Differential Capacity Fractal Dimension and Water Saturation Fractal Dimension as Parameters for Reservoir Characterization: Shajara Formation of the Permo-Carboniferous Unayzah Group as a Case Study

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ABSTRACT

The fractal nature of samples collected from the surface type section of the Shajara Formation of the permo-Carboniferous Unayzah Group is derived from the size distribution of pores. This distribution is determined by the application of mercury intrusion capillary pressure technology utilizing autopore. Two different fractal geometry models have been applied to investigate the pore size distribution heterogeneity which is a key parameter in reservoir quality assessment. These two fractal approaches are the negative differential water capacity fractal dimension and water saturation fractal dimension. Based on the applied two fractal regime, in addition to unconformity surfaces, the sandstones of the Shajara Formation is divided herein into three fractal units. The investigated units from top to base are: Upper, Middle and Lower Shajara Water Saturation Fractal Units. The obtained results showed that, the Lower Shajara Water Saturation Unit is characterized by the presence of a high, a medium, and a low permeable zone which reflects a heterogeneous system. It was also found that the fluid flow circulation capacity is positively correlated to the obtained water saturation fractal dimension.

MATERIALS & METHODS

Figure (1): Auto pore III Apparatus Used for Determination of sample Plugs Pore Size Distribution

Differential capacity is defined as the ratio of volumetric water content to capillary tension head (Globus, A.M. 2006).

$h_i = 2*\sigma/\rho*g*r_i$

Where,

H_i: capillary tension head.

σ: mercury surface tension

ρ: mercury density

g: acceleration of gravity

r_i: pore radius corresponding to each tube.

Water saturation capillary pressure model:

It is based on the method of Toledo et al (1993) who related water saturation to capillary and fractal dimension as follows:

$S_w \alpha P_c^{-(3-D)}$

S_w is water saturation.

P_c is capillary pressure measures in (psi).

D = Fractal dimension

Differentiate water saturation with respect to capillary pressure to obtain

$dS_w/dP_c \alpha P_c^{-(2-D)}$

If we take logarithm of both sides of equation with removal of proportionality sign , equation becomes

$Log (dS_w/dP_c) = (D-2)* Log P_c + C$

On a log-log plot of the ratio of water saturation to capillary pressure versus capillary pressure a straight line should be obtained whose fractal dimension is equal to slope +2.

RESULTS & DISCUSSION

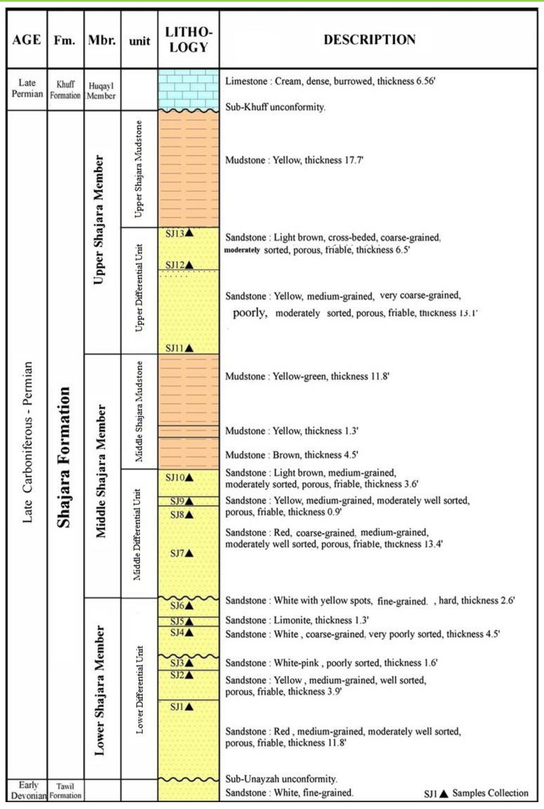

Figure (2): Surface type section of the Shajara Formation of the Permo-Carboniferous Unayzah Group Showing The Units Proved by Differential Capacity Fractal Units and Water Saturation Fractal Methods Location: N 26° 52 17.4, E 43 36 18.

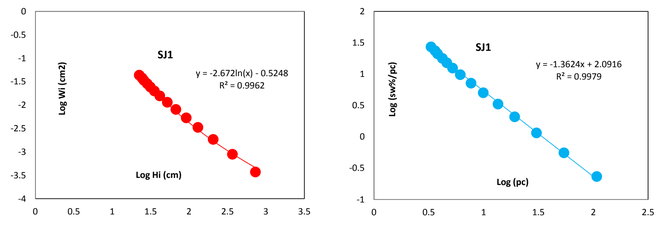

Figure (3): Differential capacity fractal dimension= 2.838 Water saturation fractal dimension= 2.235 Permeability = 1680 mD , Phi = 29%, for sample SJ1 from the Lower Shajara Member.

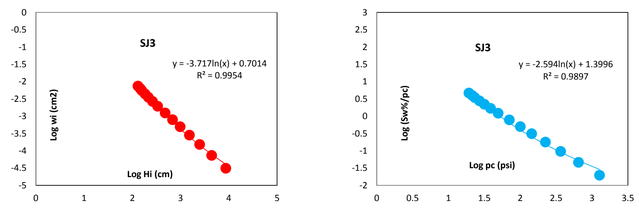

Figure (4): Differential capacity fractal dimension= 2.384 Water saturation fractal dimension = 2.075 Permeability = 56 mD , Phi = 34% for sample SJ3 from the Lower Shajara Member.

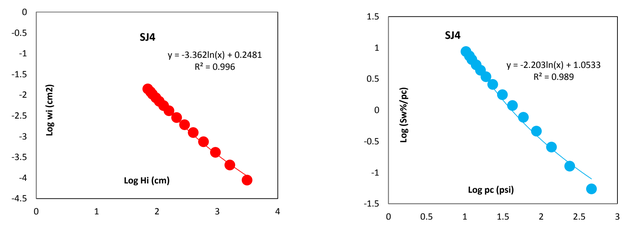

Figure (5): Differential capacity fractal dimension= 2.537 Water saturation fractal dimension= 2.109 Permeability = 176 mD , Phi = 30% for sample SJ4 from the Lower Shajara Member.

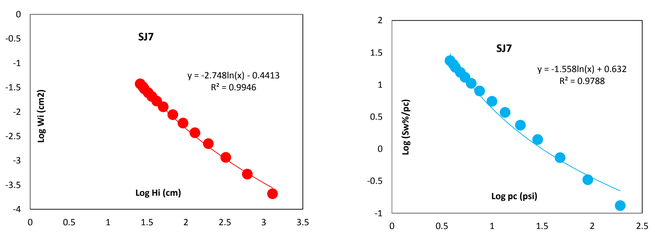

Figure (6): Differential capacity fractal dimension= 2.805 Water saturation fractal dimension= 2.211 Permeability = 1472 mD , Phi = 35 for Sample Sj7 from the Middle Shajara Member.

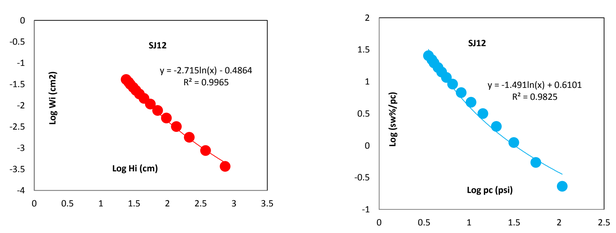

Figure (7): Differential capacity fractal dimension= 2.81 Water saturation fractal dimension= 2.251 Permeability = 1440 mD , Phi = 28% for sample SJ12 from the Upper Shajara Member.

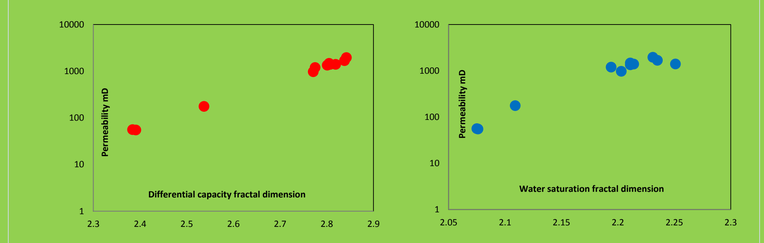

Figure (8): Permeability versus differential capacity and water saturation fractal Dimensions showing the presence of a high , moderate and a low permeable zone.

Formation	Unit	Sample No.	ϕ %	K (mD)	Differential water capacity fractal dimension	Water saturation fractal dimension
Shajara Formation	Upper Shajara unit	SJ13	25	973	2.771	2.203
		SJ12	28	1440	2.819	2.251
		SJ11	36	1197	2.775	2.194
	Middle Shajara unit	SJ9	31	1394	2.807	2.214
		SJ8	32	1344	2.801	2.211
		SJ7	35	1472	2.805	2.211
	Lower Shajara Unit	SJ5	31	55	2.391	2.076
		SJ4	30	176	2.537	2.109
		SJ3	34	56	2.384	2.075
		SJ2	35	1955	2.842	2.231
		SJ1	29	1680	2.838	2.235

Table (1): Differential water capacity fractal dimension and water saturation fractal dimension of Shajara Formation Reservoirs.

CONCLUSION

❖The use of determined negative differential water capacity fractal dimension and water saturation fractal dimension and their plots versus permeability has revealed the occurrence of three fractal dimension units characterizing the reservoir quality of the Shajara Formation.

❖The obtained results of the fractal dimension units are positively correlated to the fluid circulation flow capacity (permeability). An increase of permeability match to an increase of fractal dimension.

❖Variation on fractal dimension values reflect their variation on textural characteristics including grain size distribution in addition to their compaction. In other words fractal dimension value increases with increasing grain size and decrease compaction.

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