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Quantitative Evaluation of Hydrocarbon Payzones in Kalol Formation Cambay Basin

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Most of the world is still developing conventional hydrocarbon reservoirs with the effect that the peak production maybe 5 to 10 years away. After the peak production, the utility and production of conventional resources may decline. Once this decline starts, it will be very difficult to stop it. Demand for oil will continue to increase for the foreseeable future .The future of Petroleum as a fuel remains somewhat controversial. US Today news report in 2004 that they were 40 years of Petroleum left in the ground. Some argue that because the total amount of petroleum is finite, the dire predictions of the 1970 have merely been postponed. Others claim that technology will continue to allow for the production of cheap hydrocarbons and that the earth has vast sources of unconventional Petroleum Reserves in the form of Tar sands, bitumen fields and oil Shale that will allow for the petroleum use to continue in the future, with both the Canadian Tar sands and United States oil shale deposits representing potential reserves matching existing liquid petroleum deposits worldwide. The wealth of mankind depends on the applications of science to production and transformation of natural resources useful to man. Therefore the exploration of Hydrocarbon resources must have a higher priority in economic planning of any country, particularly the countries like India.

I. INTRODUCTION

Before spudding an exploratory well, it is necessary to make a thorough study of the various logs, stratigraphy and other information from contiguous area. On the basis of this information and other experience factor, a well- prognosis can be outlined i.e. known as Geo-Technical Order (G.T.O). A G.T.O has all the information i.e. expected zones of complication, pressure and temperature data, mud, casing and cementing policies etc. After preparing the GTO we start drilling we have to do different operations i.e. known as Well site operations. Under this operations we look over Drilling Parameter ,Geological information, Wire line logging , Casing and Cementing .Mud logging Unit play vital role in these operations .MLU records different parameters like Rate of Penetration, Rotation per minute , Lithological description , Gas records etc in the form of Mud Log. Wire line logging gives the actual information of subsurface geology on the basis of the physical parameter of rocks. Logging may be done in cased hole or open hole. Correlation of Mud log and wire line log gives a clear picture about the zone of interest. On the basis of above parameters we collect the information of hydrocarbons bearing zone. To confirm the economical viable reserve we carried out well test after perforation.

FOR WELL #4 Pay Zone 1

$$\text{Temperature Gradient} = \text{B.H.T} - \frac{\text{Surface temperature}}{\text{Total depth}}$$

B.H.T=222.5°F

=> (222.5 – 80)/1965mt = 142.5/6446.8 feet

= 0.022°F/feet

Formation Temperature at 1622 mts or 4866 feets = Depth × geothermal gradient +surface temperature

= 4866 × 0.022 + 80°F = 187.05°F

At 1622 mts or 4866 feets Temperature = 187.05°F.

The average temperature at pay zone = 187.05°F.Rmf at 0.05 at 65°F temperature.

A. Rmf at formation temperature = R2=R1(T1 + 6.77)/T2 + 6.77

Here R1 = 0.05, T1=65°F, T2= 187.05°F.

R2 = 0.05(65+6.77)/187.05+6.77

= 3.58/193.82

RMF = 0.0184(Ω-m) at 187.05°F

Rw= 0.20(Ω-m) at 187°F.

$$^{*}V_{sh} = \frac{GR_{(zone)} - GR_{(clean)}}{GR_{(shale)} - GR_{(clean)}}$$

$GR_{(zone)}$ = 75 ; $GR_{(shale)}$ = 93 ; $GR_{(clean)}$ = 55

V_{shale}= 75-55/93-55=20/38=0.5

B. Larionov :

(Older rocks), $V_{sh} = 0.33(2^{2 \times I_{RA}} - 1.0)$

(Tertiary rocks), $V_{sh} = 0.083\ (2^{3.7 \times I_{RA}} - 1.0)$

For tertiary rocks $V_{sh} = 0.083\ (2^{3.7 \times I_{RA}} - 1.0)$

$= 0.083\ (2^{3.7 \times 0.52} - 1.0)$

$= 0.083\ (3.78 - 1.0)$

$= 0.083\ (2.78)$

$= 0.230$

C. Porosity Calculation

Parameter	Value
a	0.81
m	2
n	2.0
Rw(Ω-m) at 282°F	0.22
Rho matrix(gm/cc)	2.65 for Sandstone
Rho fluid(gm/cc)	1.0

Porosity $\phi_D = (p_{ma} - p_b) / (p_{ma} - p_f)$

$p_{ma} = 2.65\ for sandstone$

$p_f = 1.0$ Usually water or mud filtrate in the zone investigated by density rock.

Average p_b = 2.30 (gm/cc)

ϕ_D = (2.65 – 2.30)/(2.65 – 1)

= 0.35/1.65 = 0.21 gm/cc.

Porosity ϕ_N from log = 0.54

D. Density log porosity reading in adjacent shales ($\phi_{D(shale)}$)

$$\phi_{D(shale)} = \frac{P_{mat} - P_{b(shale)}}{P_{mat} - P_{f(fluid)}}$$

Where,

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P_{mat} : density of matrix, common value of P_{mat} for shale is 2.50gm/cc.
$P_{f(fluid)}$: densities of fluids , common value of $P_{f(fluid)}$ is 1gm/cc.
$P_{b(shale)}$: bulk density of shale read by the density log.

$$\phi_{D(shale)} = (2.5 - 2.35) / (2.5 - 1)$$
$$= 0.13/1.5$$
$$= 0.086\text{gm/cc}$$

Correct $\phi_{D(log)}$ and $\phi_{N(log)}$ readingsfor shaliness

The Neutron and Density log responses are used to solve for both shaliness and effective porosity. In the case of the Neutron log, the correction for shaliness (V_{sh}) is done as follows:(The university of new south wales , Distance learning program, “Porosity Responses from Well Logs”, PTRL6107,Formation Evaluation (Open Hole), Volume 2,unit 11)

$$\phi_{Dcor} = \phi_{D(log)} - V_{sh}.\phi_{D(shale)}$$

$$\phi_{Ncor} = \phi_{N(log)} - V_{cl}.\phi_{N(shale)}$$

here,

ϕ_{Dcor} : Formation density log readings in the formation, corrected for shaliness(V_{sh}).
ϕ_{Dcor} : Neutron log readings in the formation, corrected for shaliness(V_{sh}).
$\phi_{D(shale)}$: Density log porosity reading in adjacent shales.
$\phi_{N(shale)}$:Neutron log porosity reading in adjacent shales.
V_{sh} : Shaliness of the formation being studied.

Here $\phi_{D(log)} = 0.21$, $V_{sh} = 0.230$, $\phi_{D(shale)} = 0.086$

$\phi_{Dcor} = \phi_{D(log)} - V_{sh}.\phi_{D(shale)}$
$\phi_{Dcor} = 0.21 - 0.23\times0.086 = 0.19$
$\phi_{Ncor} = \phi_{N(log)} - V_{cl}.\phi_{N(shale)}$

Here,

$\phi_{N(log)} = 0.54$, $\phi_{N(shale)} = 0.60$, $V_{cl} = 0.230$
$\phi_{Ncor} = 0.54 - 0.23\times0.60$
$= 0.40$

E. *Effective Porosity*

$$\phi_e = \frac{7\phi_d + 2\phi_n}{9}$$
$$= 7 \times 0.19 + 2 \times 0.40/9$$
$$= 1.33 + 0.8/9$$
$$= 2.13/9$$
$$= 0.23$$

Effective Porosity = 23 %

Average Porosity = $\phi_{Dcor} \times 0.7 + 0.3 \times \phi_{Ncor}$
$= 0.19 \times 0.7 + 0.3 \times 0.4$
$= 0.133+0.12$
$= 0.25$
=25% Lime stone scale and 30% in sand stone scale

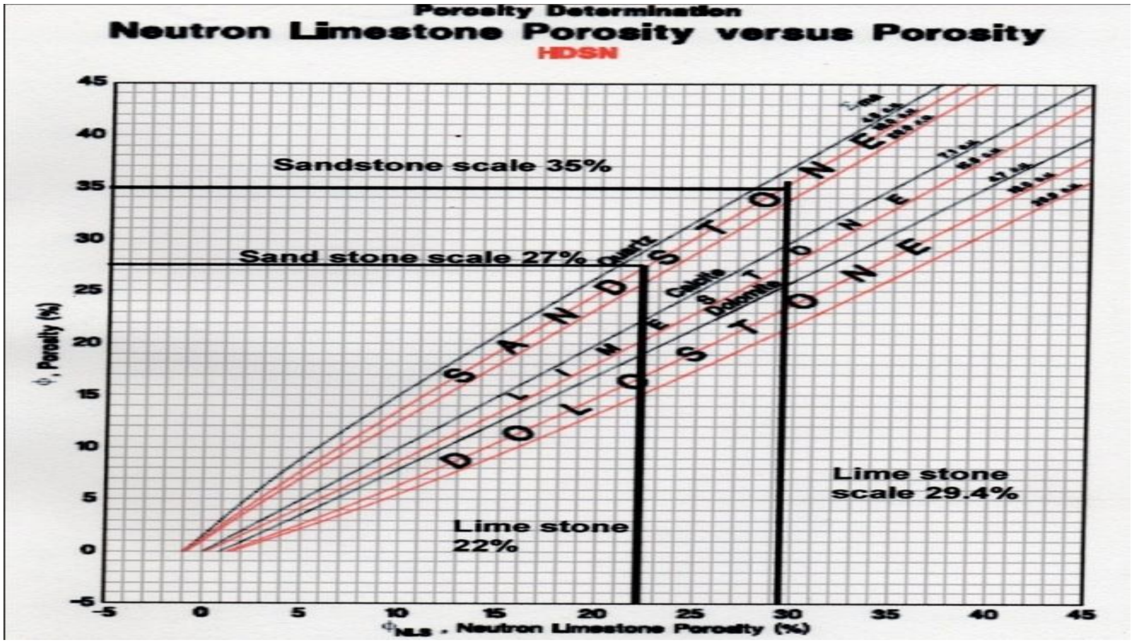

Figure.1.1. Conversion chart of Porosity Limestone to Sand stone scale

F. Calculation of Hydrocarbons Saturation (S_h) for SiltyShaly Reservoir

We have two equations for this calculations; one is Archie's equation and second Indonesian equation but Archie's equation is for clean sand so we use Indonesian equation (Richard piggin) for water saturation which is given below-

$$\frac{1}{\sqrt{R_t}}=[\frac{V_{cl}^{(1-\frac{V_{cl}}{2})}}{\sqrt{R_{cl}}}+\frac{\phi_e^{m/2}}{\sqrt{aR_w}}].S_w^{n/2}$$

$$\frac{1}{\sqrt{R_t}}=\left[\frac{V_{sh}^{(1-\frac{V_{sh}}{2})}}{\sqrt{R_{sh}}}+\frac{\phi}{\sqrt{aR_w}}\right].S_w$$

Parameter	Value
a	0.81
m	2
n	2.0
$R_w(\Omega-m)$ at 282°F	0.22
Rho matrix(gm/cc)	2.65 for Sandstone
Rho fluid(gm/cc)	1.0
A veg R_t	4.0
V shale	0.230

Where,

S_w: $Watersaturation$

R_{cl}: Resistivity of clay

R_t: Receptive value of Later log Deep (LLD)

V_{cl} : Volume of shaliness

R_w: Resistivity of formation water
a : Archie's constant / Tortuosity factor
m : Cementation exponent n: Saturation exponent

$$\frac{1}{\sqrt{4.0}} = [\frac{0.230^{1-0.23/2}}{\sqrt{1.5}} + \frac{0.30}{\sqrt{0.81}} \times 0.22]S_w$$

$$\frac{1}{2.0} = [\frac{0.23^{0.885}}{1.22} + 0.3/0.42]S_w$$

$$0.5 = [\frac{0.27}{1.22} + 0.71]S_w$$

$$0.5 = [0.22 + 0.71]S_w$$

$$0.5 = 0.93S_w$$

$$S_w = 0.5/0.93$$

$$S_w = 0.54$$

$$S_o = 1 - S_w$$

$$S_o = 1 - 0.54 = 0.46$$

Hydrocarbon saturation of this zone is 46%

G. Movable Hydrocarbon Index (MHI)

MHI = S_w / S_{xo}
Where $S_{xo} = (S_w)^{1/5} = (0.54)^{1/5} = 0.88$
MHI = 0.54/0.88 = 0.61 Movable.
If MHI ≥ 1.0 No movable hydrocarbon.
MHI < 0.7 for Sand Stone – movable hydrocarbon.
MHI < 0.6 for Carbonate – movable hydrocarbons.
Like this we can calculate above parameters for all the wells.

Tables of calculated parameters of Pay zones of different wells
Table No. 1.1 Well # 1

Sr. No	interval	GR (API)	LLD (ohmm)	RHOB (gm/cc)	V_{sh}	ϕ_d (%)	ϕ_n (pu)	ϕ_e (%)	S_w (%)	S_o (%)	MHI
1.	1632-1642	60	15	2.35	0.032	18	56	26	18	82	0.25
2.	1648-1657	60	7.0	2.40	0.013	14	56	23	20	80	0.28

Average Effective porosity = 24%, Average Oil Saturation = 81%, Movable Hydrocarbon

Table No.1.2 Well # 2

Sr. No	interval	GR (API)	LLD (ohm m)	RHOB (gm/cc)	V_{sh}	ϕ_d (%)	ϕ_n (pu)	ϕ_e (%)	S_w (%)	S_o (%)	MHI
1.	1621-1633	68	5.0	2.20	0.03	26	55	32	45	55	0.52
2.	1635-1642	70	7.0	2.40	0.08	14	53	22	40	60	0.48

Average Effective porosity = 27%, Average Oil Saturation = 57%, Movable Hydrocarbon

table No. 1.3 Well # 3

Sr. No	interval	GR (API)	LLD (ohm m)	RHOB (gm/cc)	V_{sh}	ϕ_d (%)	ϕ_n (pu)	ϕ_e (%)	S_w (%)	S_o (%)	MHI
1.	1620-1628	62	5.0	2.25	0.08	23	62	32	46	54	0.54
2.	1634-1650	60	9.0	2.40	0.06	14	54	22	22	78	0.29

Average Effective porosity = 27%, Average Oil Saturation = 66%, Movable Hydrocarbon

Table No. 1.4 Well # 4

Sr. No	interval	GR (API)	LLD (ohm m)	RHOB (gm/cc)	V_{sh}	ϕ_d (%)	ϕ_n (pu)	ϕ_e (%)	S_w (%)	S_o (%)	MHI
1.	1620-1628	75	4.0	2.30	0.23	19.0	40	23	54	46	0.61
2.	1634-1650	75	9.0	2.28	0.27	50	38	47	24	76	0.32

Average Effective porosity = 35%, Average Oil Saturation = 61%, Movable Hydrocarbonbove calculation shows that these wells have very good potential of hydrocarbon and in this Well#1 and Well#3 are very good having average oil saturation of 81% and 66% respectively.

II. CONCLUSION

For delineation of pay zone, Shale volume gives the net effective pay thickness with effective porosity and permeability. Water saturation gives percentage of irreducible fluid, and movable hydrocarbon which totally gives the amount of oil saturation and the extent of the pay zone. The results concluded from different wells that the average effective porosity varies from 24 to 35% whereas the averages oil saturation varies from 57 - 81%.After calculating all the parameters it is clearly indicated that the pay zones hydrocarbon potential is good as its porosity is showing compatible values and oil saturation is also having good percentage. The conlusions are also supported by Schlumberger MDT test in Well#4 they collected good amount of oil and gas samples.

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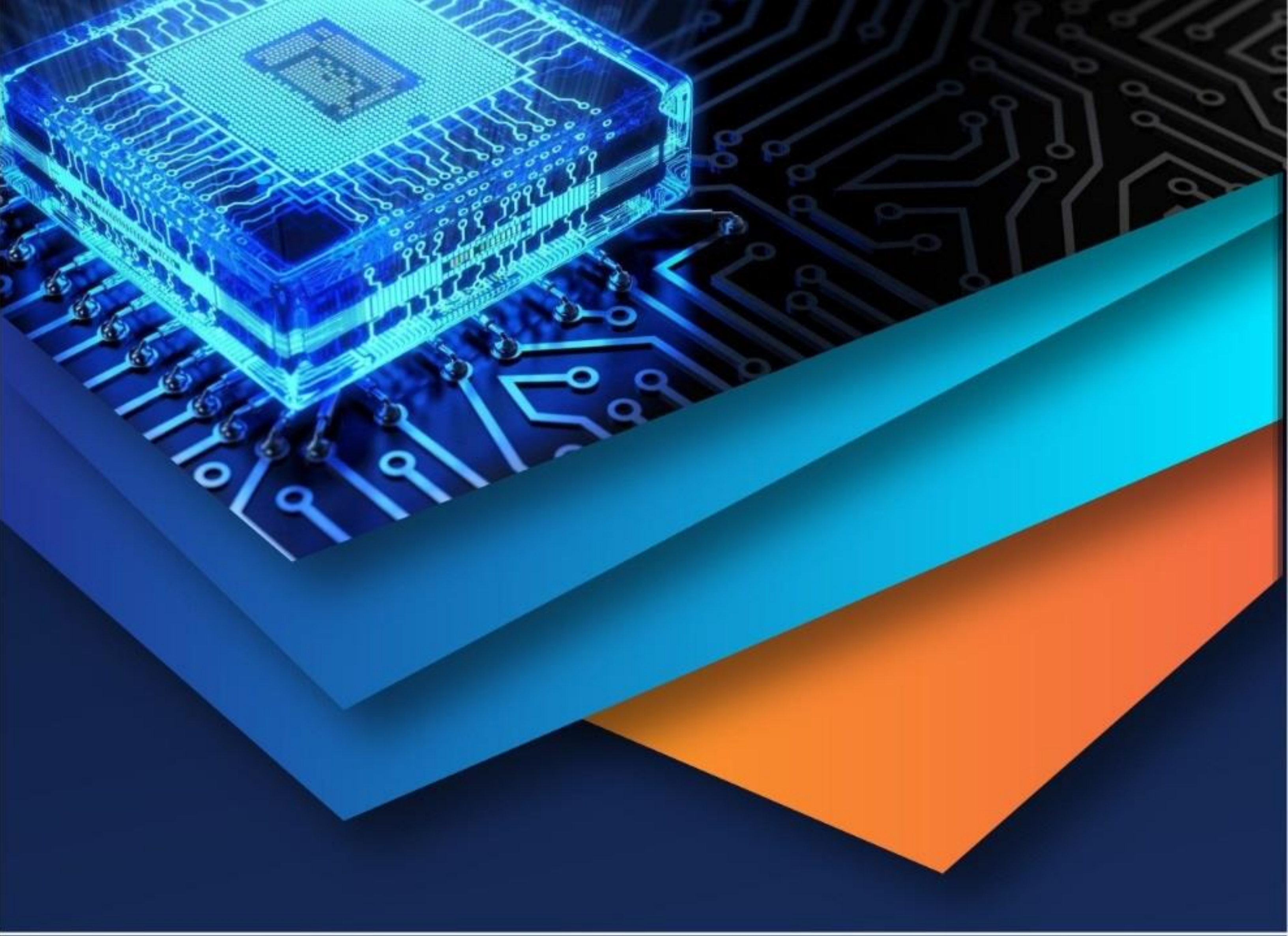

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