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Integrated 2d seismic interpretation of Missa Keswal area and petrophysical analysis of Missa Keswal well 03 in Potwar sub-basin, Gujar Khan, Punjab Province, Pakistan

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Abstract

The 2D seismic and Petrophysical data were integrated to define the subsurface structural alignments and reservoir assets of Missa Keswal well-03. The research study was undertaken using the seismic lines, 994-GJN-09 and 994-GNA-12of Missa Keswal well-03. A synthetic seismogram was articulated to relay seismic and well data from a seismic section. The seismic to well tie has further ensured the fidelity of seismic maps. The 2D Seismic was utilized in horizons mapping and faults identification. The two horizons were figured out on time domain and later on depth domain by changing time grid to a depth function with the help of interval velocity. The seismic interpretations has discovered an anticlinal structure with both limbs dislocated by the two detachment faults headed towards each other from east to west in response to the compressional stresses in the area. The thickness of two horizons, the Chorgali and Sakesar Limestone Formations was gauged from the perceptible depth intervals at 1870 m to 1983 m in the well using Petrophysical interpretations beside the determination of environment of deposition, effective porosity, saturated contents of hydrocarbon and extent of pay zone. Study has revealed variable environments of deposition ranging from fluvial to marine for both Chorgali and Sakesar Limestone Formations. A high porosity, permeability and hydrocarbon saturation was encountered in the well. The pay zone was much thick in Sakesar Limestone Formation than Chorgali Formation. The 2d seismic data and Petrophysical parameters indicate that the Sakesar Limestone Formation can act as a reservoir.

Keywords: Seismic, petrophysical, seismogram, perceptible, interpretations, Sakesar, Chorgali, parameters.

Introduction

The Missa Keswal is found almost 70 km southeast of Islamabad in the Gujjar Khan, District Rawalpindi, Potwar region of Punjab, Pakistan at longitude 73°22' 0" E and latitude of 33°12' 0" N (Figure-1). The Gujjar Khan encompasses an extent of 1,466km^2 (566sq. mi) that is exalted 451m (1,480ft) over sea level and retains semiarid climate with the temperature and rain fall variations with elevation[1]. The eastern, northern and southern Potwar is a vast, smooth and exalted land therefore known as plateau. In addition to Plateau, the ridges, fluvial valleys, inundation plains, basins and piedmonts etc. form a few topographic facets of the Potwar section[2,3]. However, the intensely deformed Plateau forms the most significant physiographic aspect of the Potwar area[4].

The early workers have executed the work of surface geological mapping of Missa Keswal Oil and Gas field. However, the Oil and Gas Development Company Limited (OGDCL), Pakistan has determined characteristics exploratory behavior of the area bydrilling four wells. The production was obtained through three wells while one well was abandoned.

Regional Geological Settings

The Missa Keswal is an asymmetrical, very tight, NE-SW trending anticline with only 1km extensive plane crustal part and is conjoined by a north dipping fault in the south. The western portion of this structure is demarcated by a small and localized back thrust without any further extension towards east[2]. The structure forms the portion of deformed Himalayan thrust sheets owing to the deformation of platform sediments on the salt range decollement during the Indian-Eurasian collision[5].

Potwar sub-basin is known for oil production and straddles towards the northern half in upper Indus Basin, Pakistan[7]. The carbonates of Eocene and Paleocene epochs have best hydrocarbon reserves and the deeper Permian formations were also recently targeted for exploration[7]. The Siwalik sequence is cropped out at upper places, although the folded inliers in few places are occupied by the upper Eocene shale and limestone[7,3]. The Kalachitta and Margalapeaks have confined it towards north. The River Indus besides Plateau of Kohat have delineated its western boundaries and the Jhelum River andHazara-Kashmir syntaxis have limited its eastern half[2].

The syncline having a great width and breadth has breached the Potwar Basin into two major zones as termed below: i. North Potwar deformed zone (NPDZ), ii. South Potwar Platform zone (SPPZ).

The NPDZ owing to extensive synclines, imbricate thrusts, and contorted folds together with the rapidly shifting deformational frameworks form east to west direction represents structure of entire region[2,8]. The eastern NPDZ is depicted by a concealed thrust front supplemented by the extension of foreland syncline towards rear portion of Dhurnal Fault[8]. While the western NPDZ is characterized by immensely deformed anticlines set apart by vast synclines, delineating emergent thrust[8]. While the South Potwar Platform zone (SPPZ) includes a thick sedimentary rock sequence. The project area falls within the eastern NPDZ.

Work Flow: The seismic section and borehole data was incorporated to define the sub-surface. The primary purpose of research was to formulate a geological model, to find out the remaining possible potential of oil in Eocene reservoir in Missa Keswal Oil and Gas field.

The 2d seismic interpretations have disclosed the structural and stratigraphic patterns of rocks at perceptible depths in Missa Keswal area. The deformational patterns like faults and anticlines were described in structural analysis while the stratigraphic analysis involved the study of the extents of formations. However, the interpretations were finalized in few steps. At first a base map with a cardinal point falling at 42° N zone of Universe Transverse Mercator (UTM) was designed on Petrel (version 2015) software. The shot point of four migrated seismic lines, their coordinates beside the positions of Missa Keswal wells were displayed on the base map (Figure-2).

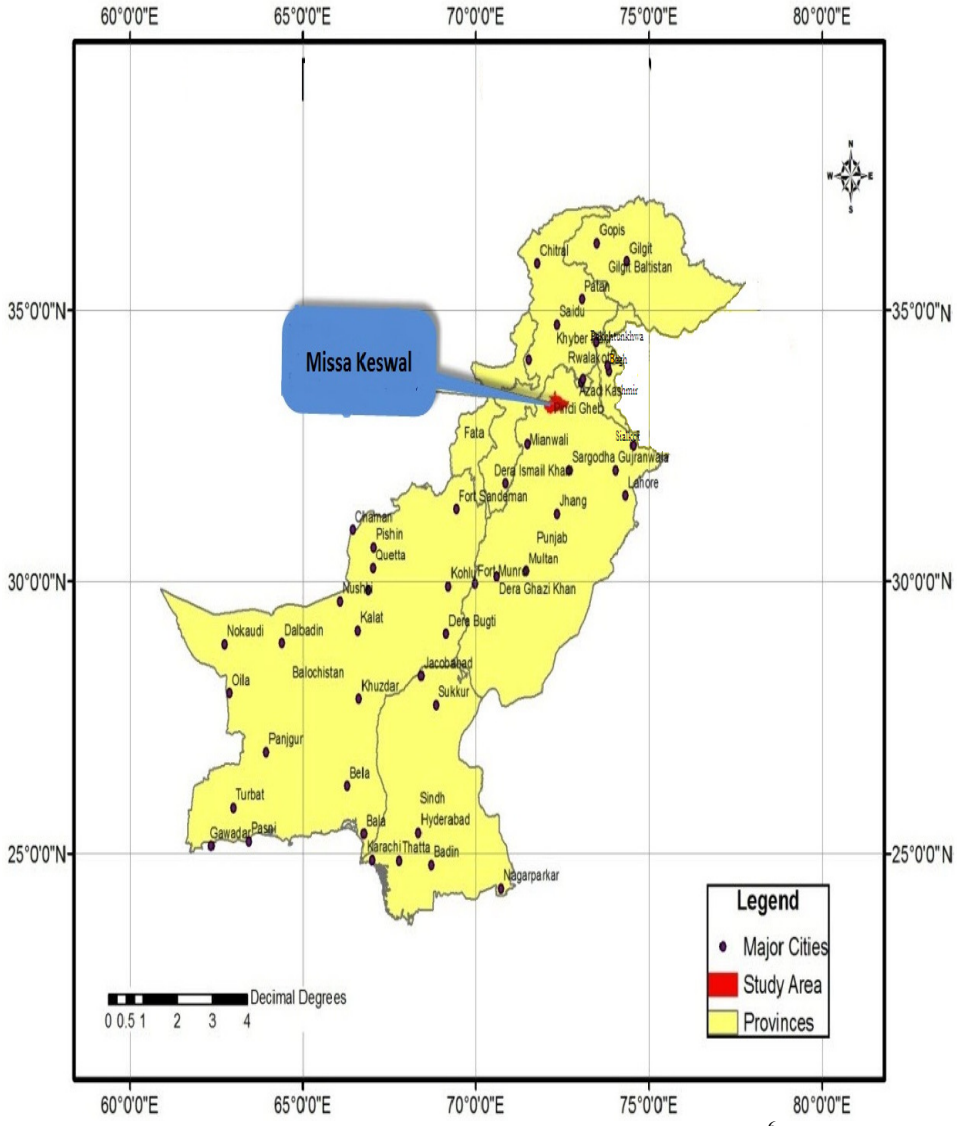

Figure-1: The allocation of the research area on a map[6].

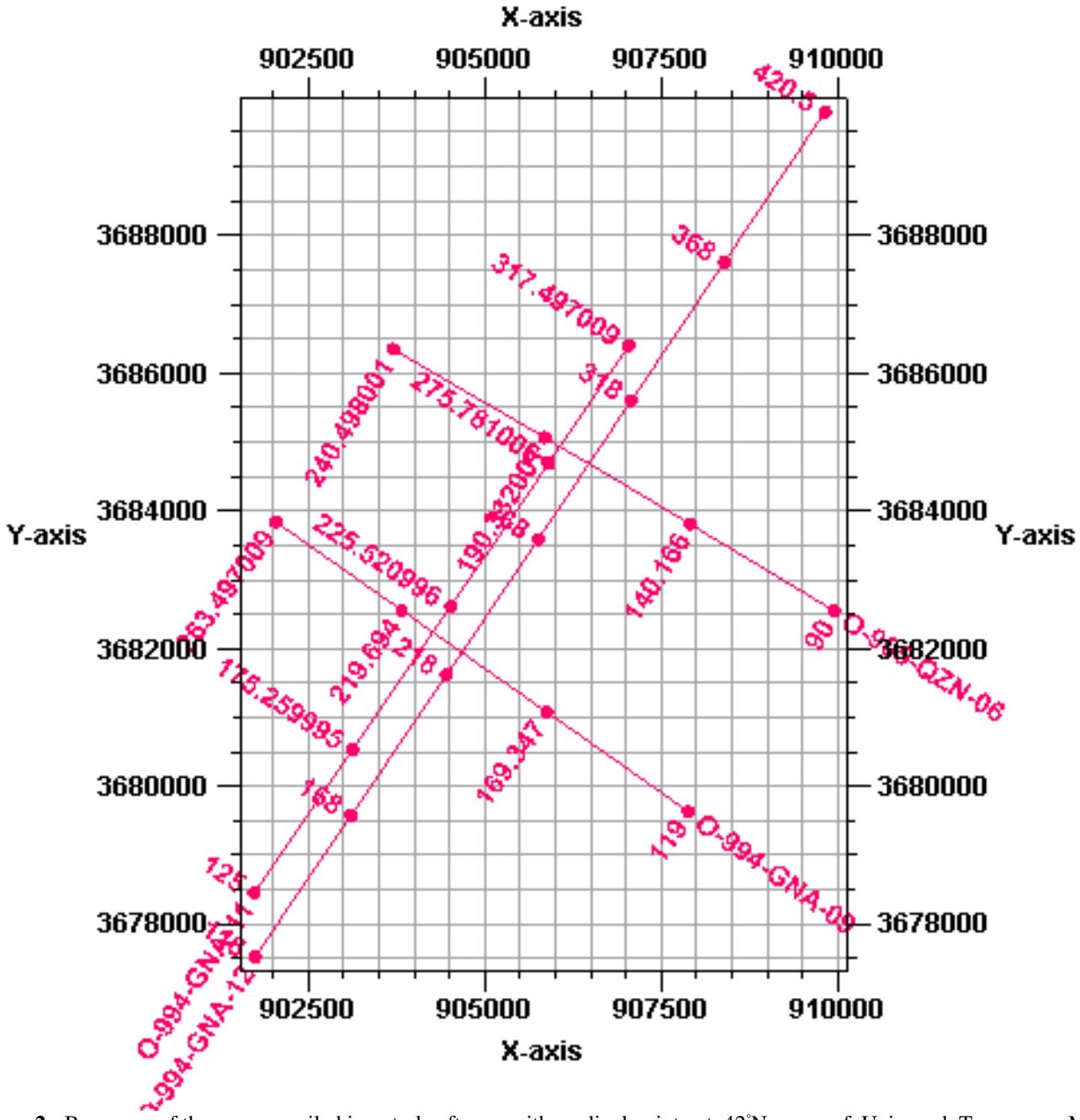

Figure-2: Base map of the area compiled in petrel software with cardinal points at 42°N zone of Universal Transverse Mercator (UTM).

Then the Geographix software was employed in developing the synthetic seismogram of Missa Kaswal-03 well utilizing Petrophysical and seismic data (Figure-3). In the beginning, an acoustic impedance log was articulated by multiplying the acoustic velocities of sonic log with density log. Then, the enduring impedance was altered to reflectivity and a compatible wavelet retaining an affinity to generate the synthetic seismogram for Missa well-03 was applied in transforming time to depth (profundity). The same wavelet was also helpful in Missa well-03 to seismic tie. On the synthetic seismogram (Figure-3), the well data was displayed on a seismic section by interrelating time and depth. However, in well ties for Missa Keswal-03, initially the horizon was traced on a seismic line before the overlaying and tying of shot points of additional lines on them. Following horizon picking, the faults and anticlinal structures (Figures-4 and 5) were identified on seismic sections, then the time and depth contour maps (Figures-6 and 7, Figures-8 and 9) were compiled from the seismic data.

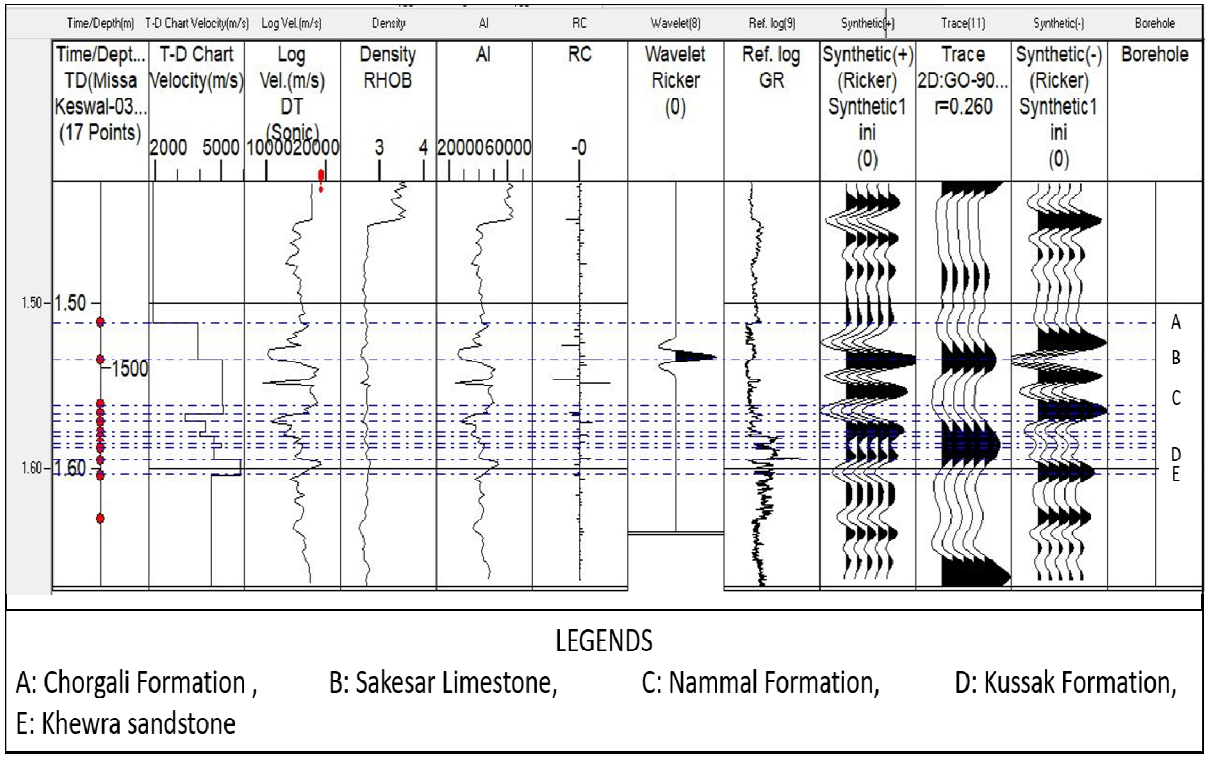

Figure-3: Synthetic seismogram of Missa Keswal well-03.

Similarly, the different petrophysical parameters including the lithology, porosity, shale content, thickness of net pay, shale volume, water and hydrocarbon saturation were interpreted using different well logs (Figure-10, Figure-11) such as Caliper, Resistivity, Gamma Ray, Density along with Porosity Logs. Data of wire line logging was set aside in the header beneath different tracks (Figure-10, Figure-11).

For resolving the shale volume in reservoir at first the Gamma Ray Index was calculated with the help of following equation[9]:

$$IGR = GRlog - GRmin / GRmax - Gmin \rightarrow \quad (1)$$

Since,
I_{GR} = Index of Gamma Ray
GR_{log} = Readings of Formation's Gamma Ray
GR_{min}= Lower limit of Gamma Ray (Carbonate)
GR_{max} = Upper limit of Gamma Ray (Shale)

Then the volume of shale was obtained through the following equation[10]:

$$Vshl = IGR/3.0 - 2.0 \times IGR \rightarrow \quad (2)$$

The equation for sonic porosity determination[11]is as follows:

$$\phi S = \Delta t - \Delta tma \div \Delta tf - \Delta tma \quad (3)$$

Where: ϕS= Sonic Porosity (µs/ft), Δt = Sonic Travel Time, Δt_{ma} = Matrix Travel Time, Δt_f = Fluid Travel Time.

Density porosity was derived through the density log using following relation[12]:

$$\phi D = \rho m - \rho b \div \rho m - \rho f \quad (4)$$

Since, ϕD = Density of Porosity, ρ_m = Density of matrix, ρ_b= Density of bulk, ρ_f = Density of fluid,

Total porosity was estimated by establishing equation[9]:

$$\phi T = \phi D + \phi N \div 2 \quad (5)$$

However, ϕT= Overall Porosity, ϕD = Porosity determination through Density logs, ϕN = Porosity resolved through neutron logs.

Effective porosity is numerated through the equation[12]:

$$\phi E = \phi T \times (1 - Vshl) \rightarrow \quad (6)$$

Where, ϕE = Effective Porosity, ϕT= Overall Porosity, V_{shl} = Shale content in terms of volume

Water saturation was determined through the Archie's equation[13] as follows:

$$Sw = \frac{(a.Rw \div \phi^{m}.Rt)1}{n} \rightarrow \quad (7)$$

Since, S_w=Water Saturation, a=1(Constant), ϕ=Porosity (Effective), m=2(Cementation Exponent), n=Saturation

Exponent, R_w=Resistivity of Formations water, R_t=True Resistivity (LLD).

The hydrocarbon saturation (S_{hc}) of formations was derived through following equation[9].

$$Shc = 1 - Sw \rightarrow \quad (8)$$

Where, S_{hc} = Hydrocarbon saturation, S_w = Water saturation.

The result of all the petrophysical parameters from well logs using equations 1-8 was summarized in a Table-4.

Results and discussion

Seismic Line 994 GNA-09 and Seismic Line 994-GNA-12: The only two seismic lines 994 GNA-09 and 994-GNA-12 from Figure-2 owing to their fair to good quality were utilized in research (Table-1).

Table-1: Seismic lines and their description.

Line name	Line Type	Line quality	UTM Zone No
994-GNA-09	Strike Line	Fair to good	42° N
994-GNA-12	Dip Line	Fair to good	42° N

The southeast-northwest oriented Seismic Line 994 GNA-09 with shot points 119-240 is a strike line while the southwest-northeast trending Seismic Line 994-GNA-12 having shot points 118-420 is a dip line (Table-1, Table-2). The two horizons (Chorgali and Sakesar Limestone Formations) were distinguished on time sections (Figure-4, Figure-5).

The interpretations have shown that the two faults (F1 and F2) breaching the flanks of anticline have developing a popup structure with moderate and tight closures with profundity (Figure-4, Figure-5). On seismic section the pulsations of time in 500 milli seconds intervals with depth are shown in Figure-4.

Table-2: Seismic lines details used for the study purpose.

Line Name	Latitude	Longitude	Shot point
994-GNA-09	$33^0$10′53.24 N to $33^0$13′17.47 N	$73^0$18′42.05 E to $73^0$22′33.97 E	119-240
994-GNA-12	$33^0$09′42.24 N to $33^0$16′30.70 N	$73^0$18′27.35 E to $73^0$23′57.95 E	118-420

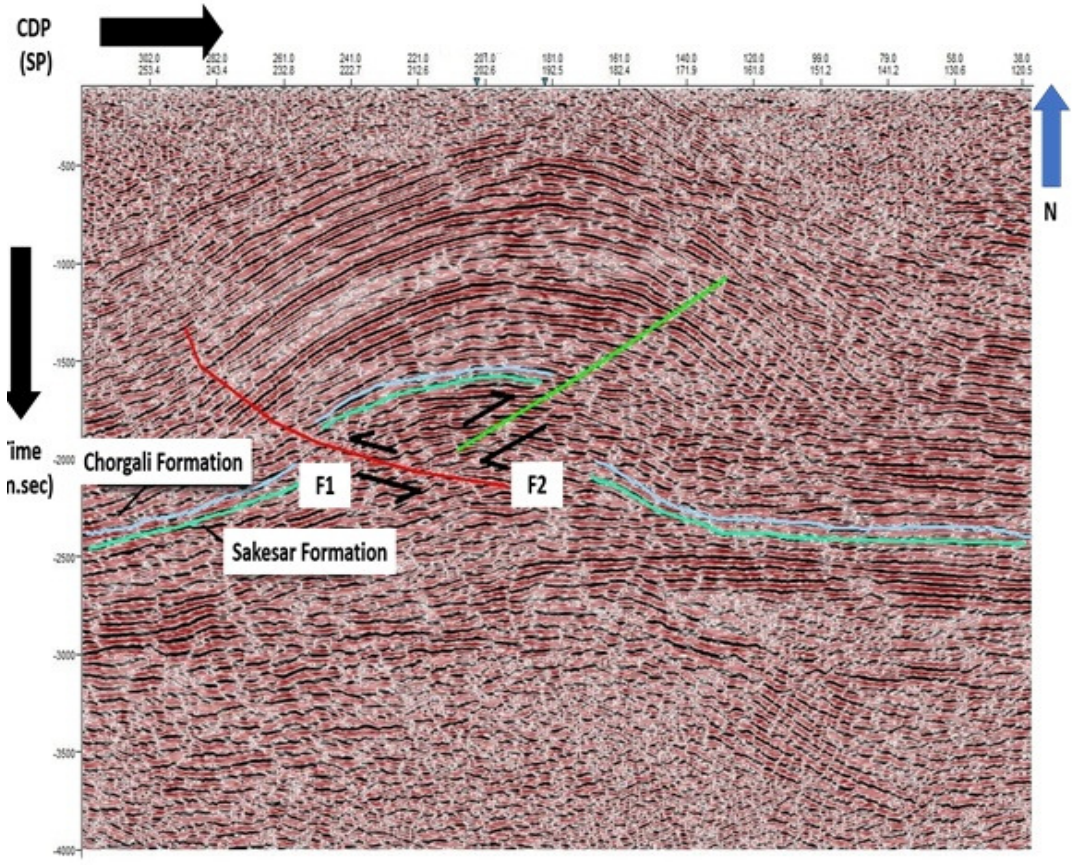

Figure-4: Interpreted time line section 994 GNA -09 of Missa Keswal area.

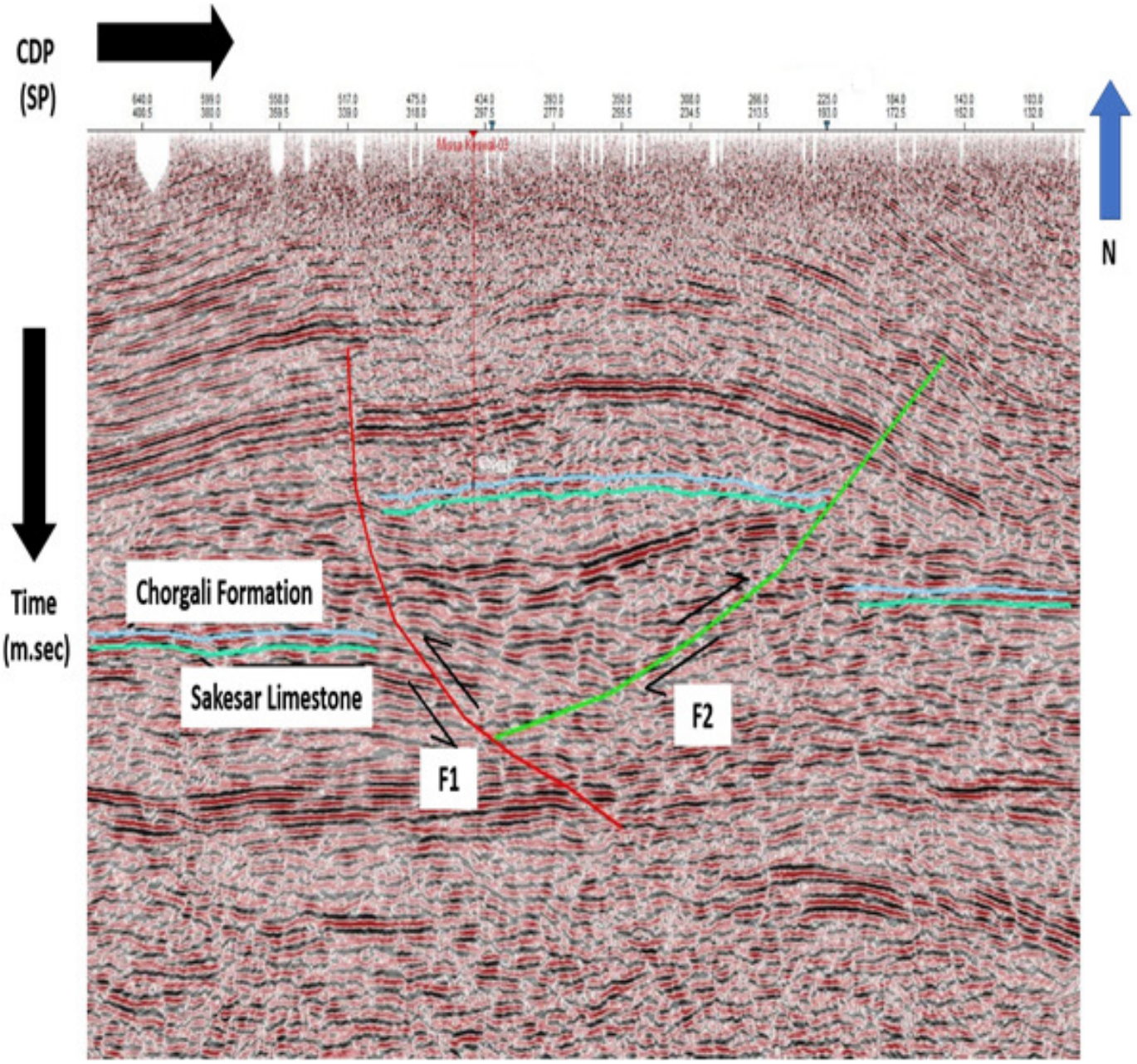

Figure-5: Interpreted time line section 994 GNA -12 of Missa Keswal area.

Time contour Map of Area: The contour lines with similar time values were portrayed on time contour maps to record the durations of time that acoustic pulses has taken in coming out of the shot holes, impinging upon the interfaces of rocks at depth and reverting back to the geophones deployed at surface. The time interval of particular horizons was recorded in a multicolored time grid.

The time contour maps of Chorgali and Sakesar Limestone Formations were compiled using one Dip and one Strike line and a popup structure was marked (Figure-6, Figure-7).

Depth Contour Map of Area: The acoustic pulses from the time grid were transformed to compatible depths (1800m to 3000m) with the intervals of 100m using velocity element through a mathematical calculation as mentioned in Equation-9.

$$S = \frac{VT}{2} \quad (9)$$

S= Distant, V= velocity, t= time.

The depth contour maps of the Chorgali and Sakesar Limestone Formations indicating a pop up structure, compiled from a migrated map are shown in figure-8 and Figure-9.

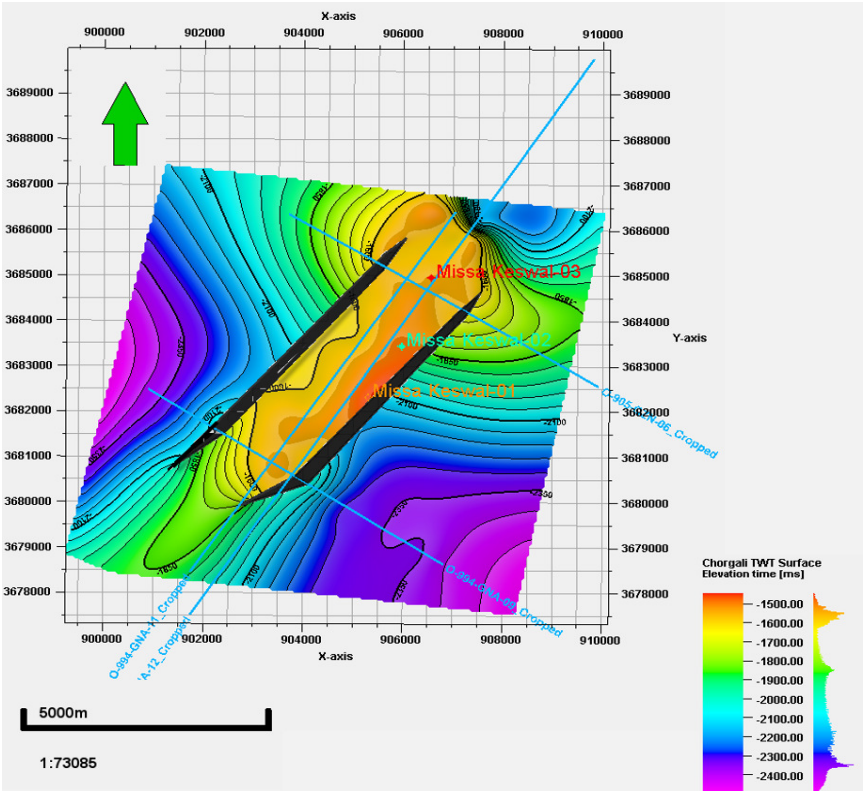

Figure-6: Time structure map of Chorgali reservoir rock formation in Missa Keswal.

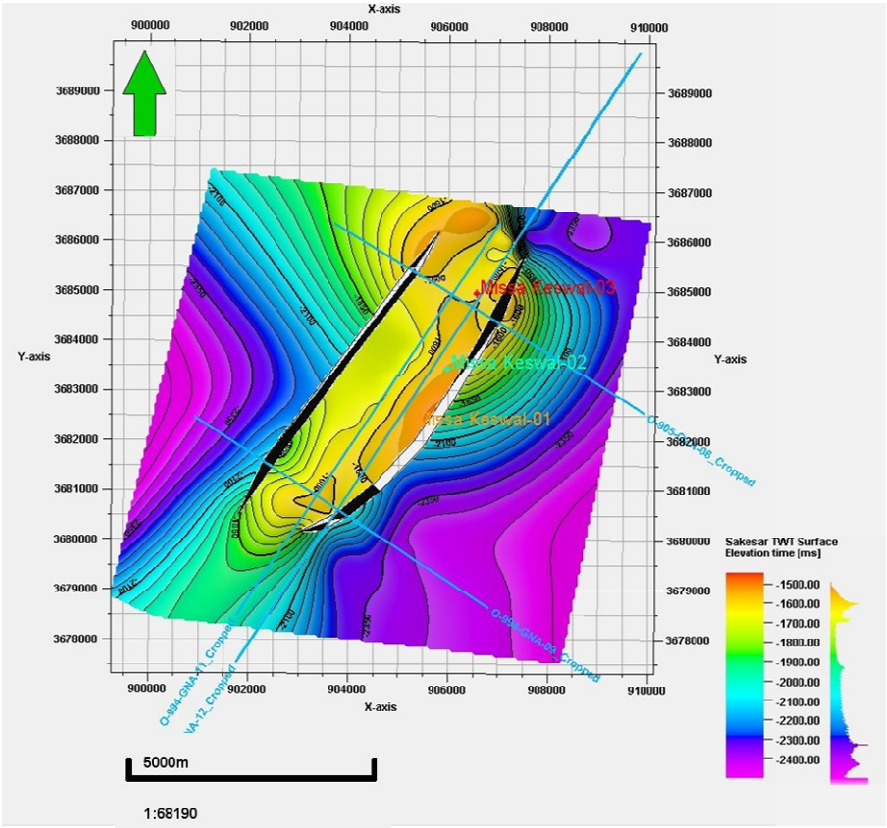

Figure-7: Time structure map of Sakesar Limestone reservoir rock formation in Missa Keswal.

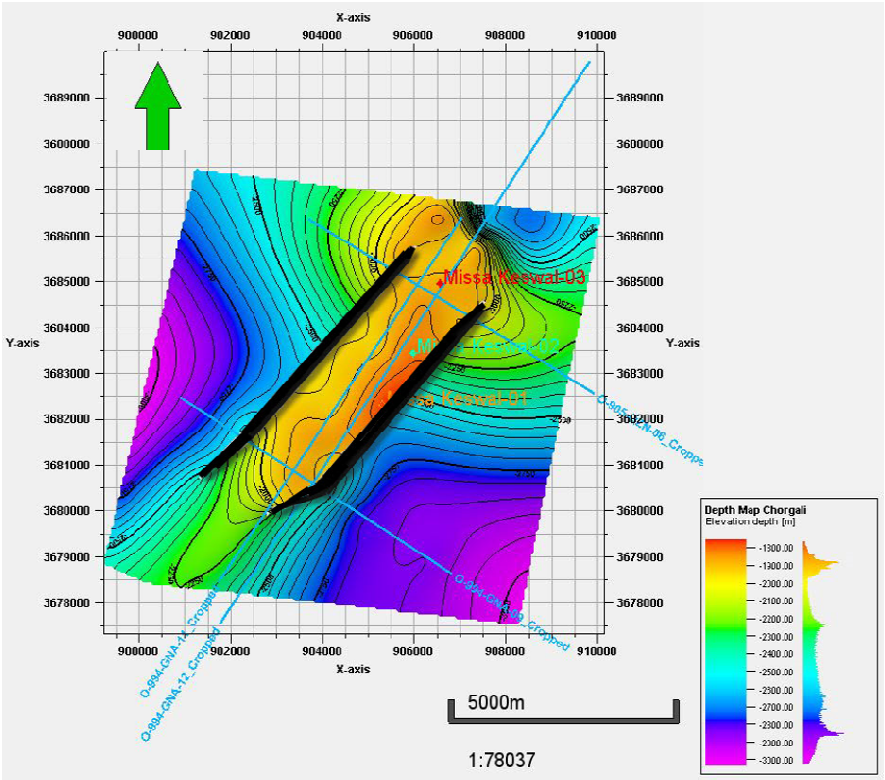

Figure-8: Depth contour map of Chorgali reservoir rock formation in Missa Keswal.

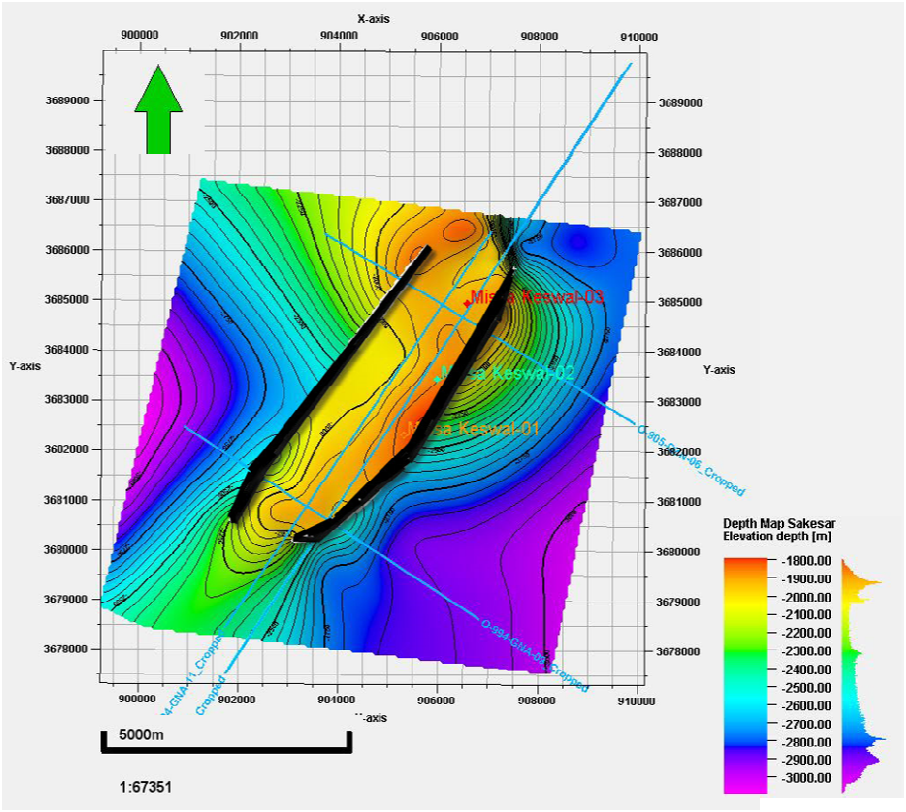

Figure-9: Depth Contour map of Sakesar Limestone reservoir rock formation in Missa Keswal.

Petrophysical interpretations: The Petrophysical study was based on the following interpretations.

Lithology: The interpretation of well logs indicate that the Chorgali Formation is dominantly shale with limestone beds with fining upward sequences (1870m-1872m, 1888m -1892m, 1896m-1914m) and coarsening upward cycles (1872m-1888m, 1892-1896m) at variable depths (Figure-10). The Formation is about 44m thick and extends from 1870m to 1914m (Figure-10). While, the Sakesar Limestone Formation is dominantly limestone with subordinate shale with the coarsening upward cycles (at the depth intervals of 1914m-1943m, 1949m-1983m) and fining upward sequences at (between 1943m to 1949m) subsurface (Figure-11). The Formation is 69m thick and extends from 1914m to 1983m on well logs (Figure-11).

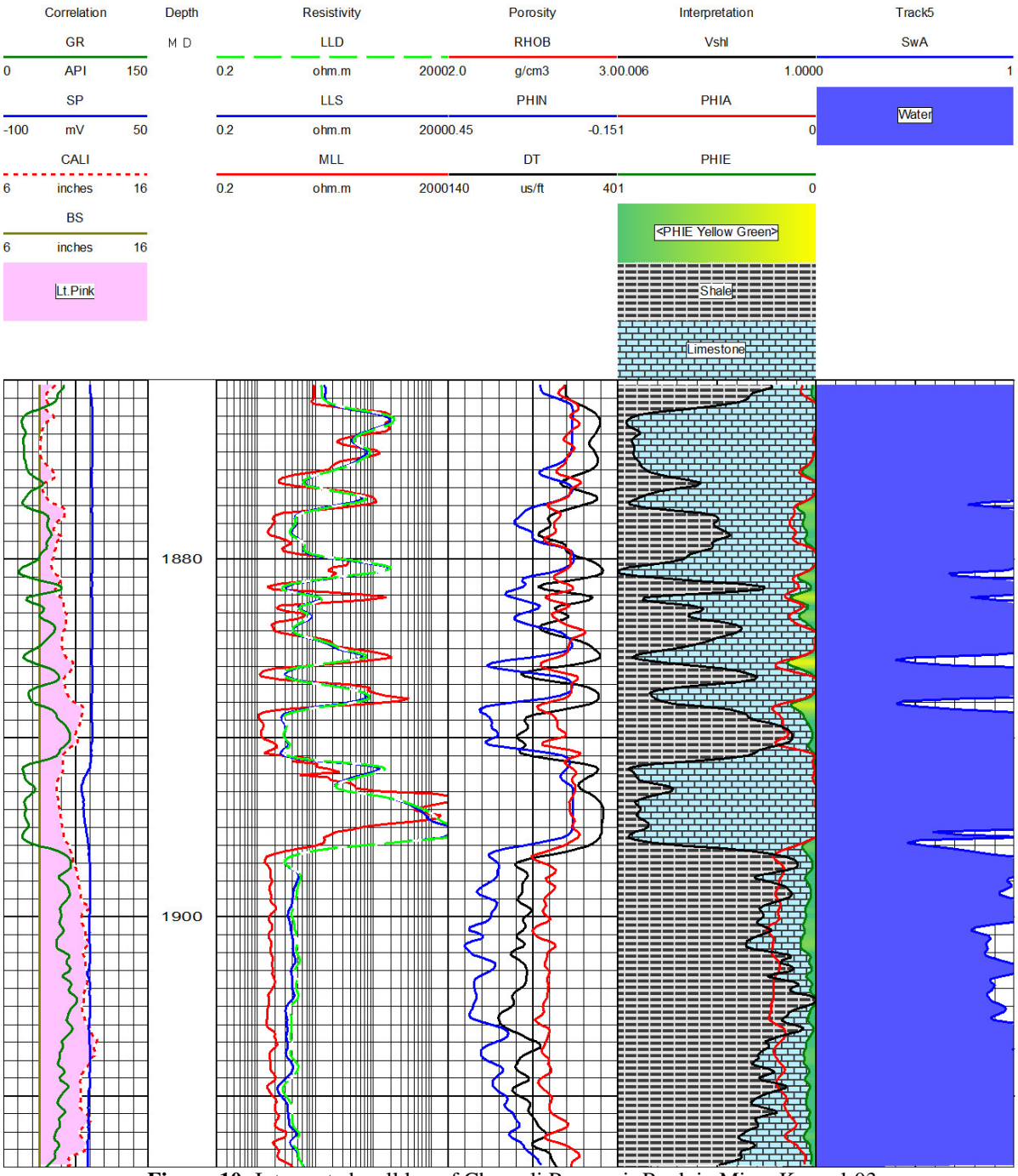

Figure-10: Interpreted well log of Chorgali Reservoir Rock in Missa Keswal-03.

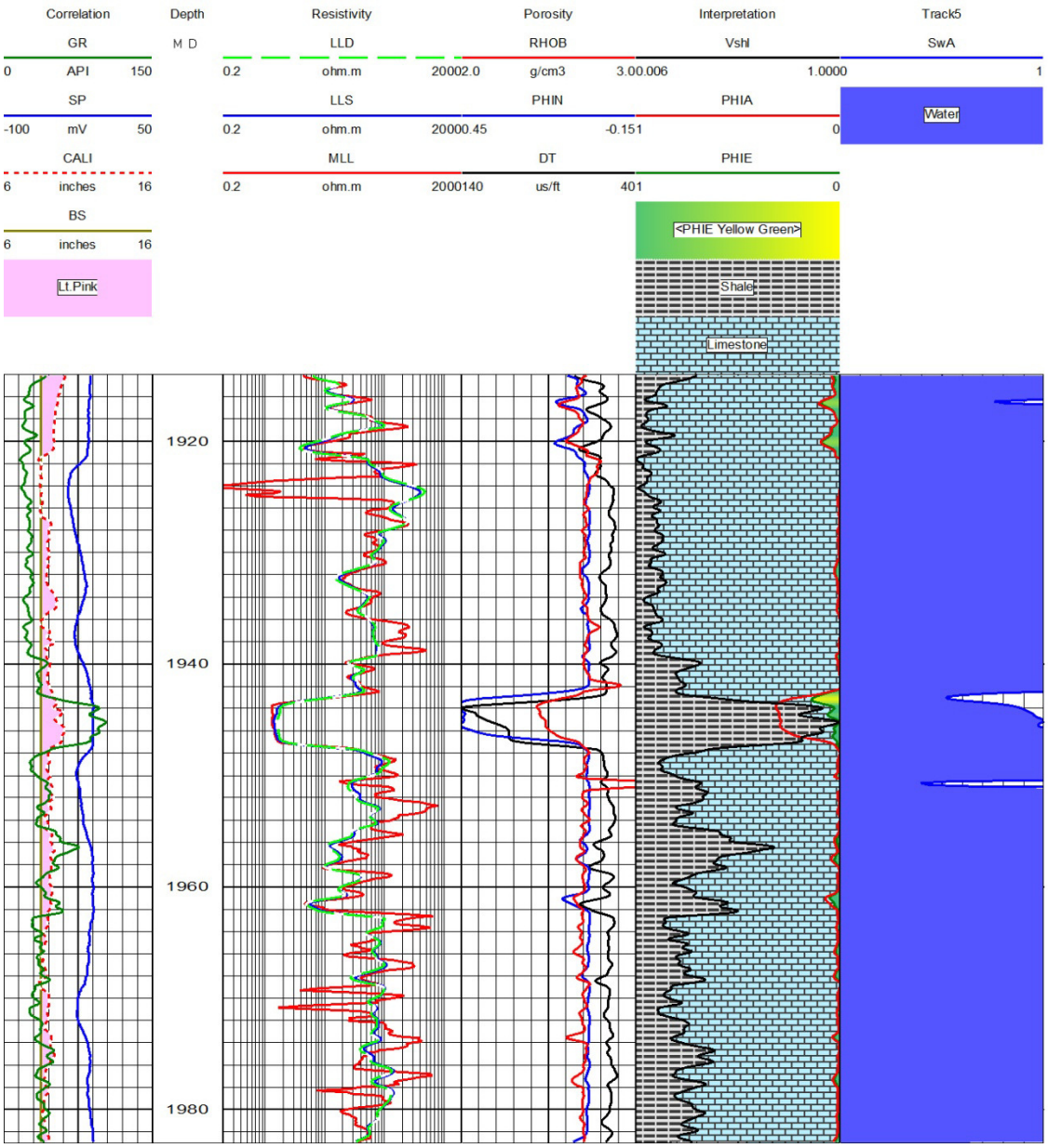

Figure-11: Interpreted well log of Sakesar lime stone Reservoir Rock in Missa Keswal-03.

Table-3: Interpretation of thickness of pay zone from the well logs of Chorgali and Sakesar Limestone Formations from Missa Keswal well-03.

Well name	Formation	Net reservoir (Meter)	Net reservoir Thickness (Meter)	Total thickness (Meter)	Total Thickness of formation
Missa Keswal-03	Chorgli	1877 - 1940 = 2	5 (m)	49 (m)	44 (m)
		1880 - 880.5 = .5			
		1882.5 - 1883 = .5			
		18911 - 883 = 2			
	Sakaser	1918 - 1940 = 22	44 (m)		69 (m)
		1952 - 1958 = 6			
		1964 - 1980 = 16			

Thickness of Pay Zone in Missa Keswal well 03: The interpretations of well logs indicate that the reservoirs are 49m thick. The pay zone is merely 5m thick in Chorgali Formation while it is about 44m in thick in Sakesar Limestone Formation (Table-3).

Table-4: Summation of the Calculations from Missa Keswal well-03.

Parameter name	Percentage
Volume of shale	35.4 %
Total Porosity	7.2 %
Effective porosity	4.5 %
Water saturation	88 %
Hydrocarbon saturation	11.9 %

Petrophysical parameters: The interpretations of other petrophysical parameters indicate a very high shale volume about 35.4%, total Porosity 7.2%, effective porosity 4.5%,water saturation 88% andHydrocarbon saturation of 11.9 % in Missa Keswal 03 well (Table-4). These results for Missa Keswal-03 well were derived by interpreting well logs from Figure-10 and Figure-11 and adding all the results from Equations (1 to 8).

Discussion: The Missa Keswal well-03 exists in Eastern Potwar Plateau, Upper Indus Basin of Pakistan and well known for Hydrocarbon occurrence. The exploratory behavior of this area was determined to attain the hydrocarbon production from the structural traps which were formed in response to the compressional stresses exerted during the tertiary Himalayan Orogeny[14].

The Precambrian to recent aged geological sequences with a few interruptions in deposition (unconformities) are well exposed in the Missa Keswal and adjoining areas[7,5].

In the integrated seismic and petrophysical study the formulation of synthetic seismogram and well ties lead to the marking of Horizons on seismic sections at considerable depths. The two horizons named as the Chorgali and the Sakesar Limestone formations of Eocene epoch were marked on each seismic section. The two faults marked as F1 and F2, displacing the anticlinal limbs with a moderate to tight closure at depth were marked on time sections and later interpreted on time and depth contour maps. The anticline was formed by the folding of Chorgali and Sakesar Limestone Formations.

The thickness of formations was calculated on the well logs during petrophysical study. The 44m thick Chorgali Formation was encountered at the perceptible depth intervals between 1870 m to 1914 m. The Formation is dominantly shale with thin limestone beds. While the 69m thick Sakesar Limestone Formation is dominantly Limestone with minor shales and was encountered at the depth intervals between 1914m to 1983m. The fining upward sequence of shales in Chorgali Formation was formed in the supratidal transgressive environment while the coarsening upward sequence of limestone was formed in the shallow marine regressive environment[16]. The other petrophysical parameters were studied to estimate the net pay of reservoir. The shale volume is about 35.4% in the Missa Keswal Well-03 (Table-4). Early studies has revealed that shale can become effective cap rocks only if their volume smudging along fault plane exceeds 25%[17]. The faults interpreted on seismic sections and on time-depth maps reflect the possibility that the fault planes have smeared a high volume of shale. Similarly the total porosity of 7.2%, effective porosity of 4.5% and a high carbonate saturation of 11.9% for Chorgali and Sakesar Limestone Formations as determined through the well logs indicates that the Missa Keswal well-03 can act as a reservoir. Moreover, the pay zone is about 44m thick in Sakesar Limestone Formation and only 5m in Chorgali Formation. However, the water saturation is very high (88%) in the reservoir.

Conclusion

The 2D seismic and Petrophysical study of Missa Keswal can be concluded as follows.

The Missa Keswal area is one of the intensely deformed regions of Northeastern Potwar of Punjab, Pakistan. In seismic interpretation, the Chorgali and Sakesar limestone formations were two horizons marked on seismic sections. Further seismic interpretation carried out on time-depth chart illustrated a popup structure in depth that may act as a seal rock.

The Petrophysical analysis based on well log studies indicates the supratidal environment of deposition for Chorgali Formation and shallow marine neritic environments of deposition for the Sakesar Limestone Formation. The Petrophysical analysis was also helpful in determining the reservoir's net pay and the interpretation of well logs indicates that the shales can act as an effective cap rock due to enormous volume especially if the fault plane has smeared its 25% volume, while the high total porosity of 7.2% and Hydrocarbon saturation of 11.9% in both Formations indicate that the carbonates of each formation can act as a reservoir. The pay zone is 44m thick in Sakesar Limestone Formation than the Chorgali Formation with 5m thickness.

The popup structure interpreted on seismic sections and time depth maps reflects the possibility of structural traps for hydrocarbon reservoirs of the area. The high porosity, hydrocarbon saturation and thickness of pay zone interpreted on well logs favor Sakesar Limestone Formation as effective reservoir, while the higher shale volume and minimum thickness of pay zone favor Chorgali formation as a seal rock.

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References

1. Ahmad K.S. (1969). Oxford school atlas for Pakistan: Karachi. *Oxford University Press*, 57 *str.*

2. Kazmi A.H. and Jan M.Q. (1997). Geology and Tectonic of Pakistan. *Graphic publishers*, Karachi, Pakistan, 94-139. *ISBN* 969-8375-00-7.

3. Shah S.M.I. (2009). Stratigraphy of Pakistan. *Geological Survey of Pakistan, Memoirs*, 22, 1-381.

4. Elahi M.K. and Martin N.R. (1961). The physiography of the Potwar, West Pakistan. *Geol. B. Pun. Uni.*, 1, 5-14.

5. Baker D.M., Lillie R.J., Yeats R.S., Johnson G.D., Yousuf M. and Zamin A.S.H. (1988). Development of Himalayan frontal thrust zone, Salt range, Pakistan. *Geol. Soc. Am.*, 16(1), 3-7. https://doi.org/10.1130/0091-7613(1988)016<0003:DOTHFT>2.3.CO;2

6. Gee E.R. and Gee D.G. (1989). Overview of the geology and structure of the Salt Range, with observations on related areas of northern Pakistan. *Geological Society of America Special Papers*, 232, 95-112. DOI:https://doi.org/10.1130/SPE

7. Kadri I.B. (1995). Petroleum Geology of Pakistan: Pakistan Petroleum Limited. *Ferozsons. Private Limited*, 36-177.

8. Kemal A., Zaman A.S.H. and Humayon M. (1991). New directions and strategies for accelerating petroleum exploration and production in Pakistan. In Proceedings, International Petroleum Seminar, 22th-24th, Nov., 76-105.

9. Schlumberger (1974). Log Interpretation Principles. *Schlumberger Education Services*, Houston, Texas, 230.

10. Thomas E.C. and Stieber S.J. (1975). The distribution of shale in sandstones and its effect upon porosity. *In SPWLA 16th annual logging symposium. Society of Petrophysicists and Well-Log Analysts*.

11. Wyllie M.R.J., Gregory A.R. and Gardner G.H.F. (1958). An experimental investigation of factors affecting elastic wave velocities in porous media. *Geophysics*, 23(3), 459-493. https://doi.org/10.1190/1.1438493.

12. Hilchie D.W. (1978). Applied Open hole Log Interpretation. In: D. W. Hilchie, *Golden Colorado,* 350.

13. Archie G.E. (1942). The Electrical Resistivity Log as an Aid in Determining Some Reservoir Characteristics. *Trans. AIME.*, 146(1), 54-62.

14. Moghal M.A., Hameed A., Saqi M.I. and Bugti M.N. (2007). Subsurface geometry of Potwar sub-basin in relation to structuration and entrapment. *Pak. J. Hydroc. Res.*, 17, 61-72.

15. Khan M.A. and Raza H.A. (1986). The role of Geothermal Gradient in Hydrocarbon exploration in Pakistan. *J. Pet. Geol.*, 9(3), 245-258.

16. Emery D. and Myers K.J. (1996). Sequence Stratigraphy. Oxford, *Blackwell*, 297. Print ISBN: 9780632037063; Online ISBN:9781444313710 doi.org/10.1002/ 9781444313710.

17. Weber K.J. and Daukoru E.M. (1975). Petroleum geology of the Niger Delta," in Proceedings of the Ninth World Petroleum Congress. *Geol*, *Apl. Sci. Pub. Ltd.,* 2, 210-221.