



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).

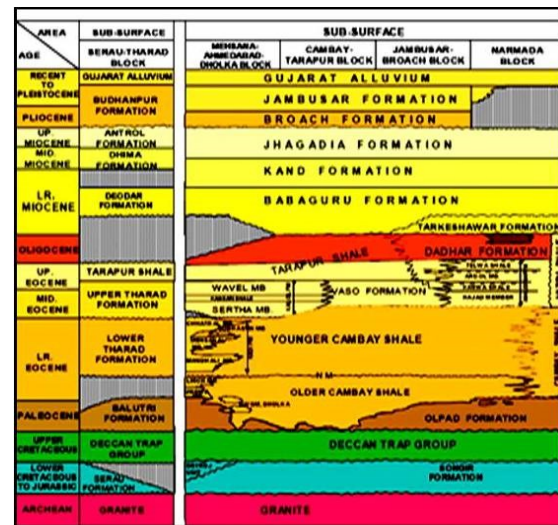


Fig- 1: General Stratigraphy of Cambay Basin.

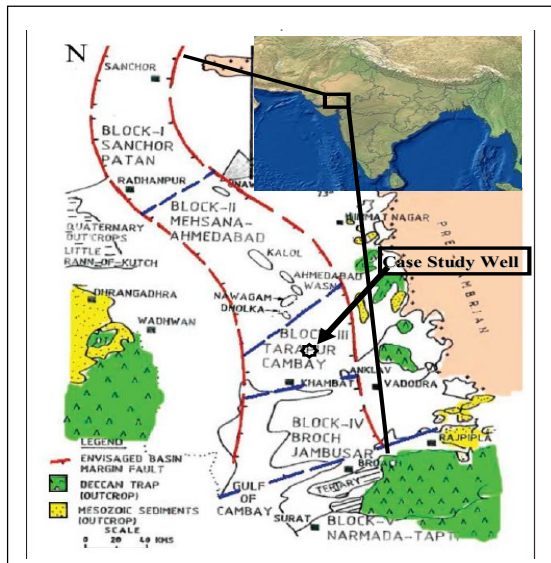


Fig-2: Location Map of Study Area (Source IHS Energy 2005.)

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

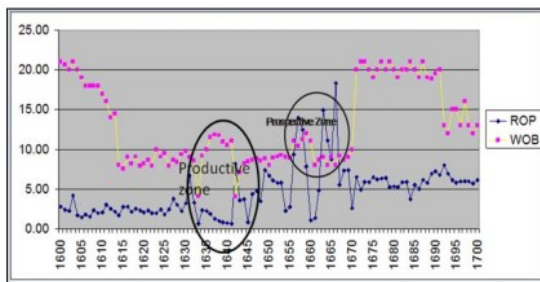


Fig- 3: Cross plot of ROP and WOB of Study Well.

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 montmorillonite 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.

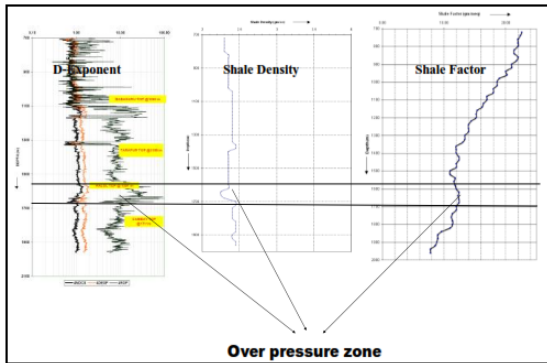


Fig- 4: Graphical representation of D-Exponent, shale density and shale factor.

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 °F, a=1, m=n=2 and formation BHT 222 °F 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%.

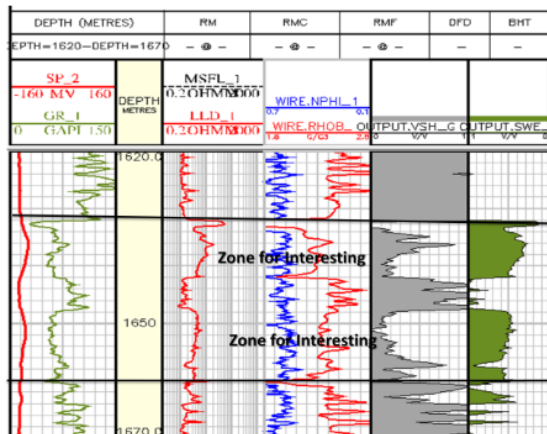


Fig-5: Perspective Zone identification from petrophysical analysis

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

$$HCM = (Fs / Fd)^{0.5}$$

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.

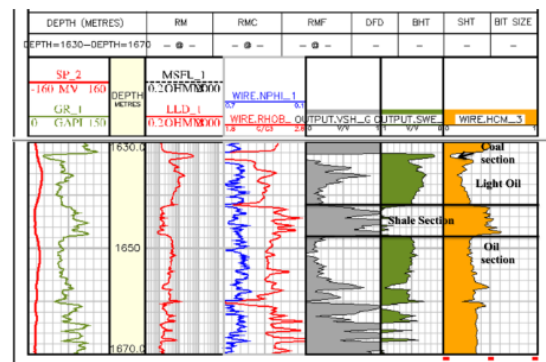


Fig-6: Hydrocarbon mobility Factor in Reservoir Section



Depth	F5	FD	HCM=F5/FD*0.5
1632.009	1.724908	33.015	0.267661727
1632.109	1.68831	83.9189	0.173918222
1632.209	1.571355	155.9831	0.100505229
1632.309	1.509881	187.7625	0.09058375
1632.409	1.482344	213.1865	0.083560158
1632.509	1.485635	232.8373	0.079878658
1632.609	1.450062	243.0168	0.077303299
1632.709	1.416028	241.2936	0.076653117
1632.809	1.38369	226.4684	0.078172226
1632.909	1.391435	171.8922	0.092475487
1633.009	1.391498	110.0063	0.155803166
1633.109	1.378591	41.0299	0.195291833
1633.209	1.471109	24.6866	0.25851441
1633.309	1.552667	17.4847	0.29860576
1633.409	1.598078	16.0784	0.315552848
1633.509	1.610213	16.2622	0.314727025
1633.609	1.61675	16.6367	0.311743963
1633.709	1.623288	16.8568	0.31032483
1633.809	1.62459	17.003	0.309112763
1633.909	1.627409	17.4697	0.305478805
1634.009	1.637189	18.7888	0.295410054
1634.109	1.651895	20.9322	0.281909028
1634.209	1.669686	23.9227	0.265486723
1634.309	1.692431	28.813	0.243736743
1634.409	1.715178	32.7661	0.229480282
1634.509	1.735488	36.6694	0.218026375
1634.609	1.745273	41.9951	0.204565149
1634.709	1.737842	45.2513	0.19612751
1634.809	1.722605	45.6301	0.195795301
1634.909	1.712943	34.7669	0.225835781
1635.009	1.705276	30.2671	0.237378601
1635.109	1.699749	29.7285	0.239121308
1635.209	1.703052	29.1347	0.24179909
1635.309	1.715562	28.704	0.244489264
1635.409	1.736073	28.7443	0.246125375
1635.509	1.778283	36.3209	0.223740475
1635.609	1.798578	42.5022	0.206388953
1635.709	1.798643	47.415	0.194766527
1635.809	1.798707	48.4096	0.192780704
1635.909	1.806424	52.3297	0.186554814

Coal Zone

Light oil to Oil

Table-1: HCM values in reservoir section

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 @ 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- Tortosity factor
 m- Cementation Factor
 n- Cementation exponent
 HCM- Hydrocarbon moveability factor

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