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# Amalgamation of Seismic Attributes, Rock Properties and Petroleum Potential Of Chiltan Limestone In Zindapir Anticlinorium, Pakistan

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**Abstract:** This paper discusses Petroleum Potential of Zindapir Anticlinorium by utilizingS Seismic Attributes and Rock Properties of Chiltan Limestone in detail. With the aid of the Attributes; properties like lithological boundary delineation, Hydrocarbon presence indication, Thin Bed Detection are evaluated in Dhodak Anticline. Then Rock Properties of Zindapir-1 are also computed. The method is a straight forward approach of Seismic Attributes and Rock properties computation via specific algorithms with the help of geophysical software. The results are illustrated by means of figures and the comparison affirms the Chiltan Limestone's Reservoir Potential in the Dhodak Anticline. Petrophysical interpretation of Zindapir -1 is interpreted to calculate immovable/immovable potential of Jurassic Limestone and result confirms the presence of hydrocarbon.

**Keywords:** Seismic interpretation, Seismic attributes, Rock Physics, Petrophysical analysis, Dhodak, Zindapir, Central Indus Basin

## 1. INTRODUCTION

Sulaiman mountain range is the major geological feature that runs North to South (N-S) and numerous surface anticlines are observed and mapped along this range. Safed Koh block is located in the South of Sulaiman mountain range and 80 km north of district Dera Ghazi Khan of Punjab province, Pakistan. Indus River runs along its Eastern boundary.

The associated oil field, Dhodak is drilled on the northern lower most culminations of the Safed Koh Range. Dhodak structure is basically formed from Rodho anticline. A Thrust fault cuts the southern limb of Dhodak anticline and dips in north (Raza *et al*., 1989).Chiltan Limestone is the formation that is considered for this particular study, the gas is already discovered by Dewan Petroleum Limited in Rodho culmination, our study involves the affirmation of the Hydrocarbon presence in this formation in Dhodak Anticline present in Safed Koh Block.

The Reflector identification is primarily determined by using the Well tops (Zindapir-01) as displayed in Table I by subtracting the Kelly Bushy effect; the well tops are shifted to surface elevation and then these true depths were considered, the KB elevation of the used well was 400.86 m. The crude depth to time conversion suggests that the Reflector of Chiltan Limestone lies somewhere near 2500-2700 milliseconds; marked seismic section SK-04 is shown in (**Fig.1)**.

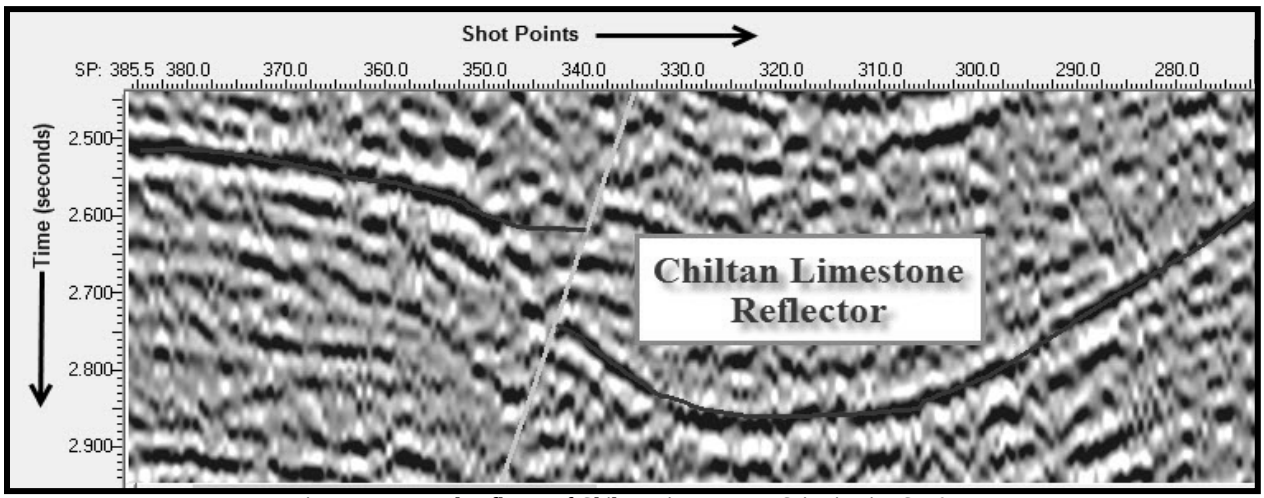



**Fig. 1: Interpreted Reflector of Chiltan Limestone on Seismic Line SK-04**

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**Table 1: Well Tops of Zindapir-01 Well**

| Zindapir-01 | | | |
|---|---|---|---|
| **Formation** | **Depth (m)** | **Formation** | **Depth (m)** |
| Mughal Kot | -216 | Chiltan L.St | -1767 |
| Parh L.St | -622 | Loralai | -2611 |
| Goru | -714 | Alozai | -3181 |
| Sembar | -1528 | | |

## 2. MATERIAL AND METHOD

2D seismic reflection data profile had been used along with the available wells. Seismic to well tie was performed to confirm the marked horizon of interest. The proven reservoir of this area is Chilton formation (Jurassic). After horizon correlation, seismic attributes are calculated by applying various algorithms. These results are calibrated by calculating rock physical properties of the zone of interest. Finally, petrophysical analysis is done to find out the movable and unmovable hydrocarbons.

## 3. ATTRIBUTES ANALYSIS

Taner (2001) and Barnes (2006) have discussed about various attribute, their application and significance in detail. Few of them are used in the present study.

### Instantaneous Phase for a Post Stack Seismic Section

Let $\phi(t)$ is Instantaneous phase attribute and measured in measured in degrees $(-\pi,\pi)$. It is not dependent upon amplitude and shows event as continuity and discontinuity. Following relation is used to find Instantons Phase

$\phi(t)=\arctan |H(t)/T(t)|$

Where

T(t) is seismic trace
H (t) Hilbert transform

As H (t) is related to the envelope E(t) and calculated by following formula

$T(t) = E(t) \cos(\phi(t))$

While e phase $\phi(t)$ is derived by following relation:

$H(t) = E(t) \sin(\phi(t))$

The instantaneous attribute of a seismic section (**Fig. 2)** illustrates the typical characteristic of the attribute which is continuity, making the interpretation easy. Not only is this but the fault marking is made easy as well at the discontinuity. Here the Reflector of Chiltan Limestone is prominent and thus this attribute plays an important role in marking the desired reflector.

### Signal Envelope (E) or Reflection Strength

The Signal Envelope (E) is calculated from the complex trace by the formula:

$E(t) = \sqrt{T2(t) + H2(t)}$

This is the signal envelope and has a low frequency and only positive amplitudes. It expresses main seismic features. It is useful for exposing discontinuities, changes in lithology, faults, and change in deposition, of sequence boundaries.

Bright spots (the highest reflectivity zones) are aligned along the Chiltan Reflector highlighting the presence of Hydrocarbon essentially Gas **(Fig. 3)**.

### Average energy for a Post Stacked Seismic Section

Average energy is a post-stack wavelet attribute, in which, within a specified window the square root of the sum of squared amplitudes is calculated and divided by their number of samples. The wavelet attributes are computed at the peak of the envelope, which represent the attributes of the wavelets within a zone defined by the trace envelope minimum. These attributes indicate spatial variation of the wavelets and therefore relate to the response of the composite group of individual interfaces below the seismic resolution. Average energy attribute usually indicates bright spot and Dim spot; figure 4 indicates the same phenomenon and confirms the presence of hydrocarbon in the Chiltan Limestone.

## 4. ROCK PROPERTIES

Rock Physics Tools for Siesmic Analysis give the promising results when applied in the study area as follows:

### S-Wave Velocity

S-Waves are also called transverse waves and they travel only through solids, as fluids (liquids & gases) do not support shear stresses.

Castagna *et al.*, 1985 described mathematical formula for the calculation of S-wave as:

$$Vs = (Vp - 1.36)/1.16$$

S-wave Velocity calculated by using the above equation varies from 2600 m/sec to 4200 m/sec. The highlighted zones have lesser values of the S-wave velocity than the actual trend which may be related to the hydrocarbon presence in Chiltan Limestone **(Fig.5)**.

### Density

Density is an important property of rocks and it directly affects the P-Wave velocities passing through it. Density Curve is shown in **(Fig.5)**. Khalid in 2010 described calculation formula for P-wave velocities by relation as:

$$\rho = 0.31 * Vp^{0.25}$$

Average density values computed lies between 2.51-2.72 within the range for Limestone. Two zones that are delineated in **(Fig.5)** have lesser density; this suggests that the zones having low mass/unit volume are

fluid filled porous zones (may indicate Hydrocarbon Presence).

**Bulk Modulus**

The bulk modulus (K) of a substance measures the substance's resistance to uniform compression. It is the ratio of volume stress to volume strain. It is defined as the pressure increase needed to affect a given relative decrease in volume. It describes the material's response to uniform pressure. For a fluid, the bulk modulus is meaningful. When pressure is applied to a specimen its volume decreases but shape and mass remain unchanged, however the density of the specimen increases (Robinson, 1988). It is computed by using the following equation:-

$$K = \rho(V_p{}^2 - \tfrac{4}{3}V_s{}^2)$$

The Bulk Modulus values vary from 20 GPa - 40 GPa; A large Bulk Modulus indicates a relative incompressible fluid. The two zones that are delineated in the **(Fig. 5)** have lesser Bulk Modulus this suggests that the zones have a fluid that has lesser compressibility, thus suggesting possibility of hydrocarbon Presence.

**Shear Modulus**

Shear Modulus gives the ratio of shear stress to the shear strain which basically describes the material's response to shearing strains relation moduli. Generally, the value increases as we move deeper due to its dependency upon the density. (Robinson, 1988) The shear modulus can be calculated by using relation;

$$\mu = \rho * Vs$$

The Sheer Modulus lies from 11 GPa – 43 GPa, The two zones that are delineated in the Figure 5 have lesser Sheer Modulus this suggests that the zones have a fluid present and it can be presumed that the fluid is Hydrocarbon.

**Vp/Vs Ratio**

Vp/Vs relation is the key to determine of lithology from Seismic and Sonic log data as well as for direct seismic identification of pore fluids using e.g. AVO analysis (Mavko *et al*., 1998), with the passage of time as the waves go deeper, its values are decreasing. Shear wave travel time is very helpful in determining mechanical rock properties. It is found that compressional wave is sensitive to the saturating fluid type. The use of the ratio of compressional wave velocity to shear wave velocity, $\frac{Vp}{Vs}$, is a good tool in identifying fluid presence.

The Vp/Vs values of the delineated zones in the **(Fig. 5)** clearly show that they have higher values due to the decrease in the Vp values. It is observed that the Vp/Vs decrease as we go deeper but here increase in the values depict that the zone may be hydrocarbon saturated.

**Poisson's Ratio**

Poisson's ratio is useful property for describing the elastic properties of solids its value becomes zero in ideal liquids and gases. Bulk modulus and Poisson's Ratio logs show the opposite character because Bulk modulus apply on solids, liquids and gases whereas. Khalid in 2010 described following relation for calculation of Poisson's ratio:

$$\sigma = \frac{0.5(Vp^2 - 2Vs^2)}{Vp^2 - Vs^2}$$

The value of Poisson ratio is decreasing with depth, the case may arise due to the fact that there is less penetration of seismic waves in the deeper layer, thus will have low value of P-wave velocity. The highlighted zones of sudden increase in the Poison ratio, just like the previous rock properties that could be related to hydrocarbon presence in the Chiltan Limestone.

## 5. AMALGAMATION OF ROCK PHYSICS AND ATTRIBUTES

The sufficient Rock Properties are estimated to delineate the zones of interest for the Hydrocarbon; the calculated results are estimated and plotted. There are two zones within Chiltan formation. Envelope and Average Energy Attribute indicate the Hydrocarbon Presence as well. Thus, both of them prove Chiltan can be a production zone in Dhodak field **(Figs. 2, 3 and 4)**.

## 6. PETROPHYSICAL INTERPRETATION OF ZINDAPIR-1

During the process of drilling, invasion of flui took place into the formation and displaces oil or gas. The oil or gas that is moved/displaced ahead of the invasion is called moveable hydrocarbons and those hydrocarbons which left behind is called residual oil or residual gas or immovable hydrocarbons. The difference between the shallow and deep saturation tells us how much oil has moved. Petrophysical interpretation of Zindapir-1 shows that presence of moveable/immovable hydrocarbons in Goru Sands of Early Creatceous and Jurassic carbonate of Chiltan Limestone in small quantity (Fig.6Petrophysical Interpretation was carried by GeoScience Software (GS) of GeoScience Software Inc., USA.

Nazeer *et al*, (2012-2013) discusses active petroleum system in Zindapir Structure and recommends additional seismic data to study compartment in the subsurface structure. Limitation of seismic data is major risk for successful discovery in Zindapir-1. Seismic Grid is wide and open to map the

subsurface compartments of Zindapir-1 **(Fig.6)**. Dhodak, Rodho, Afiband and Zindapir structure share same geology, tectonic setting and petroleum charge model because these structures are part of big anticlinorium called as Zindpir Anticlinorium. Chiltan Limestone is a proved reservoir in Rodho, Afiband and Zindapir structure and same could be in Dhodak structure.

## 7. CONCLUSIONS

This investigation concludes that the Seismic Attributes are of primal importance; this technique gives a new way to interpret seismic data and structures with more confidence in Zindapir Anticlinorium. Like the delineation of Reflectors; possibility of hydrocarbon presence, are some of the distinctive features of Seismic Attributes. This provides with significant result when used along with study of Rock Properties. This clearly commends the results indicating the presence of Hydrocarbon in the Dhodak Anticline of Safed Koh Block. Petrophysical analysis of Zindapir-01 shows a small fraction of movable hydrocarbon.

## 8. SUGGESTIONS & ECOMMENDATIONS

It is clearly indicated by the Rock Properties Estimation and Attribute Computation that the Chiltan Limestone is most likely suited for the Hydrocarbon storage. But further studies must also undergo like Advanced AVO analysis and Modeling, Overburden Pressure and Temperature Calculation and TOC Calculations for Chiltan Limestone.

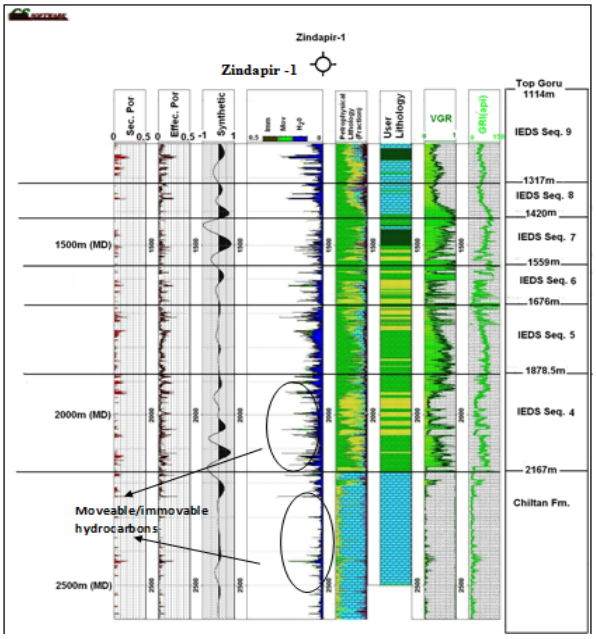



**Fig.2: Petrophysical interpretation of Zindapir- 01 is showing fraction of moveable hydrocarbon in Chiltan and Guru less than 0.5%.**

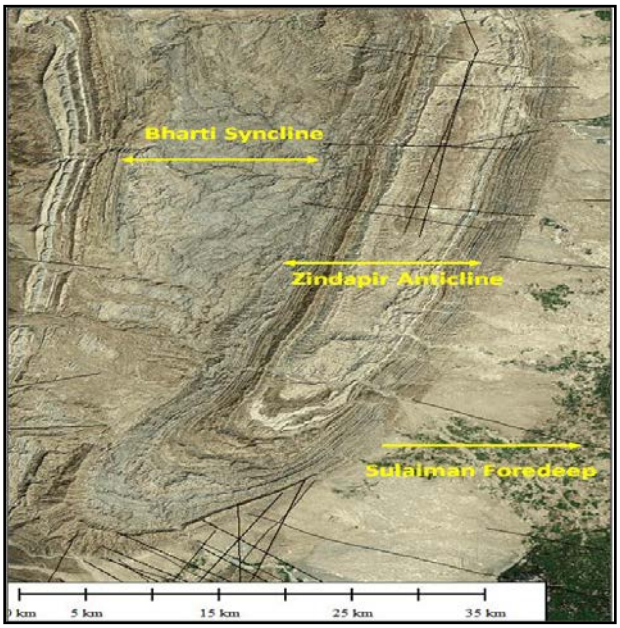



**Fig-3- Aerial View of Zindapir Anticlinorium**

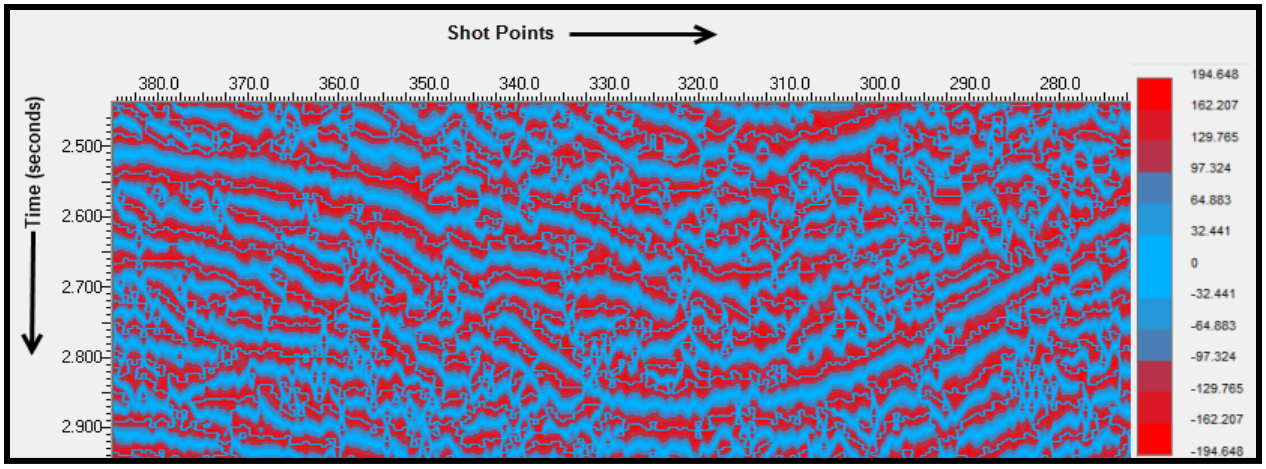



**Fig. 4: The Instantaneous Phase Attribute delineating the bed boundaries**

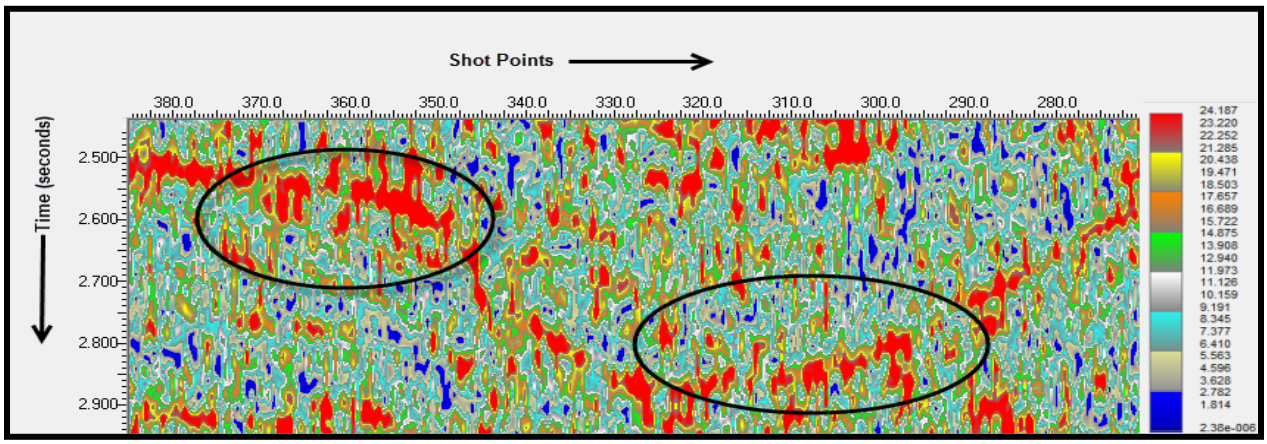



**Fig. 5: Envelope Attribute indicating the Bright Spot along the Chiltan Limestone**

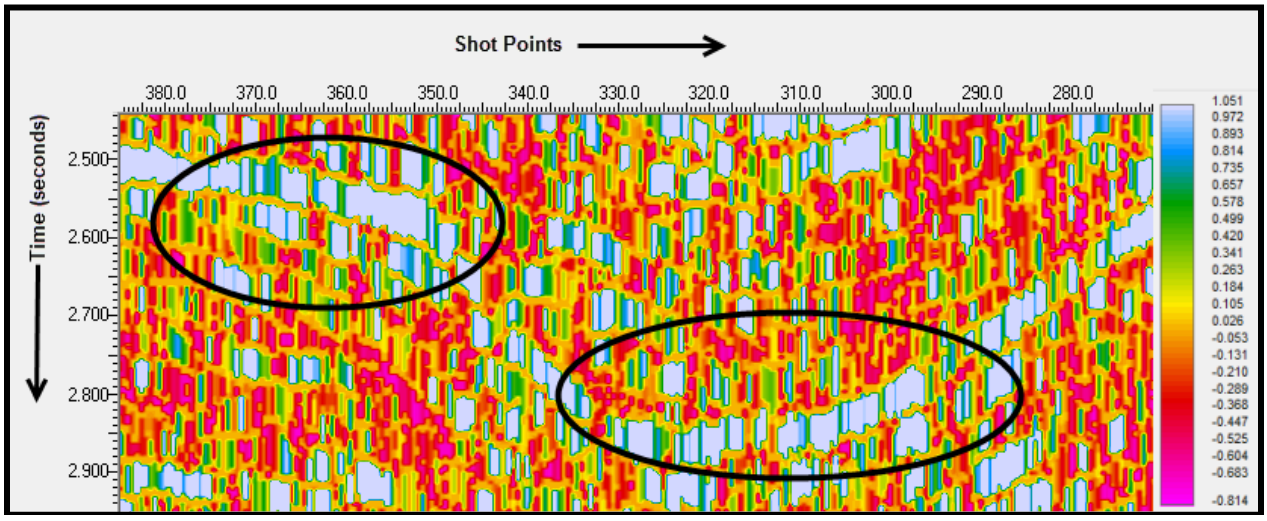



**Fig. 6: Average Energy Attribute section showing the hydrocarbon zones**

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