METHODS OF DETERMINATION OF POROSITY AND PERMIABILITY IN THE HETEOGENEOUS CARBONATE RESERVOIRS- A REVIEW

Submitted by-

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EXTENDED ABSTRACT:

Carbonate reservoirs are invariably heterogeneous due to complex depositional and diagenetic environment. In many carbonate reservoirs, fluid flow characteristics are generally difficult to predict and the most porous intervals are not always the best reservoirs as the intervals of equivalent porosity can exhibit large variations in permeability. This paper provides a range of methods from the various types of core analysis, well logging techniques and 3-D modeling to predict the petrophysical properties in the carbonates.

In this discussion, a triple porosity model has been explained based on which the core analysis can be carried out. Methods such as mercury porosimetry or mercury injection capillary pressure curves, Nuclear Magnetic Resonance(NMR) , X-ray computed tomography, optical microscopy images and Environmental Scanning Electronic Microscopy (ESEM) have been discussed which constitutes for the core analysis. Mercury porosimetry[1] gives the idea of size, shape, origin and distribution of the core sample. The geometric description of the curve or the c-factor indicates the kinds of pore geometry and pore entry radius profile of the samples. In NMR, two methods are in common use to predict the permeability. One of them is the SDR(Schlumberger Doll Research Center) equation[4], which is modified for carbonates.

$$k_{SDR} = 0.5\,\varphi^2\,(\rho * T_{2LM})^2$$

The second equation is the Timur/Coates equation[4] which uses the volume of microporosity and is very effective..

$$k_{T/C} = C_T\varphi^2((\varphi - \mathrm{V_{micro}})/\mathrm{V_{micro}})^2$$

CT scanners provide a 3-D image of the core sample which upon subtraction technique gives the direct idea of porosity. Micro-CT scanners can extract valuable information from the small drill cuttings of the reservoir rocks. SEM(Scanning Electronic Microscopy) images yield information on microporosity from core plugs. The pore size distribution and pore shape information that can explain the physical properties like permeability, mainly controlled by the macropore shape in the high permeability samples and by the amount of intrinsic microporosity in the low permeability samples.

The logging techniques such as invasion profile permeability index honors data from the electrical resistivity logs. A general relation between the porosity and permeability, in which six different cases and conditions have been considered to correct for the universal equation developed in this approach from data of electrical resistivity logs. These considerations are gas zone, oil & transition zone, water zone, drilling fluids and facies quality. This method is generally known as the Universal Rock Permeability(UROK). Permeability Active Searching (PASZ) comprises of the Gamma Ray analysis. Using this data, a GR permeability model is developed. The real time analysis requires the permeability and the lithology predictions, which is achieved by Logging While Drilling(LWD). The correlation between the wireline data and LWD is not straight forward and there are some major differences between these two types of data. Here comes the role of the core analysis to understand the real information given by the logs.

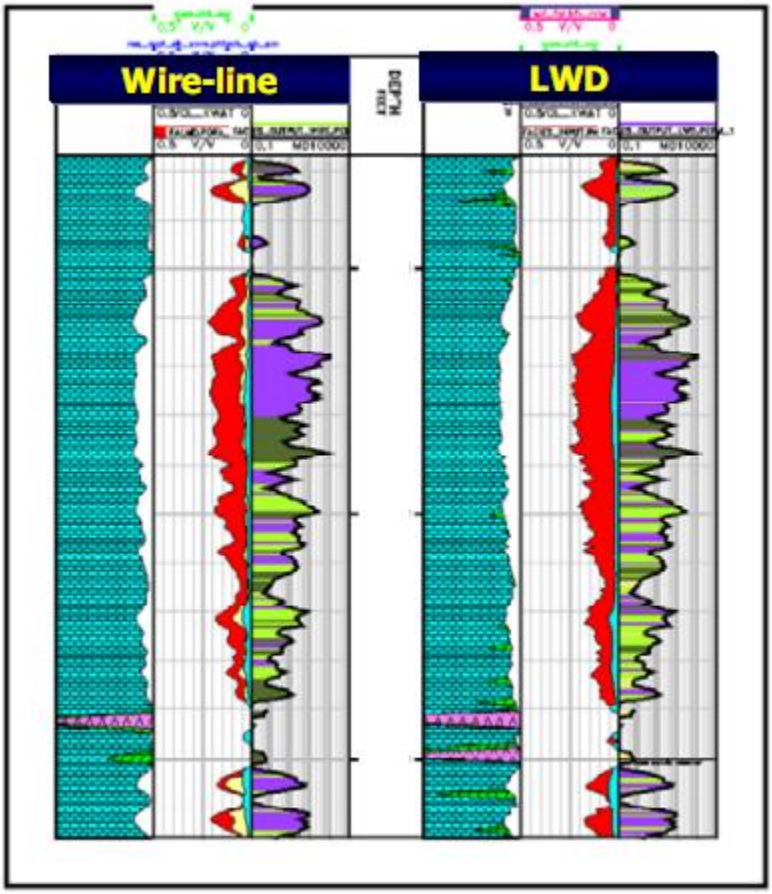

Fig.1. Shows the comparison between the wireline log and the LWD[5]

Moreover, water zone electrical resistivity logs, shallow and the deep lateral logs are also used to determine the porosity. The analysis of the P-wave by acoustic logging reflects the effect of the void space containing the fractures and voids, thus the matrix porosity.

The comparison of results from the logs and the core analysis has been done. In this context the Archie's equation has been discussed as a natural correlation, between well logs and core analysis. It directly relates cores and well logs. It actually transforms a multi dimensional correlation problem into a set of smaller correlations. The rock characteristics

are put in the terms of commonly available well logs. The Archie's equation[6] can be plotted as

$$-\frac{n}{m}\log(S_{wi}) = \log(\varphi) - \frac{1}{m}\log\left(\frac{R_w}{R_t}\right)$$

Also a permeability determination method using the mud invasion method[7] has been studied. Here, we simulate the process of invasion with both water and oil based muds. Resulting spatial distributions of water saturation and salt concentration in the near-borehole region gives rise to electrical resistivity which is used to numerically simulate lateral log and induction apparent resistivity logs. If the input values of the porosity and the permeability are not correct, the simulation of the mud-filtrate invasion will result in a poor match of the resistivity logs. In such cases, we update the porosity and permeability until securing a good match between measurements and simulations.

This paper uses almost all the methods available till date and puts forward a holistic approach towards the determination of the porosity and the permeability in the carbonates.

KEY WORDS:

Carbonate Reservoirs, Scanning Electronic Microscopy (SEM), SDR(Schlumberger Doll Research Center) equation, Universal Rock Permeability(UROK), Permeability Active Searching (PASZ).

NOMENCLATURE:

Sl. No.	Symbol	Description
1	k_{SDR}	Permeability using SDR equation(mD)
2	φ	Porosity(fraction)
3	ρ	Surface rlaxivity(μm/sec)
4	T_{2LM}	Log mean average of T2 distribution(msec)
5	$k_{T/C}$	Permeability using the Trimur/Coates equation
6	C_T	Constant adjusted to the specific voloume
7	V_{micro}	Volume of micro porosity(fraction)
8	n	Cementation factor
9	S_{wi}	Residual water saturation
10	R_w	Resistivity of water

11	R_t	Total resistivity
12	m	Saturation exponent

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