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SP log as an aid in determining some Reservoir characteristics

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ABSTRACT

Self-Potential (SP) logging was carried out in an un–cased, or open hole containing a water base fluid between an electrode on the sonde in the borehole and a stationary reference electrode at the surface in part of Niger Delta area of Nigeria. The two components of SP curve were used to detect the Permeable beds and to locate boundaries between beds in order to obtain good values for formation water resistivity. The result of the field work show that sands are water bearing and there are sufficient proportion of shaly material which explained the reduction of SP, the sands are not only shaly but they also contain oil or gas. As confirmed by the analysis of the cores.

KeyWords: Sp, Log ,Niger Delta, shaly

Introduction

A petroleum reservoir is a trap containing fluids such as gas, oil and water in vary proportions. Oil reservoirs are composed of sediments, which were originally saturated with salt water. Part of this water was displaced in the process of the formation of oil accumulations. That which remained in the formation has been given the name *"Connate interstitial water" or connate water* and always means the water in the formation when development of the reservoir was stared. It is commonly believed that water is found exclusively in the lower portion of a reservoir.[4]

The SP curve is a measurement of the potential that exists between an electrode in a well hole and an unchanging reference ground. Differences in potential are recorded when the wellbore electrode passes from shale to a sand or lime formation. The SP baseline generally corresponds to shale impervious bed. Permeable beds are generally indicated by peaks. Variation with lithology makes the SP a valuable correlation curve. The slope of the SP. curve at any level is proportional to the intensity of the SP current in the mud at that level. Consequently, the shape of SP curve and the amplitude of the deflection opposite a permeable bed depend on several factors, which affect the distribution of the SP.

current lines and the potential drop takes place in each of the media through which the SP. current flows:

(a) Resistivity, h, and true resistivity, R_t, of the permeable bed,
(b) Resistivity, R_{xo}, and diameter of the zone contained by filtrate,
(c) Resistivity, R_s, of the adjacent formations,
(d) Resistivity, R_m, of the mud and diameter d_h, of the borehole.

The principal uses of SP. curve are to

(1) Detect the permeable beds, e.g sand versus shale formations.
(2) Locate the boundaries between beds.
(3) Permit correlation of equivalent beds from well to well.
(4) Obtain good values for formation water resistivity.[7]

Description And Principles Of Sp Logging

The spontaneous potential tool measures natural electrical potentials that occur in boreholes and generally distinguishes porous, permeable sandstones from intervening shales. The "natural battery" is caused when the use of drilling mud with a different salinity from the formation waters, causes two solutions to be in contact that have different ion concentrations. Ions diffuse from the more concentrated solution (typically formation water) to the more dilute. The ion flow constitutes electrical current, which generates a small natural potential measured by the SP tool in millivolts.[1]

When the salinities of mud filtrate and formation water are the same, the potential is zero and the SP log should be a featureless line. With a fresher mud filtrate and so, more saline formation water, a sandstone will show a deflection in a negative potential direction (to the left) from a "shale base line" (Figure 4). The amount of the deflection is controlled by the salinity contrast between the mud filtrate and the formation water. Clean (shale-free) sandstone units with the same water salinity should show a common value, the "sand line". In practice, there will be drift with depth because of the changing salinity of formation waters. The displacement on the log between the shale and sand lines is the "static self-potential" SSP.

$$E_c = -K \log \frac{a_w}{a_{mf}} \quad \text{------------------ (1)}$$

where E_c = total electrochemical potential
a_{mf} = chemical activity of mud filtrate.
a_w = chemical activity of formation water.
K = a coefficient proportional to the absolute temperature and composition of salt for NaCl formation water and mud filtrate. which is equal to 71 at 25^oC(360K). However, if solution contains substantial amount of salt other than Nacl, the value of K at 360K may differ from 71.

In oil well logging, electrochemical potentials are of utmost importance.

An electro kinetic, εk (also know as streaming potential) is produced by the flow of an electrolyte through a non-metallic, porous medium. It arises from the difference in pressure between fluids in the well and those in the surrounding formation.[6]Electro kinetic potential is observed when a solution, of electrical resistivity and viscosity is forced through a capillary or porous medium. The resulting potential difference between end of passage is given by

$$E_k = \frac{\Phi \Delta P \varepsilon\rho}{4\Pi \eta} \text{------------- (2)}$$

where E_k = electrokinetic potential .

Φ = absortion (or zeta) potential.

ΔP= pressure difference.

$\varepsilon\rho$ = solution dielectric constant.

Φ the absorption potential is the potential of a double layer(solid-liquid) between the solid and solution Streaming potential is observed in SP. In practice the net E_k contributes to the SP. Deflection is usually small and it is normally regarded as negligible.

In thick shale bed adjacent to clean permeable sand, the maximum potential difference will develop between two points in the well located some distance from interface. The SP gives the shale base line value and the sand base line. The difference is called the static SP or SSP. The magnitude depends on the following field conditions:

i difference in salinity between the mud and formation water.

ii if salinity of formation water changes e.g. below or above an unconformity, the shale base line would shift.

iii if formation water is fresher than mud the SP Phenomenon is reversed.

iv when sand is not clean, the full SSP is not developed.[2]It is possible to determine the resistivity of water in the sand from static SP, as follows

$$SSP = -k \log \frac{R_{mf}}{R_w} \text{---------------- (3)}$$

where SSP = voltage difference between shale and sandstone (millivolt)

K= constant near 71

R_{mf} = resistivity of mud filtrate (Ohm-m)

R_w = resistivity of formation water

The Rmf can be estimated from a monograph (which is only a graphical representation of the above relation) knowing SSP, k and R_{mf} the value of R_w is easily obtained.

Stratigraphy Of The Studied Area

The Niger Delta occur at the southern end of Nigeria bordering the Atlantic ocean and extends from about longitude 3o.9 E and latitude 4o.30' – 5o.20'N. The proto delta developed in the northern part of the basin during the capanian transgression and ended with the poleocene transgression.

It has been suggested that the formation of the modern delta basin which enhanced and controlled the development of the present day Niger delta, developed by rift faulting during the Precambrian. Sedimentological and funal data suggest that the modern Niger delta has a configuration similar to that of the past.[3]

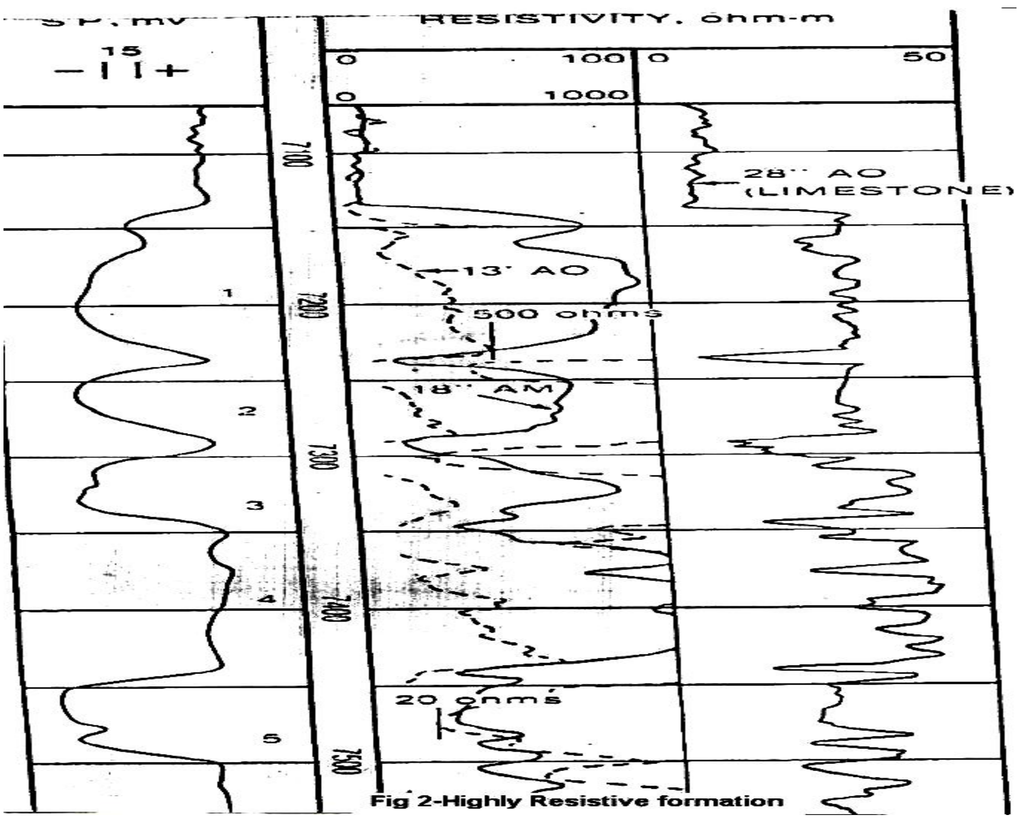

Fig 1: Highly Resistive Formation

TABLE 1: CORE ANALYSIS RESULTS

SAMPLE NUMBER	DEPTH (Ft)	DEPTH (m)	PERMEABILITY (HORIZONTAL) Kair md	(VERTICAL) Kair md	POROSITY (HELIUM) %	GRAIN DENSITY gm/cc	DESCRIPTION	GAMMA
CORE 1 E2 SAND DEPTHS 8250.00—8280.00 FEET								
166	7250.0 7250.5	2209.8 2210.0	3390.00	3440.0	NON	2.66	Sst.brn.f gr.lam.p cmt.	20.00 10.00
167	7251.0 7251.5	2210.1 2210.3	4440.00		NON	2.65	Sst.brn.f-m gr.p cmt.	17.00 11.00
168	7252.0 7252.5	2210.4 2210.6	2770.00		33.9	2.65	Sst.brn.f gr.lam.p cmt.	17.00 23.00
169	7253.0 7253.5	2210.7 2210.9	3120.00		36.7	2.64	Sst.brn.f gr.p cmt.	28.00 17.00
170	7254.0 7254.5	2211.0 2211.2	21080.00		39.6	2.64	Sst.brn.f gr.p cmt	22.00 12.00
171	7255.0 7255.5	2211.3 2211.5	1640.00		32.8	2.64	Sst.brn.f gr.p cmt	20.00 23.00
172	7256.0 7256.5	2211.6 2211.8	7460.00		34.3	2.64	Sst.brn.f gr.p cmt	14.00 22.00
173	7257.0 7257.5	2211.9 2212.1	5370.00		33.8	2.62	Sst.brn.f-m gr.p cmt	11.00 15.00
174	7258.0 7258.5	2212.2 2212.4	22400.00		33.2	2.64	Sst.brn.cr gr.p cmt	17.00 22.00
175	7259.0 7259.5	2212.5 2212.7	24500.00		34.9	2.65	Sst.brn.cr gr.p cmt	07.00 17.00
176	7260.0 7260.5	2212.8 2213.0	23000.00	20720.0	35.0	2.64	Sst.brn.cr gr.p cmt	11.00 18.00
177	7261.0 7261.0	2213.2 2213.3	10400.00		32.3	2.65	Sst.brn.m gr.p cmt	05.00 14.00
178	7262.0 7262.5	2213.5 2213.6	10700.00		32.8	2.63	Sst.brn.m gr.p cmt	06.00 12.00
179	7263.0 7263.5	2213.8 2213.9	15400.00		36.1	2.65	Sst.brn.m gr.p cmt	18.00 14.00
180	7264.0 7264.5	2214.1 2214.2	13300.00		34.7	2.66	Sst.brn.m gr.p cmt	19.00 24.00

Application Of Sp Computation In Field Study

The characteristic shape for highly resistive formations is observed in Fig 3. In particular, the lateral curve appears lopsided downward opposite beds 1,2,3,4, whereas the limestone sonde shows fairly constant values of apparent resistivities. According to the SP log four thick bodies1, 2,3,5 appear as permeable and zone 4 as tight. This interpretation is confirmed by the core analysis as shown in table 1. The curve recorded with the limestone sonde, moreover, contains numerous sharp peaks and depressions, which shows that each of the bodies includes numerous tight sections and permeable zones, and also shale breaks. Some of the depressions are easily related to shales with the help of the SP log, for example at 7238ft (2206.1m) and 7290ft (2222.0 m), but the discrimination between permeable zones and shale in most cases is difficult. The resistivities obtained with all three devices opposite beds 1,2,3, are higher than opposite bed 5 . The difference is particularly marked for the lateral, which shows maxima of about 500, 300, and 300 Ohms for beds 1,2,3, and about 20 Ohms for bed 5. The difference is much less with the lime stone device because the spacing of the lime stone sonde is very short, and the resistivities are largely reduced by the effect of conductive mud. Consequently, it can be assumed that beds 1,2,3 are oil bearing and that bed 5 may contain a substantial amount of salt water. In fact, the core analysis, made according to the indications of the log, confirmed that beds 1,2,3 were saturated throughout their whole thickness, whereas bed 5 produced oil and water.

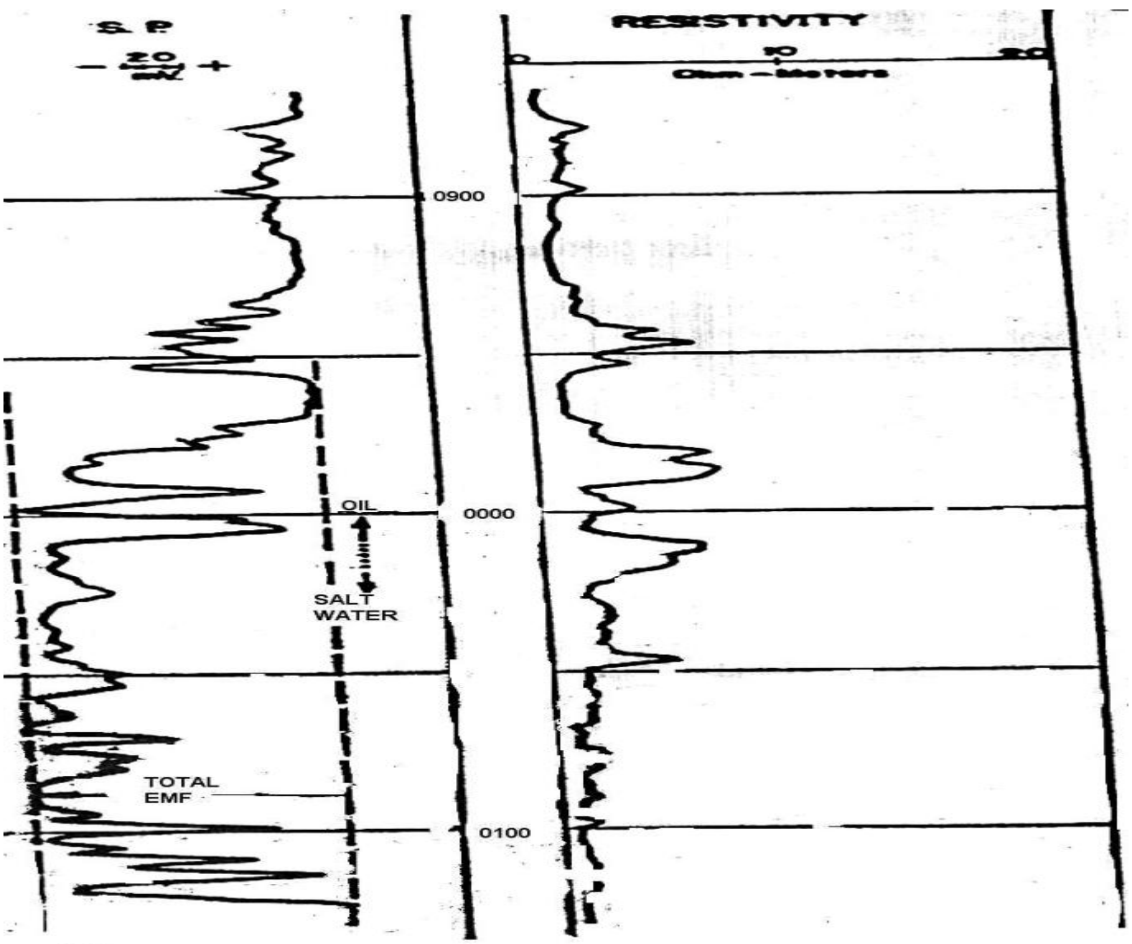

FIG 3 ——— Field example of S.P Log showing shaly oil sand

In this particular instance a qualitative interpretation of the logs in terms of fluid content was comparatively easy, because the formation under survey was clearly divided into thick bodies, respectively permeable and impervious, on the average. In particular, bed 5, which is more conductive than the adjacent beds, was thick enough that the response of the lateral device was not too much altered by the presence of adjacent formations, and 20 ohms is apparently close to the average value of R for this bed.

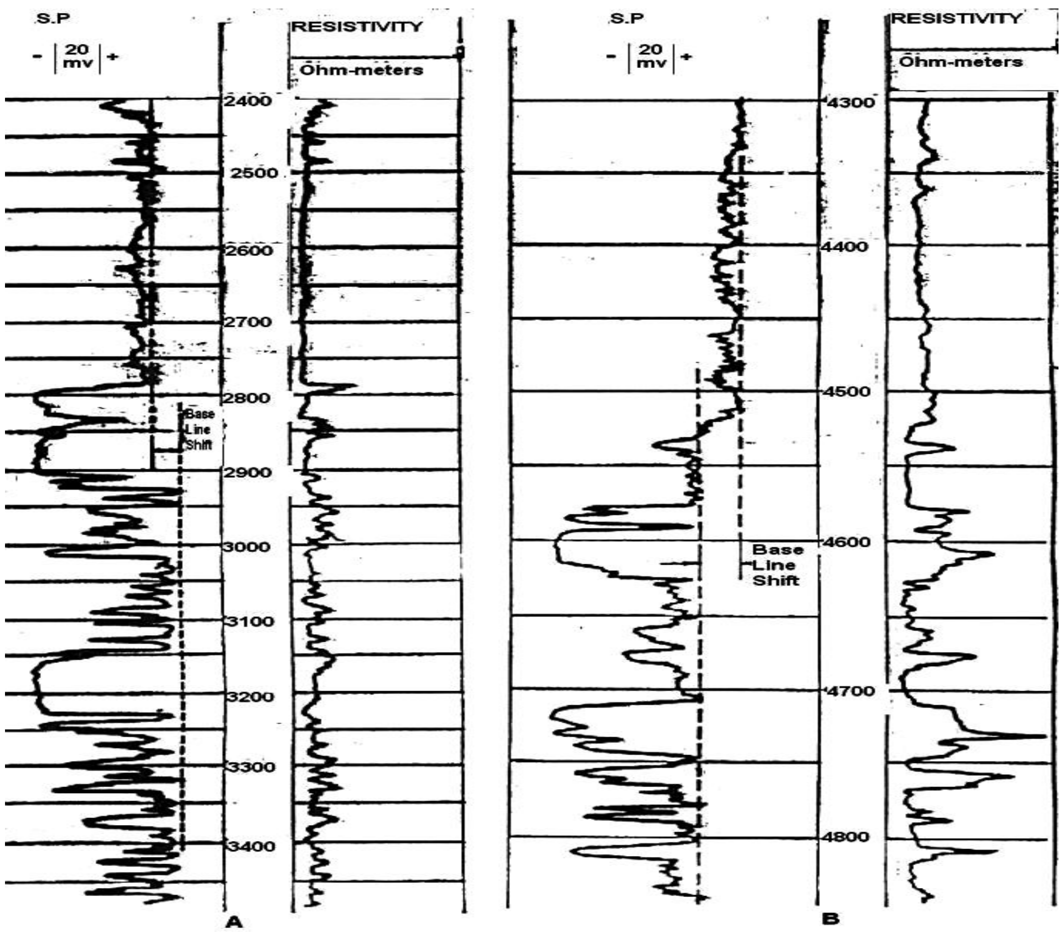

FIG.4- FIELD EXAMPLES OF S.P. LOGS SHOWING BASE LINE SHIFT

SHALY OIL SAND

An instance of a shaly oil sand is shown in fig 4. A comparison of the field log with computed SP charts for clean sand shows that the computed peaks are too sharp to match those of the field log, particularly in the upper section 4550 to 4560 ft and 4700 to 4780 ft (1386.8 to 1389.9 m and 1432.6 to 1456.9 m), when using the thickness determined by the reflection point and the resistivity ratios given by the reflection points and the resistivity ratios given by the resistivity log. Assuming that the total emf is given by the total deflection in the lower salt- water section, a pseudo- static SP is required to explain the SP log for the upper sands. Such pseudo-static SP suggests that the sands are shaly, and in fact this is borne out by the core record. The required value for pseudo-static SP. can be explained by two different sets of conditions:

(1) the sands are water bearing and they contain a sufficient proportion of shaly material to explain the reduction of the static SP. with respect to the total emf.
(2) The sands are not only shaly but they also contain oil or gas, and, in that case the proportion of shale required to explain the reduction in the static SP. is less than in case 1.The resistivity of

sands, as given by the resistivity log, is too high to be compatible with case 1 and therefore the interpretation should be that the sands are oil or gas bearing. This is confirmed by the analysis of the cores.(Table 1).

BASE LINE SHIFTS

The examples of Fig 4 A and B show base line shifts. The shale's in the upper parts of the log are known to be of different character from the shale present in the character section. In this case, the static SP for the different categories of shale are sufficiently different to shaft the base line. The level where the shift occurs constitutes a horizon marker and thus provides an identification of the geological section through the use of electric logs[5]. It is seen that the zones otherwise known as permeable, are indicated on the log by curved parts with convexity towards the negative.

CONCLUSION

The result of the core analysis of this well section , obtained from permeability vs.porosity, permeability, porosity and grain density histograms, indicate that the flow capacity (permeability) is about 296763.5 md per m, the storage capacity (porosity) is about 1188.5 φ-m, while the grain density has an arithmetic average of about 2.65gm/cc.
The SP. curve is sometime noisy or affected by magnetism; however, it is unusual to be unable to read SP. deflection with a good accuracy due to either noise or magnetism. Bimetallism (superimposition of a resistive component on the SP. measurement) is more difficult to detect, hence more likely to cause interpretation errors. It must be borne in mind that SP. is more likely to be reliable in low to moderate resistivity. Consequently, it is not always easy to record a good SP. due to these external interferences and considering the fact that SP. plays a very role in the interpretation of exploration wells, reasonable effort should always be made to record good SP.

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