Research Article

Structural Interpretation of Missa Keswal Area, Potwar, Pakistan

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Abstract

This study pertains to interpretation of Missa Keswal area and identify the structures, source and reservoir formations and whether or not faulting prevailed in the reservoir formations. Six seismic lines were interpreted for the purpose. The four dip lines are oriented SE-NW whereas two strike lines are oriented NE-SW. Three reflectors namely Sakesar Limestone, Khewra Sandstone and Salt Range Formation of Eocene, Cambrian and Precambrian age have been selected and identified. Faults showing thrusting are also identified within these Formations. The root mean square velocities (Vrms), given in the velocity windows on the seismic section, were used to calculate average velocities and depth of the Formations. Seismic Interpretation of 2D data shows that the area was deformed by compressional tectonics and the structures were formed during two main episodes of deformation-initial normal faulting and subsequent thrusting. The structures are tightly folded and complexly faulted. Major thrusts and back thrusts bound the anticlinal and synclinal features. The Sakesar Limestone is present at a depth between 1700-3500 meters, Khewra Sandstone between 3500 – 4900 meters, whereas the depth of Salt Range Formation varies from 4300 – 5500 meters. The results show that the basement normal faults have influenced the above lying structures and the thrust and back faults in the area are due to compressional movements from northeast to southwest. The Sakesar and Khewra formations are continuous throughout the area and therefore, are good reservoirs of hydrocarbons.

Keywords: Seismic; Missa Keswal; Interpretation; Reservoir Formations; Thrusting

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1. Introduction

Missa Keswal area lies in the Potwar Basin, Pakistan. It is bounded by latitudes 33º2/-33º20/ N and longitudes 73º10/ - 73º30/ E. The Potwar sub-basin which includes the Potwar Plateau, the Salt Range and the Jhelum plain is located in northern Pakistan at the western foothills of Himalayas [1]. The sub-basin is bounded by Margalla hills, Kala Chitta Range and Main Boundary Thrust (MBT) in the North and Salt Range Thrust in the South whereas Jhelum Strike Slip Fault is present in the East and Kalabagh strike slip fault and Indus River in the West [1] (Figure 1).

The Missa Keswal oil and gas field area is located in the Upper Indus basin about 70 kilometers SSE of Islamabad in the eastern Potwar basin. On the surface, it is a thrust bounded anticline striking SW-NE. The first seismic investigation was carried out in 1980 followed by drilling of an unsuccessful well. Another well was drilled after an improved seismic program; which resulted in the discovery of oil and gas in seven different reservoir units i.e. Cambrian, Permian, Paleocene, Eocene and Miocene age. The field had, in place, proven reserves of 37.650 MMSTB of oil and 27.900 BSCF of gas. Current production from three wells is around 4500 barrels of oil and 7.3 MMSCFD of gas a day. Previous study by OGDCL had revealed that strata of platform sequence display a duplex geometry overlain by a passive roof complex of Siwaliks sequence as against earlier interpretation of a pop up structure.

The objective of this study is to map the primary and secondary structures, and reservoir formations of the area.

1.1 Geology

The Missa Keswal structure is bounded by a main thrust fault in the strike direction. Few orthogonal faults exist which may provide lateral barriers to the flow during production. The upward migration of oil from the under thrusted block of the duplex has probably contributed to the occurrence of a multi-reservoir system in the upper block. The fractured carbonates within the Eocene (Bhadrar, Sakesar) and Paleocene (Lockhart and Patala) Formations are most productive reservoirs in the Potwar basin. The Patala Shales of Paleocene age and Salt Range Formation of Infra Cambrian age are known source rocks, whereas Murree, Dandot and Kussak Formations are the major cap rocks of the area (Figure 4).

At the regional level, Potwar sub-basin is part of active foreland fold and thrust belt of the Himalayas [2, 3]. The structures are bounded by foreland verging thrusts (Figure 1). The geometry of the sub-basin has been influenced by Jhelum fault in the East and Kalabagh fault in the West [1]. Southern Hazara Range has greatest elevation in Potwar area with elevations exceeding 1200 meters above sea level whereas Indus and Jhelum river plains have lowest elevations. Paleomagnetic study carried out by Johnson et al. [4] indicates that there is an increase from 10^0 to 50^0 (western to eastern part) in the counterclockwise thrust related motion of Potwar Plateau. Local open folds paralleling the trend of Salt Range and northward dipping strata are the characteristics of southern Potwar Plateau [5]. According to Kemal (1991) [6], the hydrocarbon traps of Potwar Plateau are structurally controlled but local stratigraphic traps have also been reported.
According to Shah (1977) [7] and Baker (1988) [8], rocks of Cambrian, Permian to Middle Cretaceous, Paleogene and Neogene age overly the rocks of Precambrian age. In the Attock-Cherat Range, limestones and shales of Silurian and Devonian age are exposed [9]. In the Potwar Plateau Limestones and Evaporites of Eocene, fluvial sediments of Miocene to Pleistocene and alluvium of Holocene age are the exposed rocks [10, 11] (Figure 3).

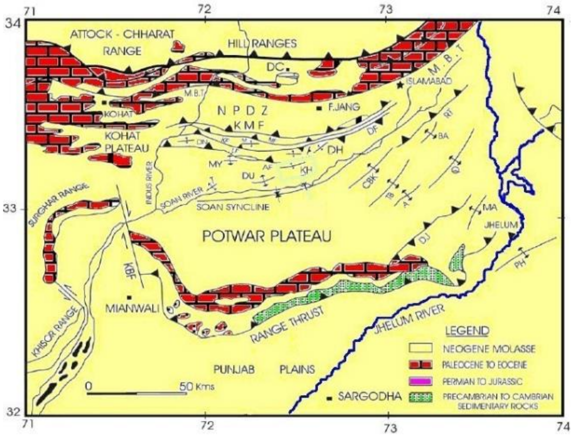

Figure 1. Generalized map of the Potwar Plateau showing the geologic and tectonic features KBF=Kalabagh Fault, MBT=Main Boundary Thrust [12].

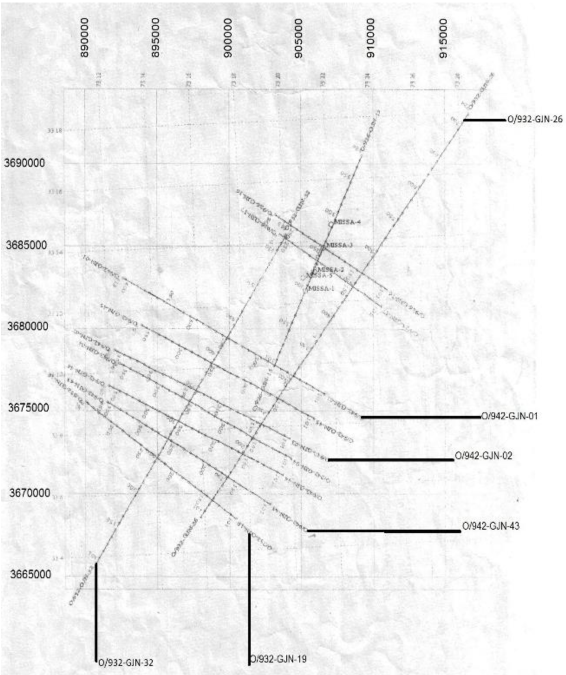

Figure 2. Base Map of Missa Keswal Area.

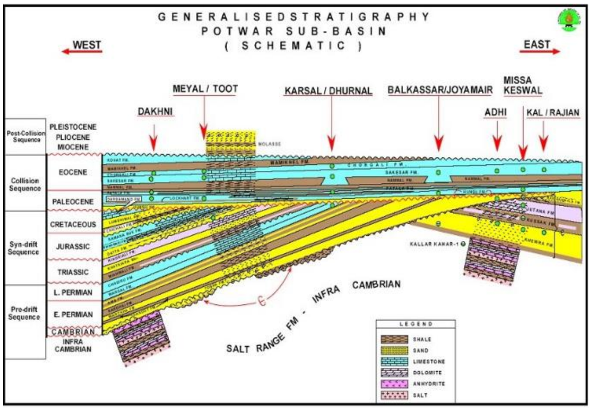

Figure 3. Generalized Stratigraphy of Potwar Sub-Basin [1].

2. Data and Methodology

The objective is to study the subsurface structures that will help in discovering the hydrocarbon accumulation in the subsurface sedimentary rocks using the reflection data. Six Seismic lines O/942-GJN-01, O/942-GJN-02, O/932-GJN-19, O/942-GJN-43 (Dip lines) and O/932-GJN-26, O/932-GJN-32 (Strike lines) were acquired for interpretation (Figure 2) from Directorate General of Petroleum Concession, Ministry of Petroleum and Natural Resources, Islamabad, Pakistan. The four dip lines are oriented SE-NW whereas two strike lines are oriented NE-SW (Figure 2).

Structural maps are constructed to display the geometry of selected reflection events. Three formations namely Sakesar Limestone, Khewra Sandstone and the Salt Range Formation (Figure 4) were chosen for the present study. The reflectors are marked on the bases of change in acoustic impedance between interfaces. These formations due to their good sedimentary characteristics have produced recognizable and continuous reflections. Previous studies have also shown that the Sakesar Limestone and the Khewra Sandstone are good reservoir rocks whereas the Salt Range Formation has acted as a source rock in the area. Later through drilling these formations proved to be producing units. Other tectonic features like faults were also identified on seismic sections (Figure 4). The root mean square velocities (Vrms), given in the velocity windows on the seismic section, were used to calculate average velocities and depth of the Formations.

Average velocities of these formations were calculated using Dix's formula

$$\mathbf{Vavg_i=(Vavg_{i-1}*t_{i-1}+0.5*((Vint_{i-1}+Vint_i)*(t_i-t_{i-1}))/t_i}$$

Whereas, the interval velocity was determined through following expression

$$V^2_{int}=\frac{(V^2_{rms,1}.t1)-(V^2_{rms,2}.t2)}{t_2-t_1}$$

(***Vavg$_i$*** *= Average Veolocity,* ***Vint$_i$*** *= Interval Velocity,* ***V$_{rms}$*** *= Root Mean Square Velocity*)

The interpretation of these seismic lines are based upon on Missa-3 well data. All formations, their thicknesses, and the major lithologies are based on this well data, which is discussed in the Table-1.

To calculate the depth on a shot point, we follow the following procedure, which is discussed below:

Depth = Velocity * Time
(OR)
Velocity = Depth / Time

Because the time that is given on the Seismic Section is always in two ways, which travel in the subsurface, therefore to convert this two way travel time into the one way travel time using the following formula.

$$\mathbf{Depth = Velocity * \frac{Time\ (2) - Time\ (1)}{2}}$$

From the seismic interpretation of the 2D data and the velocity analysis, the depth of different sedimentary structures and formations below all the shot points were calculated and utilized to develop depth and time contour maps of the Sakesar Limestone, Khewra Sandstone and Salt Range Formation. Contour maps, Surface maps and 3D time and depth maps of top Sakesar, top Khewra and base Salt Range Formation were then generated by using SURFER of Golden Software Inc. (Figures 5-12).

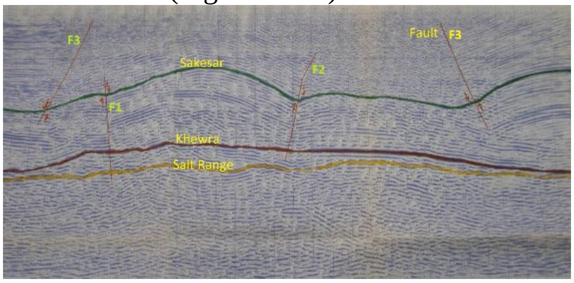

Figure 4. Seismic Section showing Sakesar Formation, Khewra Formation and Salt Range Formation.

Table 1. Missa-3 Well data showing the Formation names, Intervals, Thicknesses and major lithology's.

S. No.	Formation Name	Interval (meters)	Thickness (meters)	Major Lithology
1.	Siwaliks	0-2650	2650	Claystone, Siltstone, Sandstone
2.	Sakesar	2650-3000	350	Limestone with thin shale and marl beds
3.	Khewra Sandstone	3000-4960	1960	Siltstone, Sandstone
4.	Salt Range Formation	4960-5120	160	Gypseous Marl, gypsum, dolomite, clay, salt marl and thick seams of rock salt

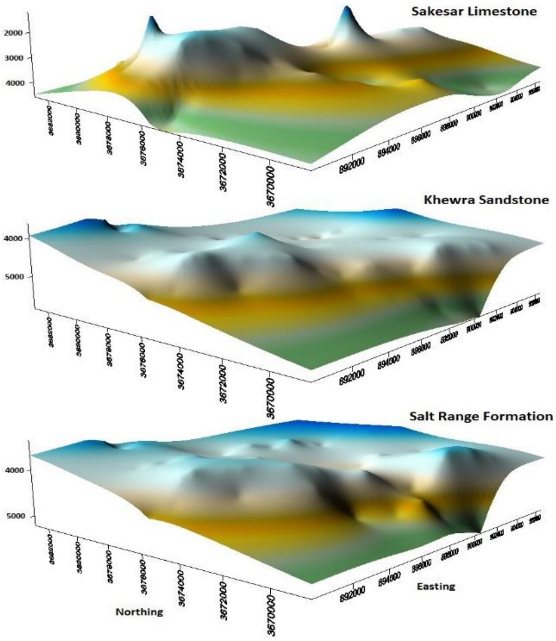

Figure 5. 3D Depth Map of Sakesar, Khewra and Salt Range Formations.

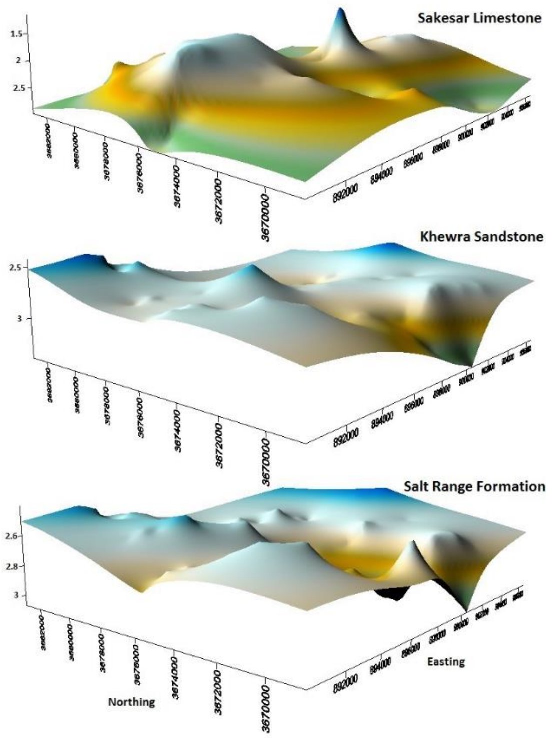

Figure 6. 3D Time Map of Sakesar, Khewra and Salt Range Formations.

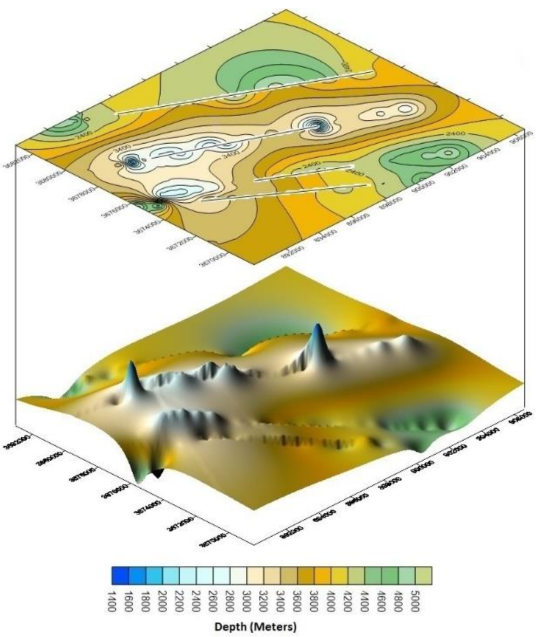

Figure 7. Depth Contour and Surface Map of Sakesar Limestone.

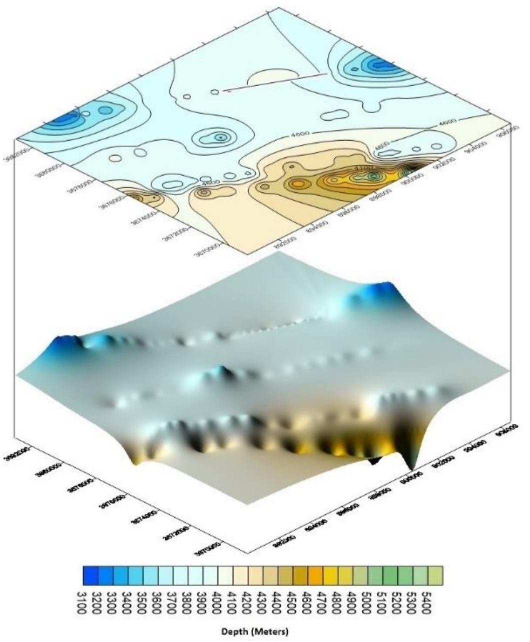

Figure 8. Depth Contour and Surface Map of Khewra Sandstone.

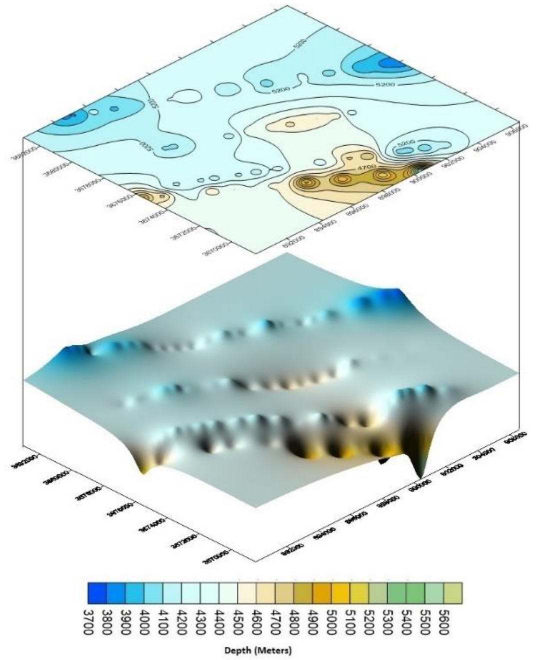

Figure 9. Depth Contour and Surface Map of Salt Range Formation.

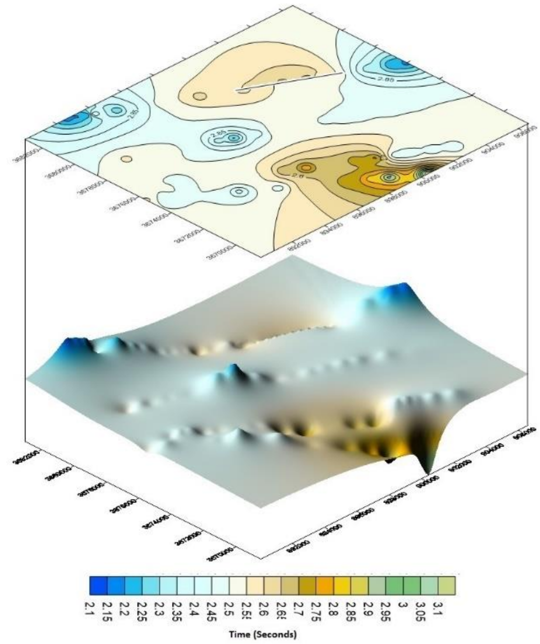

Figure 11. Time Contour and Surface Map of Khewra Sandstone.

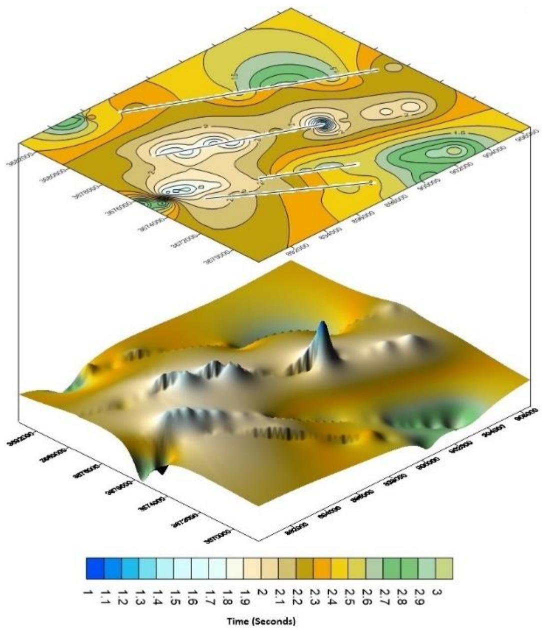

Figure 10. Time Contour and Surface Map of Sakesar Limestone.

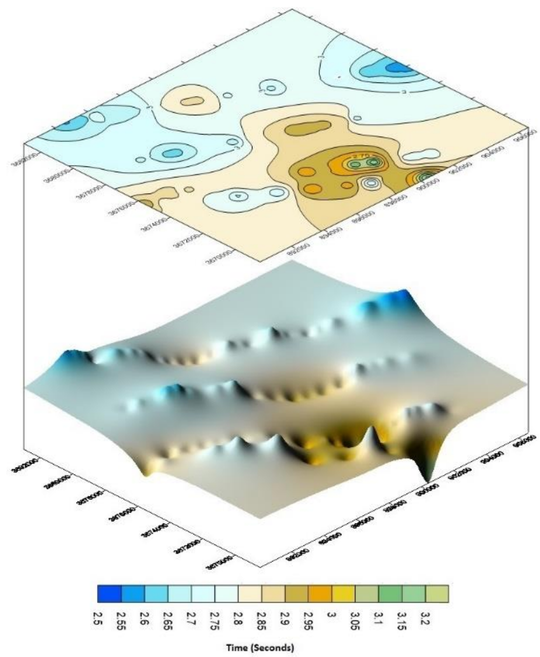

Figure 12. Time Contour and Surface Map of Salt Range Formation.

3. Result and Discussion

The seismic sections of lines O/942-GJN-01, O/942-GJN-02, O/932-GJN-19, O/942-GJN-43, O/932-GJN-26 and O/932-GJN-32 are interpreted by selecting three prominent reflectors viz. Sakesar Limestone, Khewra Sandstone and Salt Range Formation. The Sakesar Limestone and Khewra Sandstone act as reservoir, whereas Salt Range Formation is the source rock. The formations reflect the past tectonic activity that prevailed in the area through its anticlines and thrust faulting. Three types of faults are identified in the study area. First type of fault (F1) is present in all three formations and represents severe phase of tectonic activity. Second type of fault (F2) is present in Sakesar Limestone, Khewra Sandstone and Siwaliks and is younger than first type of fault (F1). Third type of fault (F3) is present in Sakesar Limestone and Siwaliks and is youngest in age. These three types of faults represent three phases of tectonic activity. The depth of Sakesar Limestone ranges from 1700-3500 meters, Khewra Sandstone from 3500 – 4900 meters, whereas the depth of Salt Range Formation varies from 4300 – 5500 meters. Primarily compressional structural elements are present in the area. The sub-basin structures have been formed by the influence of normal faults that are present in the basement. The structures are tightly folded and complexly faulted. The deformation is mainly from northeast to southwest and major thrusts and back thrusts bound the anticlinal and synclinal features. Structural development is strongly influenced by faults and decollement levels [1].

4. Conclusion

On the basis of the current study, the following conclusions are drawn.

1. The basement normal faults have influenced the above lying structures.
2. The fractured carbonates of the Sakesar Formation are at a depth between 1700-3500 meters, Khewra Sandstone between 3500 – 4900 meters, whereas the depth of Salt Range Formation varies from 4300 – 5500 meters.
3. The thrust and back faults in the area are due to compressional movements from northeast to southwest. This implies that the structures were formed during two main episodes of deformation-initial normal faulting and subsequent thrusting.

The Sakesar and Khewra are continuous throughout the area and therefore, are good reservoirs of hydrocarbons.

5. Acknowledgements

We are thankful to Directorate General of Petroleum Concessions (DGPC) for providing the data.

6. References

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