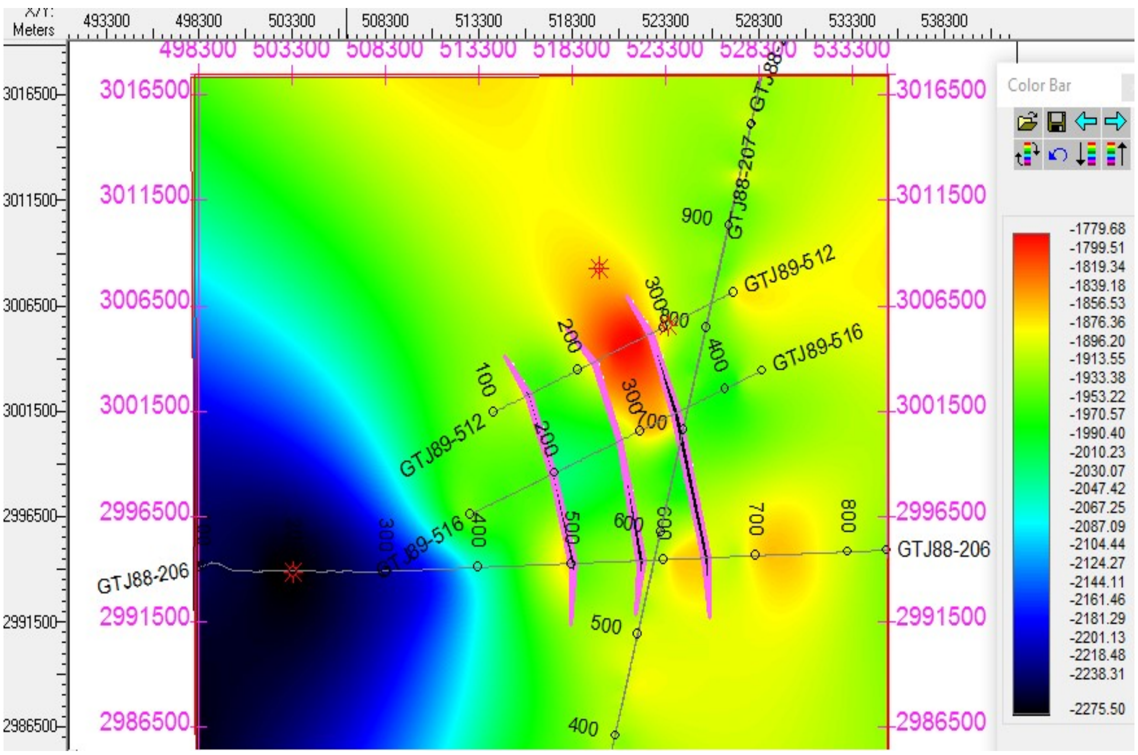


Fig: depth section of upper goru formation

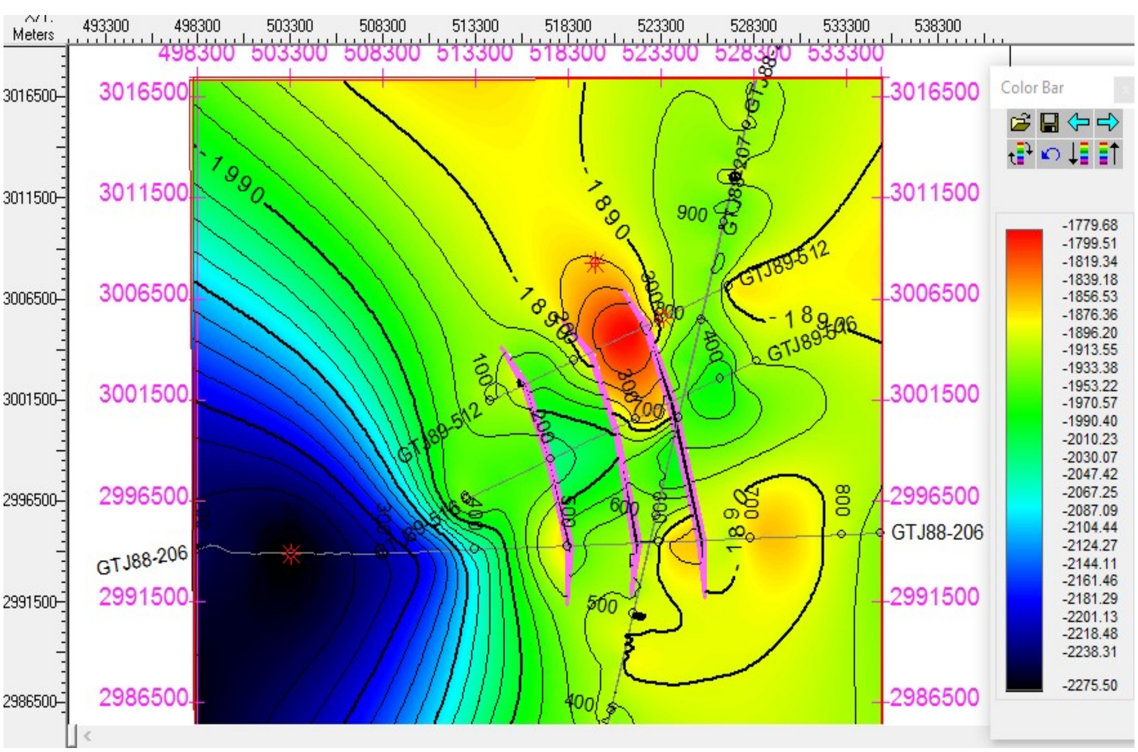


Fig: time contour section of upper goru formation

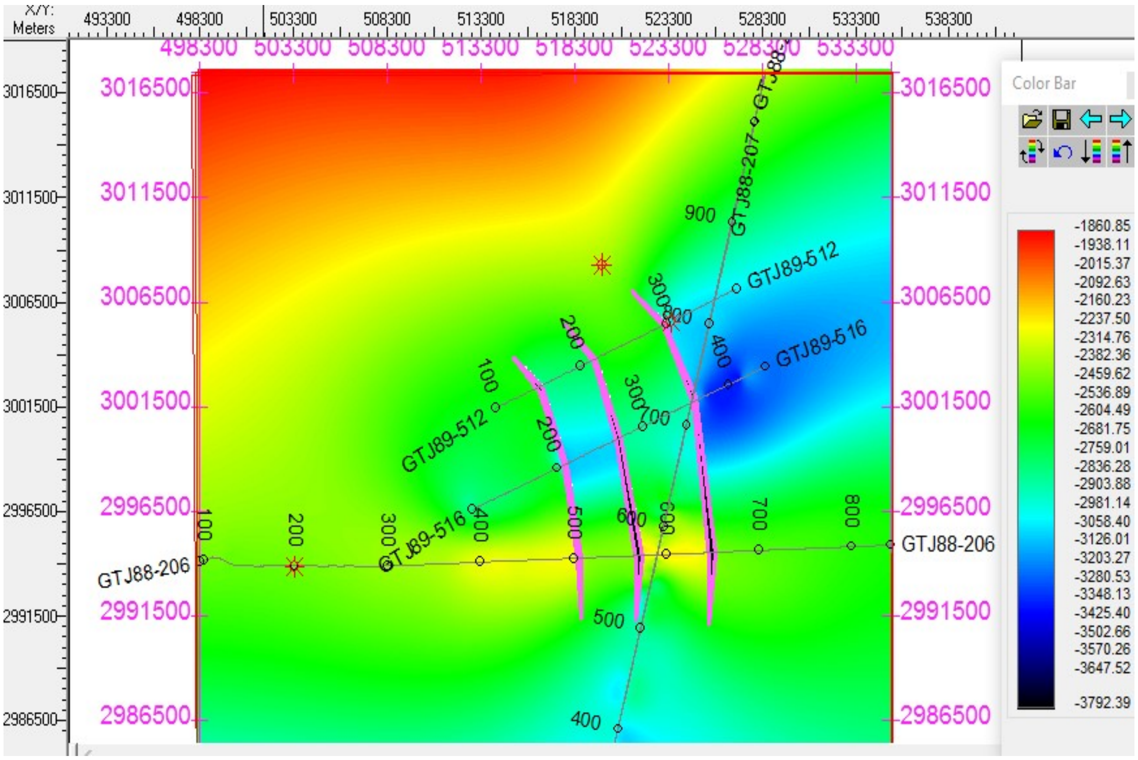


Fig: section of lower goru formation

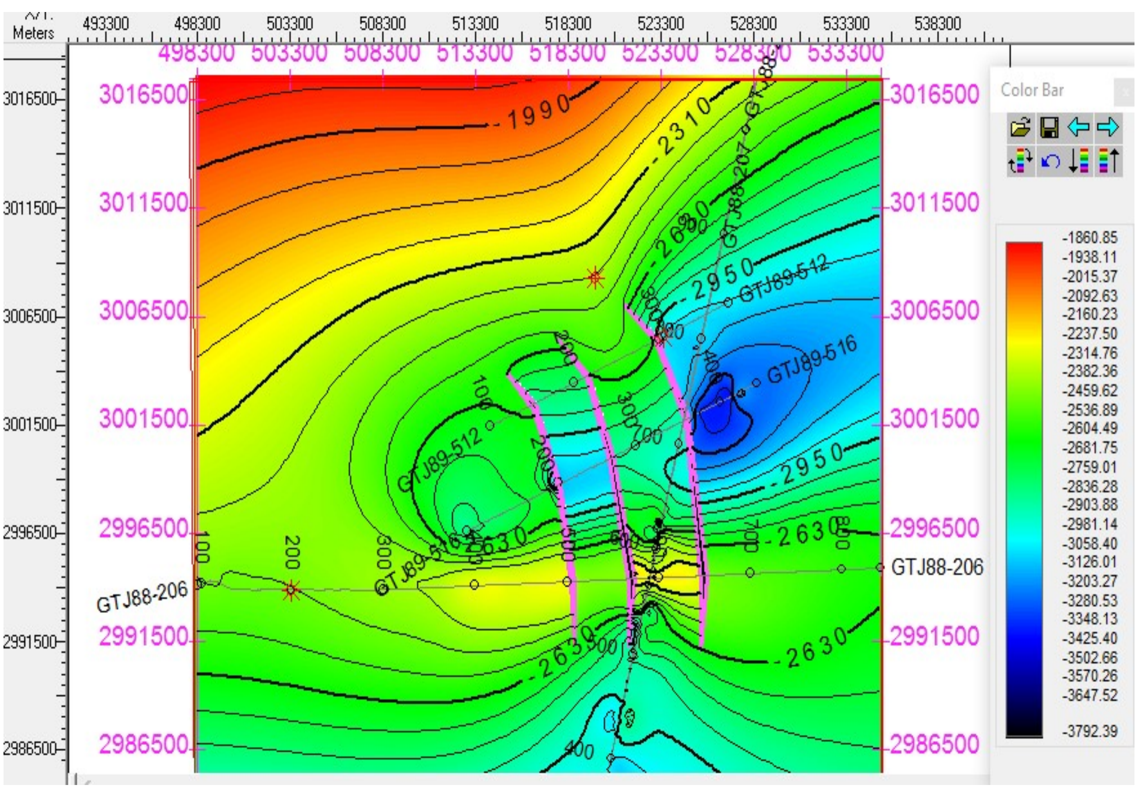


Fig: depth contour section of lower goru formation

Data available:

SEG-Y files of required lines.

One well

Kingdom SMT software is an industry level advanced geo-scientific interpretation tool. It has the following features:

- Advanced horizon tracking algorithms
- Attributes generated by advanced horizon tracking algorithems
- Surface curvature attributes
- Horizon modeling and faults
- Gridding
- Contour and mapping
- 2d view of seismic section

Petrophysics:

We use different techniques to achieve our goals. The most basis techniques are

- Rock physics
- Petropysics

The term rock physics contains the range of techniques that relate the geological properties(I.e porosity, lithology, saturation) of a rock at certain physical conditions (e.g pressure, temperature) with the corresponding elastic and seismic properties (e.g elastic modulus, velocity, impedance).

Importance of rockphysics:

It is the brigh to determine accurate relations between rock properties and seismic attributes can to put “flesh on the bones” of a seismic interpretation. That is, rock physics allows the interpretater to put “rock properties together with seismic horizons”. (peeters). Typical rock physics studies will answer questions such as:

Can porosity and saturation be obtained from (seismic) interval velocity?

What are the velocity-porosity relations in various lithologies?

Is seismic avo response sensitive to gas saturation to gas saturation levels in a particular play?

petrophysics:

Petrophysics is the study of physical and chemical properties which defines the occurrence and behavior of rocks and the containing hydrocarbons (oil and gas). Petrophysical interpretation is the process which leads to combining the knowledge of tool response with geology, to provide a complete picture of the changes of important petrophysical properties with depth. (ellis and singer, 2007).

During petrophysical interpretation different logs were used.

Caliper log , gamma ray (GR), neutron log (NPHI), density (RHOB), resistivity logs (LLS, LLD, and MSFL), core data and production data leads to petrophysical properties estimation. Each log has its own importance and contributes in quantifying the important reservoir parameter. Gamma ray is particularly use for for defining shale beds. When the sp is distorted or when the sp is featureless. The gamma ray log reflects the proportion of shale and in many regions and it can be used quantitatively as a shale indicator. It is also used for the detection and evaluation of radioactive minerals such as potash or uranium ore. During the log analysis of wells , the gamma ray log is used for the interpretation of shale volume.(rider, 2002)

All the measurements and bore hole signatures have their own significance, but the traditional role of well logs has been limited to participation in evaluation of formation which is summerised as:

- Identification of reservoir and their nature (oil and gas)
- Delineation of pay zone in reservoir strata
- Quantification of hydrocarbon contained in the formation
- Estimation of recoverable hydrocarbons

Difference between the role of rock physics and petrophysics:

Rock physics:

- Rock physics uses sonic, density, and dipole logs if available
- Rock physics aims to establish p-wave velocity (vp), s-wave(vs), density, and their relationships to elastic moduli (bulk modulus) and rigidity modulus, porosity, pore fluid, temperature , pressure etc, for the present lithologies
- It talks about velocities and elastic parameter, because , these are what link physics rock properties to seismic expression.
- Rock physics sometimes use information provided by the petrophysicist, such as shale volume, saturation levels, and porosity in establishing relations between rock properties or in performing fluid substitution analysis.
- Rock phyrics is the interest of geophysicist (and maybe physicists).

Petrophysics:

- Petrophysicist uses all kinds of logs, core data and production data, and integrates all pertinent information.
- Petrophysics aims at obtaining the physical properties such as porosity, saturation, and permeability which are related to production parameters
- Petrophysics is generally less concerned with seismic, and more concerned with using wellbore measurements to contributes to reservoir description.
- Petrophysics can provide things like porosity, saturation , permeability, net pay , fluid contacts, shale volume, and reservoir zonation.
- Petrophysics is the interest of petroleum engineers , well log analysts, core analysts, geologist and geophysicts.

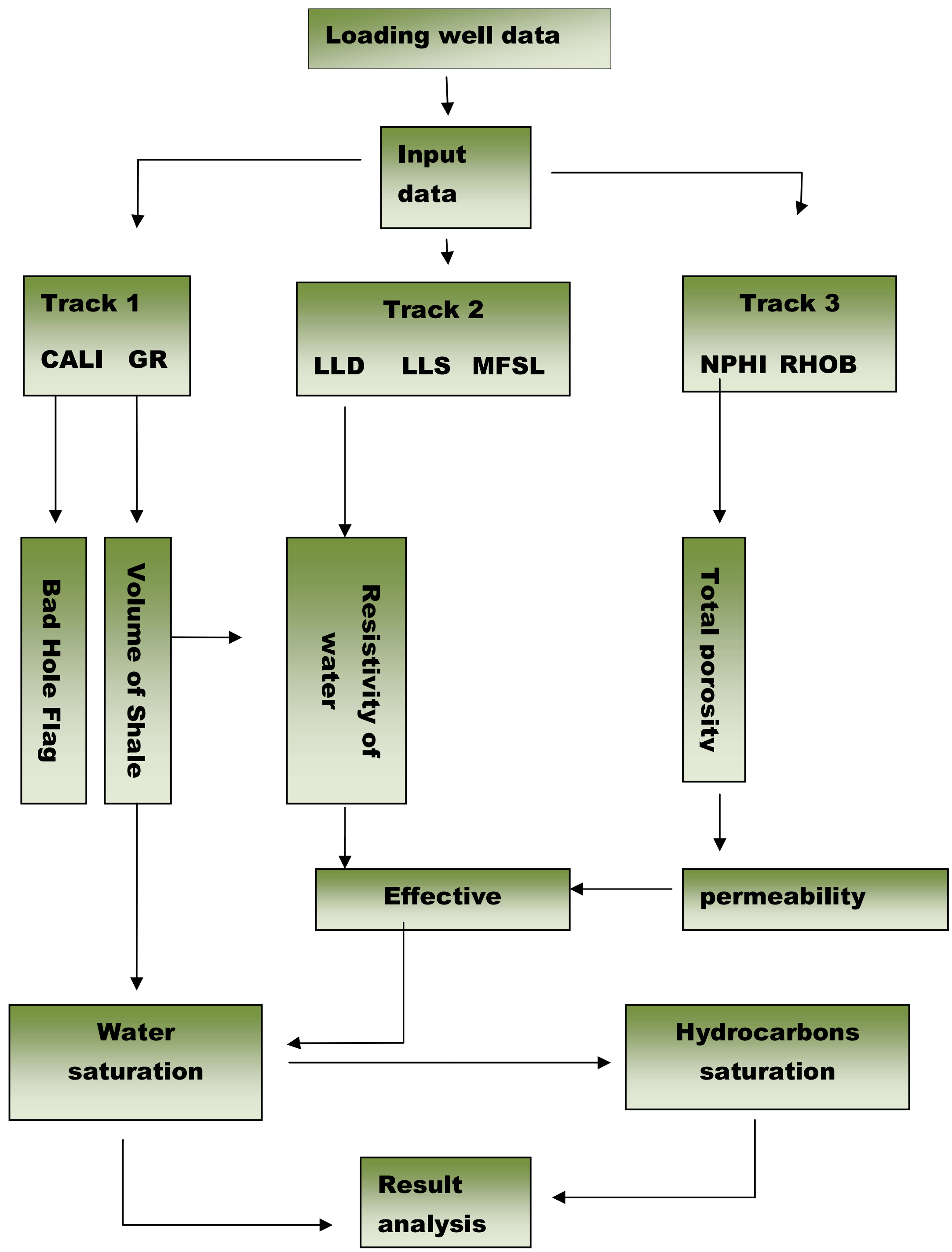
Data Set:

The petrophysical analysis has been performed for reservoir characterization of kadanwari area. To achieve the goal data set of kadanwari-10 are used.

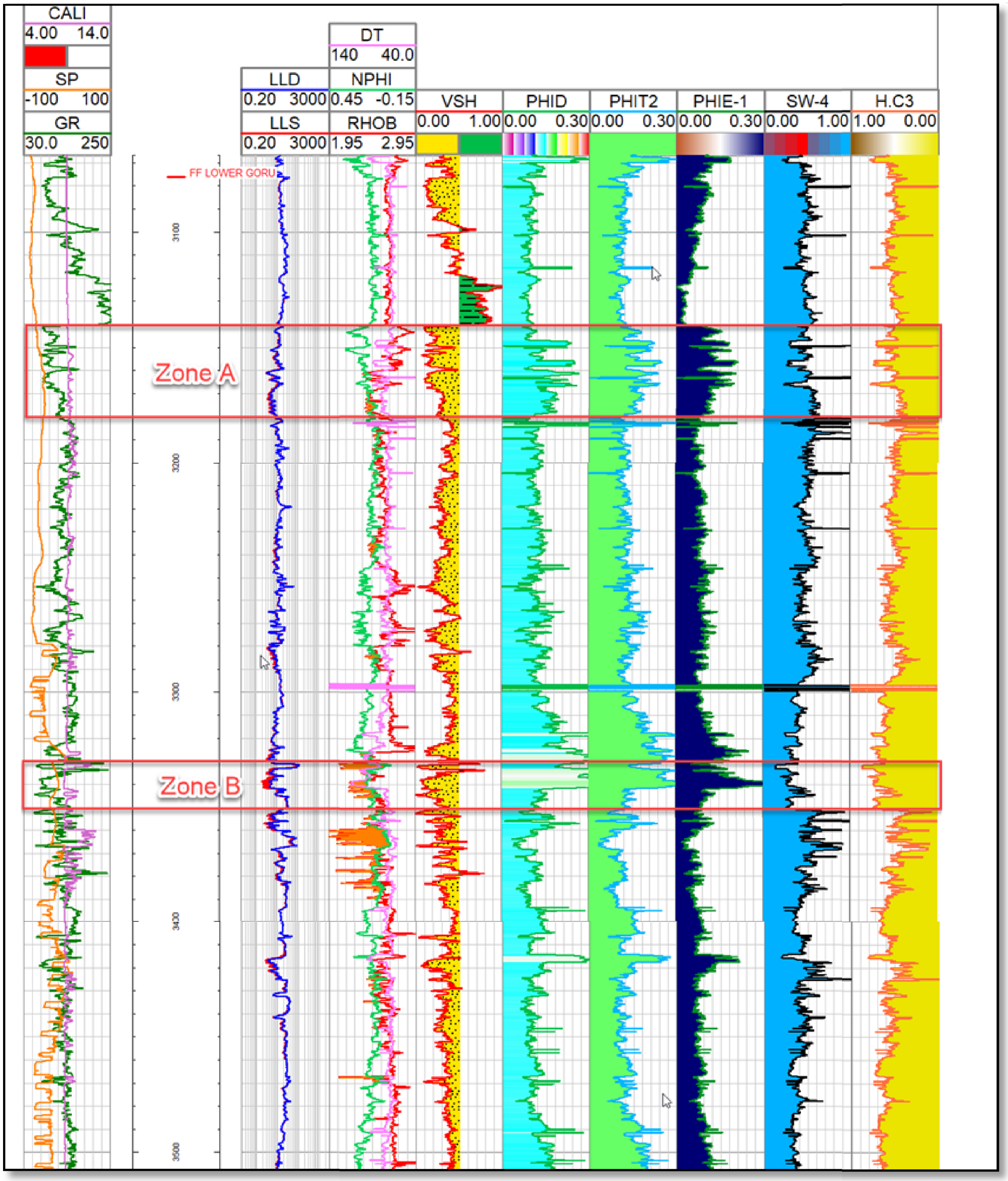
Work flow for Petrophysical Analysis:

For petrophysics analysis a step by step work flow is followed to achieve the target for calculating petrophysical properties is described In fig. the log signature I,e caliper log, gamma ray (gr), neutron (nphi), density (rhob), letro log deep (lld), letrolog shallow (lls) and micro- spherically focused log (mfsl).the steps are

- Marking the zone of interest
- Review input log curves
- Volume of shale calculation
- Calculation of formation water resistivty
- Saturation of hydrocarbons


Loading well data
Input data
Track 1
CALI GR
Track 2
LLD LLS MFSL
Track 3
NPHI RHOB
Bad Hole Flag
Volume of Shale
Resistivity of water
Total porosity
Effective
permeability
Water saturation
Hydrocarbons saturation
Result analysis

Petrophysical Analaysis:



Zone of interest:

The reservoir encountered in kadanwari wells was lower goru formations which was of lower cretaceous age. This lower goru formation was further divided into different zones. According to our data available we have two zones of interest.

Petrophysical properties of zone:

Depth range (3140m-3180m) 40m depth	
parameters	**Avg. % in zone A**
Volume of shale	23
Effective porosity	13
Water saturation	49
Hydrocarbon saturation	50

Depth range (3330m-3350m) 20m depth	
parameters	**Avg. % in zone A**
Volume of shale	22
Effective porosity	15
Water saturation	32
Hydrocarbon saturation	67

Volume of shale (V_{sh}):

Gr log is the most widely used for volume of shale determination. In the quantitative evaluation of shale content, it is assumed that radioactive minerals are absent in clean rocks as compare to shaly rocks. The volume of shale can be determined at any point with the following formula (sclumberger, 1989).

$V_{sh}= (GR_{log}-GR_{matrix}/(GR_{shale} -GR_{matrix})$

Gr log= gamma ray log

Vsh= volume of shale

Gr matrix= mininmum value of gamma ray

Gr shale= maximum value of gamma ray

Effective porosity:

Effective porosity calculation is made from log signature of neutron, density, and volume of shale (bhuyan and passy, 1994).

Pore space contribute in effective porosity in producing such a pore spaces exclude capillary-bound water as well as isolated and clay bound water. Disaggregation of core sample gives total non-solid spaces from which the total porosity can estimated (ellis and singer, 2007).

It is the amount of inter.connected pore spaces. Effective porosity is calculated with the help of the following formula.

Phie= phix*(1-vsh)

Where ,

Phie= effective porosity

Phix= total porosity

Density porosity:

The porosity can be calculated at any point by using the netron, density and sonic logs. The porosity values as computed from various sources showed reasonable agreement with each other. Using the neutron, sonic and density logs, porosity values of interested zones are calculated . then total porosity and effecteive porosity can be calculated using the porosity values of density and neutron logs.

Density porosity:

The the following formula has been used to calculated the density porosity of the formation.

Phid= $(R_{hom}-R_{hob})/R_{hom}-R_{hof})$

Where,

Phid= density porosity

Rhom=density of matrix

Rhof=density of fluids

Rhob=values of density log at given point

Neutron porosity:

Neutron logs determine the hydrogen atom concentration in a formation. Hence the neutron log measures the fluid- fluid porosity. The values of newtorm porosity can be read directly from the neutron log curve (nphi).

Total porosity:

Total porosity or average porosity us calculated with the help of the following formula.

Phix=(phid+phin)/2

Where,

Phix= total porosity

Phid=density porosity

Phin = neutron porosity

Calculation of water saturation:

During the log analysis of kadanwari wells the water saturation (sw) is calculated with the help of archie equation.

$Sw^{\wedge n}$= A/phi m * Rw/Rt

Where,

Sw=water saturation

N= saturation exponent

A= lithological coefficient

Phi= cementation factor

Rw= resistivity of water

Rt= true resistivity (deep resistivity) at that depth

The values of m, n, and a comes from the core analysis of the data. We assume these three values to be constant.

N=2 m=2 a=1

By putting values of these parameters and simplifying the above equation it becomes as follows. Archie equation is used because it gives the direct relationship between resistivity of water (rw) and true resistivity (rt) with water saturation. It is more realistic tha any other equations. Finally this water saturation is saturation is subtracted from 100% to give the hydrocarbon saturation.

$Sw(\%)= ((1/phi) ^{2} * rw/rt *100)^{1/2}$

Hydrocarbon saturation:

The values of hydrocarbon saturation are calculated with the help of formula as undr

SH(%)= 100 –SW(%)

Where,

Sh(%)= hydrocarbon saturation percentage

Sw(%)= water saturation percentage

Permeable:

Permeable is the measurement of a rock strata ability to transmit fluids, typically measured in darcies or millidarcies. Permeability calculated using water saturation and effective porosity introduced by (wyllie abd water, 1950). The relationship between permeable,effective porosity and irreducible water saturation which is later further developed by (timur, 1968).

Perm= kw* phid/swe

Where,

D=4.4

E=2

Kw= 3400 for oil

Kw= 340 for gas, according to timur modification

Petrophysical interpretation:

The petrophysical results are shown graphically for further interpretation. The crossover on the density-neutron log sometimes may be the indicator of presence of gas. Resistivity logs are very helpful to identify the hydrocarbon in reservoir rocks. Higher resistivity values usually caused by shale.

Unmoved hydrocarbons:

It is the difference between bulk volume moved water and the effective porosity . it represents the portion of pore space adjacent to the borehole in which hydrocarbons remain.

Moved hydrocarbon:

It is the difference between bulk volume water and bulk volume moved water. It represents the zone adjacent to the borehole that is invaded by mud fluid.

Conclusion:

From the interpretation work, following conclusions are deduces:

- Time and depth contour maps of lower goru help us to confirm the presence of horst and grabben structure in the given area. This structure acts as a trap in the areas, which is best for hydrocarbon
- Synthetic seismogram matches with marked reflections which confirm the presence of stratigraphic interpretation.
- Petrophysical analysis shows lower goru formation in some intervals are good reservoir. But the thickness of this is very small.
- Lower goru is reservoir in the area.
- Thin beds are present within reservoir which are measured by thin bed analysis. The shale present in this reservoir is structural shale while some portion shows the disperse shale.
- The faults marked on the seismic section are normal faults indicasting the extentional tectonics forming horst and graben geometry.
- Sember formation acts as the source rock in this area.

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