Microresistivity Log as a Viable Aid in Determining Hydrocarbon Saturation

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Abstract

In this work the microresistivity log have been described as a viable aid in the documentation of water and hydrocarbon saturation. A microresistivity device is used to measure the resistivity of flushed earth zone and to delineate permeable formations by detecting the presence of mud cake along the well bore wall. However, such measurements generally cannot provide accurate inferences or the formation permeability. The types, composition and method of logging with microresistivity devices are discussed. Two geophysical wells in clean formation were interpreted. The result of which shows that with the various assumption made the water saturation were found to be 11% and 15% from which the hydrocarbon saturation was estimated to be 89% and 85% respectively.

Introduction

Formation Evaluation can be defined as the derivation from Borehole measurements of properties of interest of the media surrounding the borehole. To the petroleum engineer this might translate to determination of the volume of hydrocarbon reserves; to the civil engineer it might mean estimates of elastic coefficients; To the mining engineer it might entail estimating ash content of A coal bed penetrated by the borehole. The diversity of interests satisfied by Format ion Evaluation Is due to the diversity in turn of the several dozen measurements Currently available and to the fact that these measurements are related to an overlapping set of rock and fluid properties. For example, one commonly made measurement is bulk density.

The petroleum engineer of the formation surrounding the borehole. Uses this parameter to estimate porosity, one of the quantities needed in making petroleum reserve estimates. Interest to the civil engineer, since elastic coefficients such as compressibility are closely related to porosity. Engineer density provides a way to estimate the ash content of coals. Density is also of to the mining so Formation Evaluation can and does successfully serve a number of masters with diverse interests. This course is concerned primarily with applications in the petroleum industry, and even in this field of interest alone, the several dozen measurements available lead to over a dozen significant applications The petroleum applications can be conveniently divided into three categories:

1.Hydrocarbon reserve estimates (oldest and best established of the applications)

2.“Special” Applications (specialized applications often derived as “fall-out “ from efforts to improve reserve estimates)

3.Exploration applications (fast growing and newest of the applications categories).

Most of our concern here will be with the first and third categories.It is assumed that we are having a basic awareness off the measurements available in the formation evaluation. Information regarding the measurement systems themselves will only be incorporated as needed to account for effects on the interpretation process. The measurements can be grouped for convenience into three broad categories:

A.Measurements on rock samples (cuttings samples, cores)

B.Wireline measurements (wel1 logs)

C.Measurements obtained from Productivity (fluid flow) tests.

Together, these make up a “shopping list” of several dozen measurements that can be made in the borehole or on rock samples.It turns out that each of the available measurements is affected by not one, but a number of properties and factors.

The properties would include things 1ike the chemical and physical properties of the matrix and fluid materials making up the rock “Factor s” would include things 1ike the distribution of

The matrix and fluid materials within the rock, stress, temperature and conditions (borehole size, logging speed, etc.) under which the measurement is made. The number of properties and

factors significantly affecting each of the measurements normally ranges from half a dozen to a dozen.

This situation leads to the concept of response relations or equations, where in each borehole measurement can be related quantitatively to a number of properties. For example, the most

common acoustic measurement is reciprocal compressional velocity (“Δt”). It turns out that this measurement is affected significantly by:

i.Porosity

ii.Lithology

iii.Rock stress

iv.Grain Contact areas

v.Rock competency

vi.Fluid content

(in certain situations)

Through hard-won experience, it has proven possible to quantitize these effects in the form of a equation for most of our measurements. We have employed short electrode spacing so that they have a shallow depth of investigation. They can be divided into two general groups, focused and non-focused. Both groups employ pads or some kind of electrodes to reduce the effect of the mud. The chart for water saturation determination is shown below

- Define bed Boundries
- R,from Sp or other sources
- Calculate Porosity
- Saturation Sw Determined
- R_w and S_w confirmation

Theory

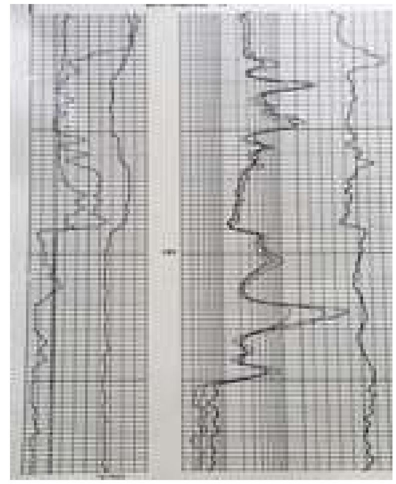
Hydrocarbon-bearing rocks are primarily sandstones, limestones or dolomites. Most sands are transported and laid down from moving water. The greater the water velocity (the energy of the environment), the coarser the sand will be. Because of this sorting mechanism, sands tend to have fairly uniform intergranular-type porosity.

Limestones, on the other hand, are not transported as grains but are laid down by the deposition from seawater. Some is precipitation from solution; some is the accumulated remains of marine organisms. Original pore space is often altered by subsequent dissolution of some of the solid matter. This porosity tends to be less uniform than ?sand and will include vugs and fissures, termed secondary porosity, interspersed with the primary porosity.

Dolomites are formed when magnesium-rich water circulates through limestones replacing some of the calcium by magnesium. This process generally is a reduction of the matrix volume. Therefore, dolomitization is an important mechanism in providing pore space for hydrocarbon accumulation. (Log interpretation seminar, 1989).

Microresistivity devices attempts to measure the formation resistivity close to the borehole well. The Microspherical focused logs(mstl) are usually run with the dual lateralog and not separately, but the proximity and microlateralog tools are run as separate surveys, usually with a micrologg (ml). The microlog however, is a special type of electric log that will probably never go out of style, and gives good indications of porous and permeable zones (Frank 1986). Formations containing only sands or carbonates are called clean formations. They are relatively easy to interpret with modern logs. When such formations contain clay/shale, they are called dirty or shaly formations. Such reservoir rock can be quite difficult to interpret. A flow chart for clean formation interpretation is shown below.

In the determination of water saturation, several methods Overlay the resistivity logs, and depth-are bound. However, wo of such methods are described herein.



they are (1) the resistivity ratio (2) the porosity resistivity shift, the resistivity scale to match in a water combination zone.

(3) Use index as in 4.5 and 6 above

Quick look value is useful even if all the above assumption is not met.

Resistivity Ratio Method

When a borehole is drilled, the formation close to the borehole is invaded with mud filtrate. In an oil-bearing zone, we normally have zone of low resistivity close to the borehole and one of higher resistivity further away. Thus a comparism of a deep resistivity device with a shallow resistivity device will detect hydrocarbons. From Archie equation we can derive an expression for water saturation as a function of the ratio of these two curves. (Archie, 1942)

$$S_w = \{(\frac{R_{xo}}{R_t})x(\frac{R_w}{R_{mf}})\}^{\frac{5}{8}} \text{.....................................2}$$

Where S_w is water saturation.

R_{mf} is the resistivity of porous zone, immediately behind mud filter cake.

R_t is the true resistivity

R_w is the resistivity of water

R_{mf} is resistivity of mud filter.

In practice, to use this equation, we assume;

1.$R_{(deep)} = R_t$ and $R_{(MSFL)} = R_{xo}$ (with negligible correction)

2.Clean formation (Shaliness < about 5%)

3.Permeable formation with moderate inversion

4.R_w is constant.

5. $S_{xo} = (S_w)^{1/5}$

The logs are recorded on a logarithmic scale which provides an easy estimate of the ratio. The Schlumberger transparent scaler is constructed to rive S_w directly from this ratio and the procedure is as follows:

(a) With simultaneous resistivity recording;

(1) Pick water zones with constant reading,
(2) Set index of exponent I scaler on shallow resistivity curve.
(3) Note new index value at deep resistivity curve.
(4) Use "exponent 5/8 scaler"
(5) Set index on deep resistivity curve
(6) Read S_w on shallow resistivity curve

(b) Alternate method with separate recording.

1. Overlay the resistivity logs
2. Shift the resistivity scale to match in a water zone.
3. Use index as in 4,5 and 6 above.

Porosity- Resistivity Combination

This method usually provides a more reliable value of Sw than the previous one (as the assumptions are less constricting). However it is slightly more time consuming. The equation used is: Once

$$S_w^2 = Fx\frac{R_w}{R_t} \text{ ....3}$$

Where

F is formation of resistivity factor.

To use this in practice, we assume;

(1) $R_{deep} = R_t$ (negligible correction)
(2) Clean formation (Shaliness< about 5%)
(3) R_w constant
(4) Porosity = quick – look porosity.

Knowing R_w ,or estimating R_w, we can solve the above equation by:

*Deriving φ from quick – look
*Deriving F from a chart
*$R_t = R_{(deep)}$
* Calculating S_w.

Once S_w is known, then hydrocarbon saturation (S_h) can be calculated using

$$S_h=1- S_w \text{ ----------------------------- 4}$$

Interpretation of Micro Logs

Two wells A and B were considered here, the first is shown in well A comprising of an SP, resistivity and a micro log. The bit size for this well is 9 $^7/_8$ in and R_m is 1.2 ohm-m, at BHT (Bottom hole temperature) of 15"F. The average value of porosity computed from the logs for the three and intervals (1, 2 and 3) are shown on the figure. These are matched with the average value derived from the core analysis. In these study intervals a, b, c, and d have been excluded because all longs indicate they contain substantial amounts of shale.

The second example, shown in well B, which has several porous and permeable sections, is indicated by the micro log curves. (Crosshatched areas on the figure).If the thin streak denoted as "a" is discarded, the quantitative analysis of the micro log curves in section A shows that the formation factor and the porosity vary within comparatively narrow limits throughout the section. In other words, the whole section can be regarded as one fairly homogenous bed. The total thickness is about 70ft; so the effect of the adjacent formations on the conventional curves, even on the long lateral curve can be neglected.

The average formation factor using 15% residual oil in the hushed zone, the average porosity is about 17" for R,

The amplitude of the p. curve is equal to 90mx with k equal to 80 at BHT the corresponding R_M/R" is about 14. A value of R_M007 ohm^{-m}at BHT, corresponding to a value of 0.5 $ohm^{-m}$for R_M/R"is thus about 00.15 $ohm^{-m.}$ The average resistivity and on the long lateral throughout the section is equal to 22 ohm-m in which after correction with the departure curves gives an average value of 130 ohm-m for R, The water saturation in the uncontaminated zone is therefore.

$$S_w = \{\frac{30x0036}{130}\}^{1/2} = 9\%$$

The Computation of water saturation in the other permeable porous sections are not so easy because these sections are comparatively thin and their resistivity cannot be determined accurately from the electrical logs. Considering section B for instance, whose thickness is about 4ft according to the micro log reading. It appears that the long lateral curve is very distorted and unreliable because of the light formation about and below the bed. It is likely that the value read on the long normal ($1000hm^{-m}$) is an upper limit for R. A reasonable lower limit is $50ohm^{-m.}$ Furthermore, the sp. Curve is not entirely developed, it can be assumed that the value of $R_w$is the same as in section A. 0.035ohm-m. The micro log interpretation gives a formation factor value of 30 therefore the water saturation value will fall between (35 *0.035/100)$^1/_2$or 11% and (35 *0.035/50$^1/_2$ or 15%. This result is of course, a very rough approximate because of the uncertain values involved, particularly R.

Result and Conclusion

A device for the delineation of permeable beds has been described. The field examples interpreted revealed that the water saturation for two beds are 11% and 15% respectively. These results are very rough estimates considering the uncertainty in some of the estimated values such as R. From the result of the water saturation the hydrocarbon saturation for wells A & B, will be 89% and 85% respectively. Adequate perforation and proper core analysis will indicate the producibility of the two wells.

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