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Advanced Concepts in Naturally Fractured Reservoirs with Analysis of Field Data

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Abstract: ***Dual porosity reservoir is mainly defined as fractured reservoir. The Two porosities are included for fracture and matrix, Flow in the fractures, oil storage in the matrix. Dual Permeability reservoir are those pay zones with flow in both the fracture and matrix systems. Single porosity means matrix, dual porosity means both matrix and fractures and triple porosity means matrix, fractures and vugs. The description of displacement mechanisms in fractured reservoirs can be construed as: oil expansion, gravity forces, capillary forces, balance of gravity and capillary forces, diffusion and convection. Fractures are usually found in limestone and dolomites due to solution, re-crystallization. Two categories of fractures are available such as: Open Fractures and Closed Fractures which depend mainly on circulation water and precipitation. Fractures which are closed at surface conditions may be open in reservoir conditions. Fractures related to folding axis are such as: longitudinal fractures, along the folding axis and transverse fractures, perpendicular to the folding axis and diagonal fractures, in relation with the folding axis. There are some pivotal issues and expressions in fractured reservoirs that in this paper, an approach to the advanced concepts in Naturally Fractured Reservoirs has been studied.***

Keywords: ***Naturally Fractured Reservoirs, Dual porosity reservoir, Dual Permeability reservoir, fracture and matrix, Open Fractures and Closed Fractures, expressions in fractured reservoirs.***

I. INTRODUCTION

Fracture density expresses the degree of rock fracturing through various relative ratios. Volumetric fracture density ratio refers to the bulk volume. Linear fracture density ratio refers to area or to a length. For a quantitative analysis of fractures, lithology, tectonic mechanisms of the layers, weight fracture parameters with the thickness and lithology define fracture intensity. Fracture intensity is the frequency of fractures in a specific width or depth of reservoir layer. Fracture intensity defines the role played by the intrinsic characteristics of each layer (permeability, porosity, cementation, etc.) during the fracturing process by the thickness of the layer and by its structural location (top center, bottom). In Dual porosity reservoirs, there are high storage capacities in matrix, low storage capacity in fractures.

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The best way to obtain overall view of fractures is outcrops that must be large to give the meaning at inter-well distances and by means of that the intensity, matrix block size, spacing, width and orientation can be observed **[**1,2**].** The matrix-fracture coupling transmissibility terms which exist between each cell of the matrix grid and the corresponding cell in the fracture grids are proportional to the cell bulk volume. There are numerous publications of experimental attempts to measure relative permeabilities and/or capillary pressure in fractures .Unfortunately, these experiments are very difficult to interpret. The most interesting case is where there is a balance between capillary forces and gravity forces in the fractures. The solution of a set of equations for the relative permeability in the fractures is a function of the ratio of these forces. With gas-oil systems the surface tension is relatively low and the density difference between phases is relatively high. In gas-oil system, with the matrix filled with oil and connate water and the fracture filled with gas the process for oil to flow from the matrix and gas flow into the matrix is a Drainage process. The pressure in the oil phase in the matrix is lower than the oil pressure in the fracture. Thus, this capillary force tends to keep the oil in the matrix rock. Standard well test of fractured reservoirs give their results in terms of Omega, Lambda and Alpha (or Sigma). Omega is storativity ratio, Lambda is inter-porosity flow coefficient, which describes the ability to flow from the matrix blocks into the fissures (fractures). The authors and Schlumberger Company have recently studied hard about the issues used in this paper **[**1,2**].**

II. MATERIALS AND METHODS

In a dual porosity system, the majority of production from the matrix blocks can be associated with various physical mechanisms, such as:

- Expansion
- Solution-gas drive
- Oil/water imbibition
- Gas gravity drainage
- Convection
- Diffusion

They may all contribute to oil production during the life of the field. For example, as the pressure drops in the fracture system, oil will flow from the matrix to equilibrate the matrix pressure with the surrounding fracture pressure . Expansion is almost due to properties of matrix and its fluids.

III. RESULTS AND DISCUSSION

Comparison of contacts and transition zones are as the following:

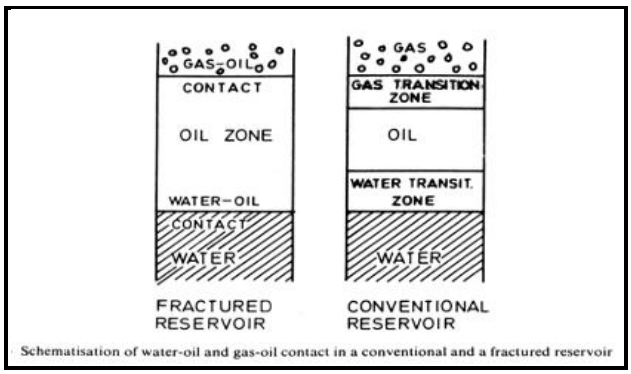

Figure: 1. Comparison of Contacts and Transition Zones [3]

In fractured reservoirs in contrast to conventional ones, there is no transition zones.

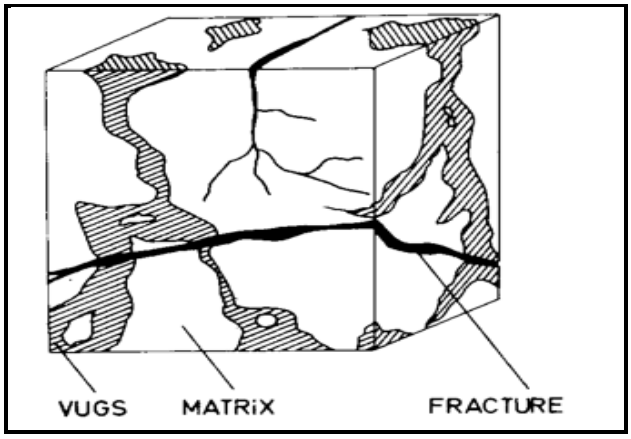

Figure: 2. 3-D Representation of Triple Porosity System [3]

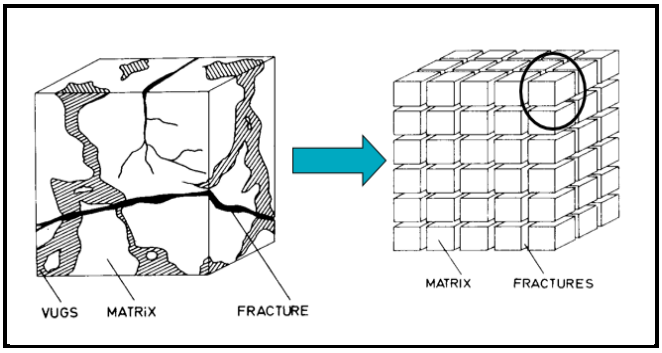

Figure: 3. Warren and Root 3-D Representation dual Porosity System [3]

The Warren and Root model consists of matrix and fractures.

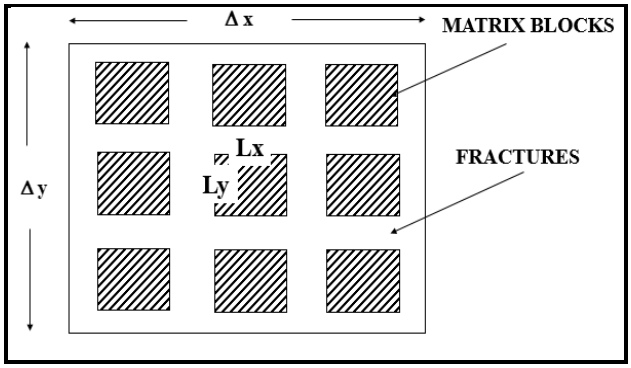

Figure: 4. Components of dual Porosity System [3]

In Figure 4. If Lx and Ly sizes change, delta(x) and delta(y) will change and also sigma value and transmissibility will change. Then as a result, the oil flow rate will change, So the oil production mechanism may change.

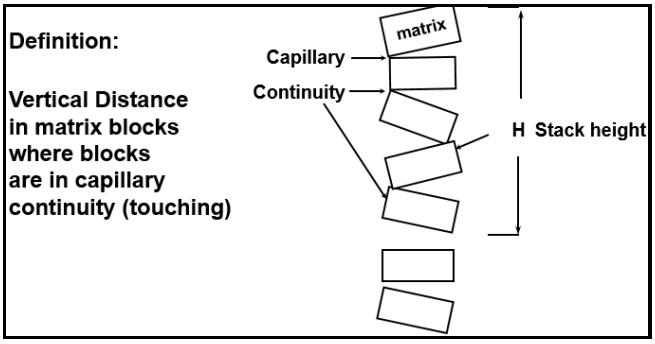

Figure: 5. Stack Height and Capillary Continuity Definition [3]

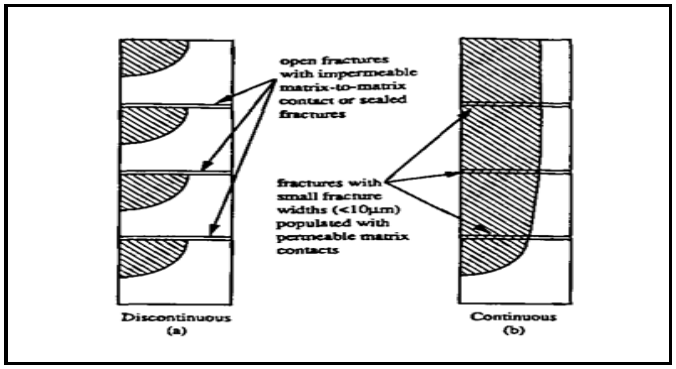

Figure: 6. Capillary continuity schematic [3]

According to the above Figure6b.the capillary continuity is when the adjacent blocks have fracture width less than 10 micro meters from each other and block to block, fluid flow in the pay zone or capillary re-infiltration occurs.

Table 1. [Field Data, SCHLUMBERGER]

Reservoir Description

Quantity	Value	Quantity	Value
h	300 ft	So	1.0
NTG	1.0	Sw	0.0
□	10.0 %	Sg	0.0
Top depth	6000 ft		
RFT-pressure	5000 psia	at	6000 ft

well Data

Quantity	Value	Quantity	Value
Orientation	Vertical	Top of Perf	6000 ft
r_w	0.3 ft	Bottom of Perf	6300 ft

Fluid Properties (dead oil)

Quantity	Value	Quantity	Value
□$_o$	0.8 cp	□$_o$	54.64 lb/ft^3
C_o	3.0E-6 /psi	T	180° F
B_o	1.2		

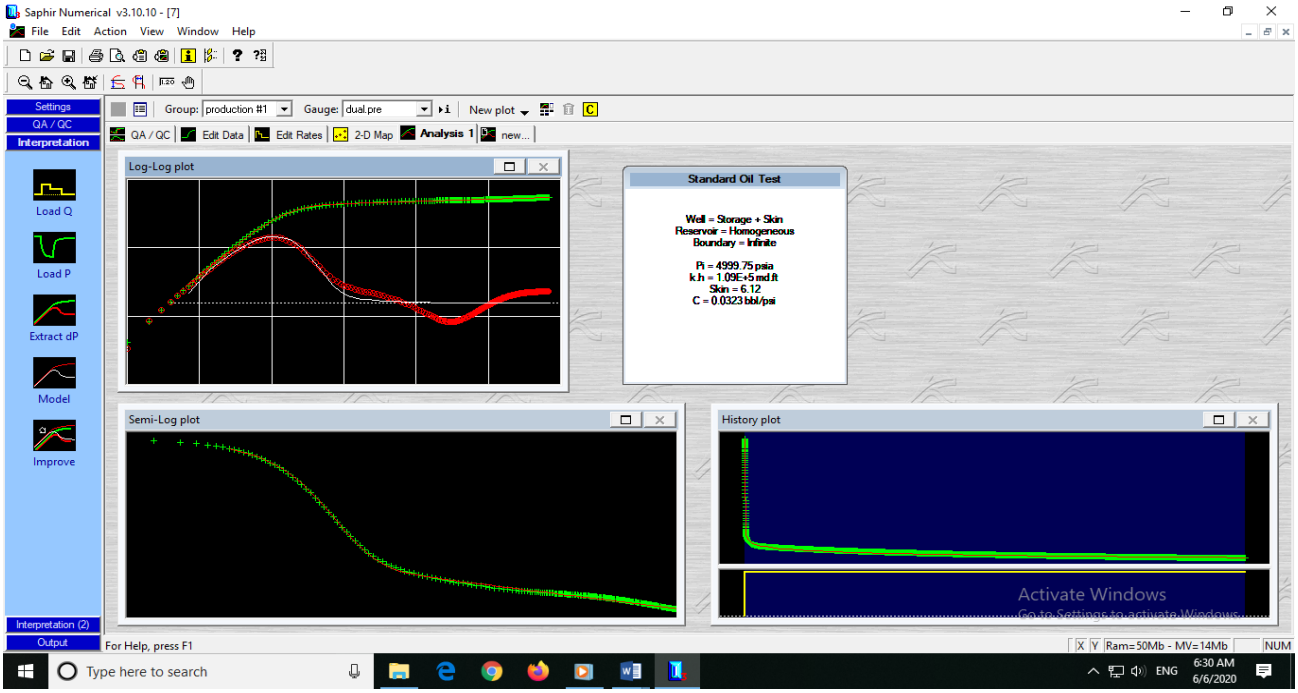

Figure: 7. Well testing of Fractured Reservoirs Simulated by Saphir Software [2]

In the analyzed well testing of a sample reservoir as above figure7. The final outputs are as the following:

C= 0.03 stb/psi
K=300 md
Savg= about 3
Productivity index=PI=J= 45.5 (stb/day)/psi
Mobility= 257 md/cp
Rinv= 7544 ft
Omega= 0.1326

In a dual porosity system the majority production from the matrix blocks can be associated with various physical mechanisms, they may all contribute to oil production during the life of the field. As the pressure drops in the fracture system, oil will flow from the matrix to equilibrate the matrix pressure with the surrounding fracture pressure. Expansion is almost entirely due to properties of matrix and its fluids. Sudation is a production mechanism that is combined effects of two set of forces which play a role in the substitution of oil in matrix by water or gas from the surrounding fractures and are consisted of Gravity forces due to the differences in densities between oil and water (or gas) and also Capillary forces due to the interaction of surface forces within the pores. Surface Tension is the stress at the surface between a liquid and a vapor caused by differences between the molecular force in the vapor and those in the liquid and by the imbalance of these forces at the interface. Surface tension is generally expressed as a pressure difference in a capillary tube or capillary pressure. [3]

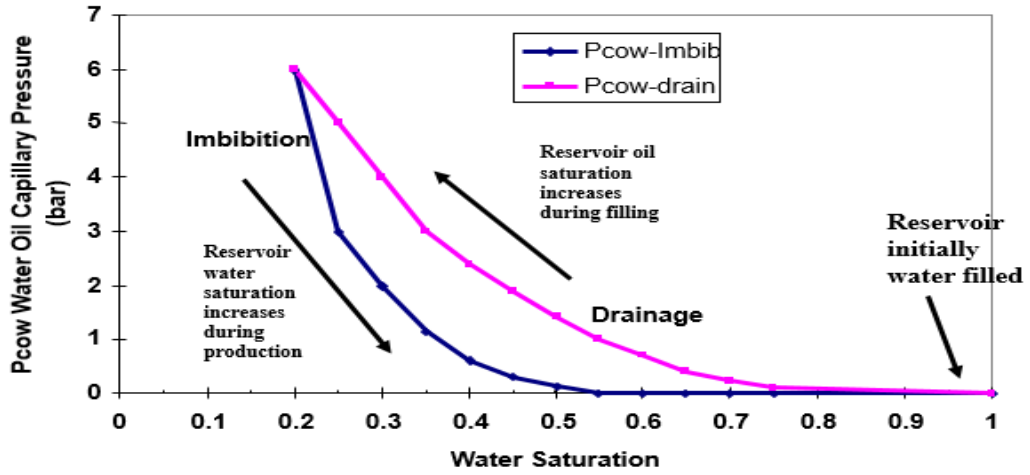

Figure: 8. Capillary hysteresis curve [3]

In a porous media, the process of one phase saturation increasing and the other(s) decreasing are called DRAINAGE or IMBIBITION, dependent on the wettability and on whether the saturation of the wetting phase is increasing or decreasing. Imbibition is when Saturation of Wetting Phase Increasing but Drainage is when Saturation of Non-Wetting Phase Increasing. In a typical water wet system the matrix rock will have a positive water-oil capillary pressure. If water is introduced into the fracture, the water will flow under capillary forces into the matrix system, displacing oil. In gas-oil systems the oil will be the wetting phase and will tend to imbibe into the matrix. [3,4]
In practice this means that if the gravity drainage model is not active then no oil production will occur from a matrix block when the associated fracture block full of gas. Capillary pressure has a negative effect on the velocity of displacement and oil production from the matrix block. For positive velocity and oil production, gravity forces must exceed capillary forces. Magnitude of Pc and Stack Height determine amount of oil recovery from matrix blocks. Convection and diffusion are often ignored when dealing with conventional reservoirs, because of the very large time scales required before their effects become significant.The presence of a network of high permeability channels accelerates these phenomena which have been detected in thick, highly fractured oil pools. In naturally fractured reservoir molecular diffusion potential may even override viscous forces when hydrocarbon or inert gases are injected and the fracture spacing is small. Diffusion can be important in fractured matrix reservoir behavior, especially when injection gas composition differs greatly from native reservoir gas. [4]

IV. CONCLUSIONS

1. There are some pivotal issues and expressions in fractured reservoirs that in this paper, an approach to the advanced concepts in Naturally Fractured Reservoirs has been studied.
2. Dual porosity reservoir is mainly defined as fractured reservoir. The Two porosities are included for fracture and matrix, Flow in the fractures, oil storage in the matrix. Dual Permeability reservoir are those pay zones with flow in both the fracture and matrix systems. Single porosity means matrix, dual porosity means both matrix and fractures and triple porosity means matrix, fractures and vugs.
3. Fracture density expresses the degree of rock fracturing through various relative ratios. Volumetric fracture density ratio refers to the bulk volume. Linear fracture density ratio refers to area or to a length. For a quantitative analysis of fractures, lithology, tectonic mechanisms of the layers, weight fracture parameters with the thickness and lithology define fracture intensity. Fracture intensity is the frequency of fractures in a specific width or depth of reservoir layer. Fracture intensity defines the role played by the intrinsic characteristics of each layer (permeability, porosity, cementation, etc.) during the fracturing process by the thickness of the layer and by its structural location (top center, bottom).
4. Standard well test of fractured reservoirs give their results in terms of Omega, Lambda and Alpha (or Sigma). Omega is storativity ratio, Lambda is inter-porosity flow coefficient, which describes the ability to flow from the matrix blocks into the fissures (fractures). In a dual porosity system, the majority of production from the matrix blocks can be associated with various physical mechanisms, such as:
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5. In Figure4. If Lx and Ly sizes change, delta(x) and delta(y) will change and also sigma value and transmissibility will change. Then as a result, the oil flow rate will change, so the oil production mechanism may change.
6. According to the above Figure6b.the capillary continuity is when the adjacent blocks have fracture width less than 10 micro meters from each other and block to block, fluid flow in the pay zone or capillary re-infiltration occurs.
7. If the gravity drainage model is not active then no oil production will occur from a matrix block when the associated fracture block full of gas. Capillary pressure has a negative effect on the velocity of displacement and oil production from the matrix block. For positive velocity and oil production, gravity forces must exceed capillary forces. Magnitude of Pc and Stack Height determine amount of oil recovery from matrix blocks.

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Authors Contributions	All authors having equal contribution for this article.

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