Integrated Approach for Identification of Moveable Hydrocarbon in tight Reservoir – A Case Study from Tarapur Area, Cambay Basin, Gujarat.

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Summary

The Kalol formation of Tarapur tectonic block, Cambay basin has intercalation of silts, shale and Coal which is very tight and permeability range 0.05 to 0.3mD. The formation is charged with hydrocarbon showing good oil saturations but no mobility in the fluid due to tightness of the formation or high viscous oils. Artificial stimulation, such as hydraulic fracturing, is usually needed in order to produce the gas unless extensive fracturing is present in the reservoirs area.

The present study aims at to determine the possible reservoir intervals having hydrocarbon moveability for which an integrated approach of evaluation of drilling and petrophysical parameters has been applied. Such studies help in understanding the tight gas reservoirs and improved drilling and completion practices.

Keywords: Low permeability, Drilling parameters, Petrophysical Analysis, Hydrocarbon moveability factor(HCM)

Introduction

The study area fall within Tarapur tectonic block of Cambay basin, in which regional litho facies analysis indicates the development of clastic reservoirs at Paleocene, Middle Eocene, Late Eocene, Oligocene and Miocene levels. The Eocene and Oligocene sands are good producers of oil and gas for the past three decades.

The Kalol formation was deposited conformably over the Cambay shale. The probable age of the formation is Middle Eocene. It is composed of intercalated silt, shale and coal sequences. The thickness of formation sequence ranges between 300 to 400 meters. This formation extends widely over the Ahmedabad-Mehsana, Tarapur and Broach blocks (Chowdhary, 2004) (Fig-1).

Kalol reservoir displays an overall regressive - transgressive - regressive nature; the regressive depositional system is comprised of fine grained sandstones, siltstones, carbonaceous shale and coals. Several wells have been drilled in the study area for the targeted reservoir of Kalol formation (Fig.2).

Fig-1: General Stratigraphy of Cambay Basin.
Methodology

I) Drilling Parameters Evaluation:
Systematic study of drilling parameters is very much helpful in identification of hydrocarbon reservoirs. Drilling parameters integrated with Shale density, D-Exponent, Shale factor etc gives indications of subsurface geology while drilling.

ROP and WOB

Fig. 3: Cross plot of ROP and WOB of Study Well.

Above cross plot indicates the prospective reservoir zone from 1630-1660mts MD.

Shale Density

Shale density increases with depth in a normally compacted and normally pressured sequence. Abnormally pressured shale often display a degree of under compaction resulting in higher porosity and hence lower density. If shale density measurements are plotted against depth a normal compaction (normal pore pressure) trend-line is established.

Any decrease in the shale density away from the normal compaction trend-line may indicate the presence of abnormal pore pressure.

Shale density values were measured from 700 – 1960m during drilling and corresponding values were plotted against depth. The shale density values vary from 2.45 gm/cc to 2.30 gm/cc. The trend indicating the marginal abnormal pressure from 1600 m 1660mts MD fig-4.

Shale Factor

Shale factor is a measure of the Cation Exchange Capacity (CEC) of the shale. The CEC of a shale sample increases with the montmorillonite content. With increasing depth and over-burden pressure, diagenesis of montmorillonite to illite occurs with expulsion of water. In normal compaction trend line, the montmorillonite content should decrease with depth. During diagenesis if expulsion of water does not take place, the abnormally pressured zones often have a higher montmorillonite content than normally pressured-shales of the same depth.

The shale factor studies were carried out on shale samples from 700 m – 1960 m. The study indicates that the Cation exchange capacity (CEC) value varies from 22.60 meq/100gm to 7.80 meq/100gm and it indicates presence of montomorillonite and illite contents of clay. The trend indicating marginal abnormal pressure from 1630 m-1660m MD fig-4.

D-Exponent

D exponent is an extrapolation of drilling parameters to get a trend while drilling into over-pressured zones. The d-exponent can be utilized to detect transition from normal pressure regime to abnormal formation pressure.

'D' exponent values were calculated from 430 m to 1961 m during drilling and corresponding pore pressure, fracture pressure and porosity were plotted against the depth. The trend shows normal pressure up to 1576 m and tending towards abnormal pressure from 1576 m to 1721 m fig-4.
Petrophysical Analysis

Petrophysical evaluation for estimation of Porosity, Water saturation and Vclay was carried out in the study area. The Electrolog and its analysis in Kalol section from 1560m-1700mts MD is depicted in fig-5. The parameters used for petrophysical analysis were; Rmf=0.047Ohm at 70°F, Rw=0.22ohm at 220 ºF, a=1, m=n=2 and formation BHT 222 ºF at 1940m MD.

The interval 1633-1642m and 1648-1658m MD were identified for testing with the help of Petro-physical interpretation. The average porosity of the Zone 8-10% and Oil saturation 60-65%.

Hydrocarbon Moveability:

Estimation of oil saturation is not only sufficient to produce the hydrocarbon from tight reservoir but estimation of mobility of the fluid is also important. Hydrocarbon mobility factor is good indicator of hydrocarbon moveability. Hamada G.M (SPE-106352) has prepared an equation on Hydrocarbon moveability factor

\[ HCM = \left( \frac{F_s}{F_d} \right)^{0.5} \]

Fd=Formation resistivity factor, (Deep) and Fd=Deep Resistivity/Rw

Fs= Formation resistivity factor, (shallow) and Fs=Shallow Resistivity/Rmf

Hydrocarbon moveability factor (HCM) were derived from shallow and deep resistivity data having scale from 0 to 1.0. If HCM is less than 0.75, hydrocarbon is moveable and if HCM is greater than 0.75, the hydrocarbon is immovable.

The HCM values in this study were calculated for the entire Kalol section. The results of the study has been displayed in Fig-6 and tabulated in Table-1. The HCM value of 0.09-0.20 in the interval 1632-1633m MD indicates Coal Gas section and 1633-1642m MD is indicating the light oil section whereas 1648-1658m MD indicates oil section. The reservoir section showing HCM values <0.75, indicates movable oil bearing zone.
Table 1: HCM values in reservoir section

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<th>Depth</th>
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Limitations

- The Hydrocarbon Moveability (HCM) technique is applicable in water based mud system only.
- The drilling parameters, which is collecting from mud logging should be accurate.

Testing Results

The zones having HCM less than 0.75 were identified in Kalol formation. On testing this zone in the interval 1648-1658m MD, produced hydrocarbon at 25m3/day with self flow with little amount of Gas. These testing results confirmed the methodology used for identification of movable hydrocarbon in the tight reservoir.

Conclusions

- Drilling parameters like Rate of Penetration (ROP), Weight on Bit (WOB), Shale Density, Shale Factor and D-Exponent are good parameters for identification of hydrocarbon zone.
- Hydrocarbon moveability factor is an excellent indicator of hydrocarbon mobility, which identifies the intervals for good production within tight reservoir.

Nomenclatures

- WOB- Weight on Bit
- ROP- Rate of Penetration
- a- Tortuosity factor
- m- Cementation Factor
- n- Cementation exponent
- HCM- Hydrocarbon moveability factor

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References


GSPC (IHS) Internal Report.