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Petrophysical Studies of Hazad Formation from Jambusar Field

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Summary

The current work, presents petrophysical studies on twelve selected core segments, identified and provided by CEWELL. The project has undertaken by CEWELL on Re-Evaluation of logs of Hazad formation of Jambusar field. The objective of the study is for better understanding of depositional environment and the hydrodynamic behavior of the sands. Petrophysical studies have been carried out and data on Effective Porosity (Φ_e), Air Permeability (Ka), Irreducible water saturation (S_{irw}), pore size distribution (PSD) pattern and Electrical resistivity parameters "a, m & n" have been generated.

Keywords: *Porosity, permeability, Irreducible water saturation, Archies's Constant, "a", Cementation Factor, "m" & Saturation Exponent, "n"*

Introduction

The current work is carried out Petrophysical studies of Hazad formation of Jambusar field to generate factual petro-physical data on twelve selected core segments from JAMBUSAR# A (cc-1) JAMBUSAR#B(CC-2 & cc-4) JAMBUSAR #C (CC-3) & JAMBUSAR# D (cc-1 & cc-3)

Method

Core samples were extracted to completely remove original reservoir fluid and salt by using toluene & mixture of acetone-methanol respectively, dressed & dried at 60^0C for about 5-6 hours as per API, RP-40, 3.12 & 3.13. Laboratory experiments were carried out to generate following parameter:

1) Effective Porosity (Φ_e), Grain and Bulk Density as per API RE-40, 3.30, 3.31, 3.32 & 4.3
2) Air Permeability (K_a) by Ultra-Perm™ 400F (Core Lab. USA). K_a values are corrected for Klinkenberg's slippage effect as per API RP-40, 3.4, 3.5.15 & 4.4
3) Capillary Pressure parameters by Mercury Injection Capillary Pressure (MICP) technique and following parameters were generated:-
   - Displacement (P_d)
   - Pore Size Distribution (PSD) pattern
   - Irreducible Water Saturation (S_{irw})
4) Electrical resistivity measurments by AERS-702, Ambient Eelectrical Resistivity System,coretest systems, USA at 200gpl brine for computation of :–
   - Archies's Constant, "a" , Cementation Factor, "m" & Saturation Exponent, "n"

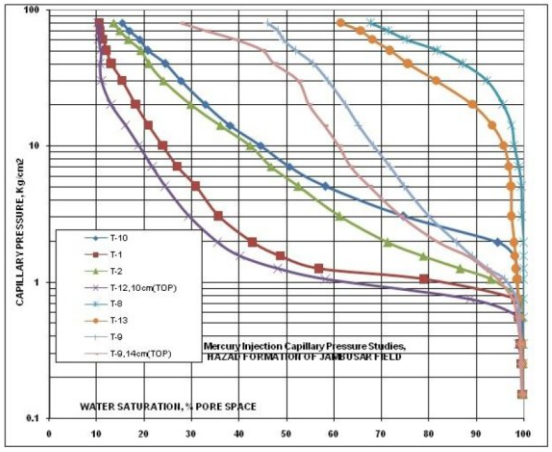

Fig.-1: Capillary pressure curves for samples from Hazad Formation of Jambusar Field

Results & Discussions

Basic Petrophysical & Mercury Injection Capillary pressure (MICP) studies:-

The data on basic petrophysical parameters of sixteen from samples from JAMBUSAR# A, CC-1, JAMBUSAR # B,

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CC-2, & CC-4, JAMBUSAR # C, CC-3, JAMBUSAR # D, CC-1, &CC-3, are given in Table-1. The capillary pressure parameters like P_d, PSD pattern &$S_{irw}$are given in Table-2. The curve of *C_p vs. S_w as % of pore space* for all the eight studied samples are given in Fig.-1. The analysis of data suggests that:

- Effective porosity (Φ_e) ranges from 1.89 – 21.93 %.
- Air permeability varies from 0.01 - 99 md.
- Grain density ranges from 2.55 – 3.20 gm/cc whereas bulk density values are in between 1.88-1.98gm/cc.
- MICP studies on eight samples for illustrating the interconnection/distribution of the pore throats/pore aperture radii & to assess P_d& to estimate PSD pattern and S_{irw}.
- MICP studies exhibit better interconnection & better distribution of the pore throats & pore aperture radii along with favorable (0.5 – 20 Kg/cm^2) Pd . Sirw varies from 11 – 66% .

Electrical Resistivity Measurements ("a, m & n" Parameters)-"a, m & n", Hazad Formation of Jambusar Area

Electrical resistivity measurements at 100% brine saturation was performed on twelve samples for the computation of "a" & "m" whereas de-saturation studies at partial saturation was performed on four samples for "RI vsSw" data at limiting sanity of 200gpl brine for the estimation of "n". The computed "a, m & n" values from Hazad formation of Jambusar field are 1.0092, 1.758 & 2.404 respectively, Table-3 & Fig.-2(A+B).

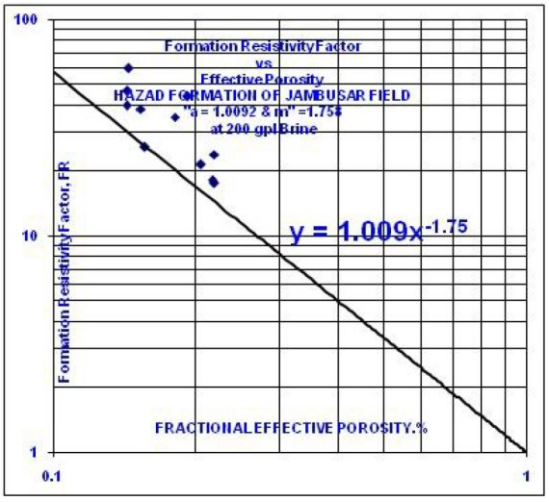

Fig.-2a: "a=1.01, m=1.758 & n=2.404" HAZAD FORMATION, JAMBUSAR FIELD- FR vs Fractional Effective Porosity

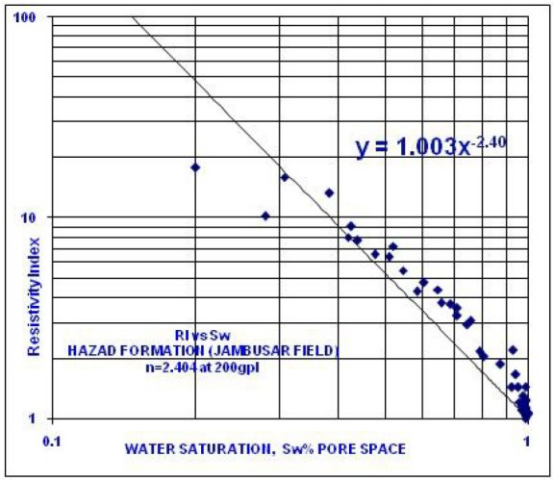

Fig.-2b: "a=1.01, m=1.758 & n=2.404" HAZAD FORMATION, JAMBUSAR FIELD, Resistivity Index (RI) vs Water Saturation (Sw).

Conclusions

The following conclusions are drawn, based on the study of cores from JAMBUSAR# A,CC-1, JAMBUSAR # B, CC-2, JAMBUSAR # B, CC-4, JAMBUSAR # C, CC-3, JAMBUSAR # D, CC-1 & JAMBUSAR # D, CC-3.

- Effective porosity (Φ_e) ranges from 1.89 – 21.93 % & geometric mean Φ_e=14.85%.
- Air permeability varies from 0.01 - 99 md & geometric mean Ka=0.38md.
- Grain density ranges from 2.55 – 3.20 gm/cc whereas bulk density values are in between 1.88-1.98gm/cc (Table-2).
- Mercury Injection capillary pressure studies exhibit the presence of macro &mesopore.
- The pore geometry is mainly fabricated by 10 to 55% macro (10-25 µm) & 8 to 50% meso (1-10 µm).
- Displacement (pd) and Threshold pressures (Pth) pressure are favorable (0.5-20Kg/cm^2) for the initiation of smooth displacement of wetting phase and entrapment / accumulation of non-wetting up to larger available pore space.
- Port pressure (P35) i.e the minimum buoyancy pressure required to accumulate 35% NWP is also favorably low (1.0-15Kg/cm^2) against the studied section.
- Non-wetting phase (NWP) saturation ranges from 34-90% whereas irreducible water saturation (Sirw) is around 10-66%.

- The computed "a, m, n" values from Hazad formation of Jambusar Field are 1.0092, 1.758 & 2.404 respectively.

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Table-1: Basic Petrophysical Data, Hazad Formation of Jambusar Field

S. N.	Well No./CC No./Int.	Segment	Lab. S.N./ Position in piece	Φ_e %	K_a md	G.D. gm/cc	B.D. gm/cc
1	JAMBUSAR#A,CC-1	T-4, 11cm	274,8cm	16.87	*	2.64	2.33
2		T-10, 16cm	275,12cm	21.93	21.70	2.63	2.22
3		T-22, 14cm	276, 4cm	14.33	0.14	2.62	2.36
4	JAMBUSAR # B, CC-2	T-1,12cm	277,8cm	21.92	99.00	2.62	2.22
5		T-2,14cm	278,2cm	17.82	*	2.58	2.26
6			279,10cm	15.60	68.03	2.60	2.32
7	JAMBUSAR # B, CC-4	T-1,13cm	280,11cm	1.89	0.01	2.57	2.54
8		T-8,18cm	281,2cm	14.30	0.01	2.57	2.32
9			282,15cm	15.34	0.01	2.55	2.28
10	JAMBUSAR # C, CC-3	T-13,16cm	283,2cm	18.08	0.01	2.64	2.31
11			284,14cm	14.45	0.012	2.57	2.32
12		T-15,12cm	285,10cm	12.15	*	2.81	2.57
13		T-27,16cm	286,,14cm	12.95	*	3.20	2.89
14	JAMBUSAR # D, CC-1	T-9,19cm	287,5cm	21.68	4.08	2.55	2.17
15			288,14cm	20.48	7.76	2.58	2.22
16	JAMBUSAR # D, CC-3	T-17,15cm	289,2cm	19.20	0.11	2.64	2.28
-* irregular Core pieces							

Table-2: Mercury Injection Capillary Pressure (MICP) Data, Hazad Formation of Jambusar wells,

S. N.	Well No./CC No./Int.	Segment provided	Lab. S.N./ Position in	Φ_e	K_a	Sirw	Pd	Pth	Pr35	PSD Pattern,%		
							Kg/cm2			>10μ	>1μ	<1μ
1	JAMBUSAR# A,CC-1	T-10, 16cm	275,12cm	21.93	21.7	13	1.8	2.0	3.0	Nil	62	38
2	JAMBUSAR # B, CC-2	T-1,12cm	277,8cm	21.92	99.0	10	0.7	0.75	1.2	45	35	20
3		T-2,14cm	278,2cm	17.82	*	12	0.7	0.8	2.5	15	50	35
4			279,10cm	15.60	68.03	10	0.5	0.55	1.0	55	30	15
5	JAMBUSAR # B, CC-4	T-8,18cm	282,15cm	15.34	0.01	66	20	25	-	Nil	Nil	100
6	JAMBUSAR # C, CC-3	T-13,16cm	284,14cm	14.45	0.012	59	10	15	-	Nil	8	92
7		T-27,16cm	287,5cm	21.68	4.08	45	0.8	0.85	15	10	25	65
8	JAMBUSAR # D, CC-1	T-9,19cm	288,14cm	20.48	7.76	25	0.5	0.55	1.6	10	52	38

Table -3: "a, m & n" HAZAD FORMATION OF JAMBUSAR FIELD

S. N.	Lab. S.N.	Position (m)	Ka md	Area	Length cm	RESIS.	Ro ohm-m	Formation Factor FR	Fractional Porosity	RI	S_w, %
JAMBUSAR #A,CC-1											
1	275	T-10,16cm	21.93	5.07107	3.978	57.506	0.733074	11.78747	0.2193		
RI vsSw, n =2.772 at 200gpl Position-T-10,16cm, Φe=21.93%, Ka=21.70md, Jambusar # A, CC - 1										1.01	98.56
										1.03	98.45
										1.04	99.16
										1.15	98.93
										1.24	98.71
										1.68	94.05
										2.17	78.82
										3.58	70.75
										3.78	65.58
										4.81	60.44
										6.42	50.94
										8.05	41.82
2	276	T-22, 14cm	0.14	5.0591	2.834	80.736	1.441254	23.17465	0.1433		
JAMBUSAR # B,CC-2											
3	277	T-1,12cm	99.00	4.99948	3.207	34.6625	0.540363	8.688768	0.2192		
RI vsSw, n =2.269 at 200gpl Position-T-1,12c m, Φe=21.92, Ka= 99.00md, Jambusar # B, CC - 2										1.07	99.36
										1.07	99.28
										1.07	98.43
										1.19	97.91
										1.30	97.57
										3.74	68.77
										5.50	54.56
										6.59	47.57
										9.16	42.46
										13.36	38.22
										19.03	30.71
										17.84	20.03
4	279	T-2,14cm,10cm(T)	68.03	5.06708	3.759	58.681	0.791012	12.71907	0.1560		
RI vsSw, n = 2.35 at 200gpl Position-T-2,14cm,10cm(T), Φe=15.60%, Ka=69.03md, Jambusar # B, CC - 2										1.07	99.89
										1.08	99.80
										1.13	98.74
										1.26	98.71
										1.44	98.43
										2.22	92.79
										2.96	74.33
										4.42	64.55
										4.32	58.28
										7.27	52.05
										7.79	43.88
										10.29	28.04
JAMBUSAR # B,CC-4											
5	280	T-1,13cm,11cm(T)	0.01	5.07506	5.211	513.41	5.000166	80.40016	0.0189		

6	281	T-8,18cm,2cm(T)	0.01	5.09104	4.035	97.714	1.232877	19.82404	0.1430		
7	282	T-8,18cm,15cm(T)	0.01	5.03919	3.726	87.607	1.184832	19.0515	0.1534		
JAMBUSAR # C,CC-3											
8	283	T-13,16cm,2cm(T)	0.01	5.02716	3.092	67.054	1.090204	17.52994	0.1808		
9	284	T-13,16cm,14cm(T)	0.012	5.04715	2.689	97.245	1.825251	29.34912	0.1445		
JAMBUSAR # D,CC-1											
10	287	T-9,19cm,5cm(T)	4.08	4.89697	4.706	53.229	0.55389	8.906279	0.2168		
11	288	T-9,19cm,14cm(T)	7.76	5.11908	4.489	57.862	0.659836	10.60982	0.2048		
RI vsSw, n = 3.688 at 200gpl Position-T-9,19cm,14cm(T), Φe=20.48%, Ka=7.76md, Jambusar # 47, CC - 1										1.07	97.82
										1.11	96.99
										1.16	96.65
										1.22	95.76
										1.45	95.20
										1.45	92.31
										1.88	87.21
										2.05	80.57
										3.09	75.63
										3.27	70.69
JAMBUSAR # D,CC-3											
12	289	T-17,15cm,2cm(T)	0.11	5.0591	3.394	91.2705	1.360479	21.87582	0.1920		