ANOMALOUS SELF POTENTIAL (SP) LOG SIGNATURES OBSERVED IN A WATER WELL AT OKWUDOR, SOUTH- EASTERN NIGERIA

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Abstract

Geophysical logging was done after drilling had been completed in a water well at Okwudor, South Eastern Nigeria. Three electric logs were run viz: Self Potential (SP), Resistivity N16" and N64" logs. An anomaly was observed in the SP log. The SP results from this well show some deviation from the standard norm. The zone indicated to be impermeable according to SP data contradicts the results of the two resistivity logs. The well was completed using resistivity data and litho log. The project became successful. Attempts are made in this paper to explain the probable cause / source of this anomaly in the SP signatures.

Keywords: *Self potentials, resistivity logs, mud filtrate, anomaly, impermeable bed.*

Introduction

A very crucial stage in water well completion is the "casing operation" during which screens are supposed to be installed at the appropriate depth i.e within the aquiferous zone where groundwater can get into the borehole through the screens. If by act of negligence, these screens are placed within impermeable beds like clay or shale, the borehole becomes abortive and the project ends up in a big financial disaster because nothing can be done to salvage the well again. It is then abandoned and a new well must be drilled. Because of the delicate nature of this aspect of well completion, geophysical logging is being made mandatory before casing especially in areas where the geology is complex. Geophysical logging can be described as scientific technique of continuous recording of a geophysical parameter with depth within a drilled borehole. Measurements can be taken from the top of the well to its bottom or vis – versa or both. Results of these measurements are plotted continuously against the depth of the well.

Some of the physical parameters usually recorded are; Spontaneous potential (SP), resistivity, acoustic, density, gamma ray etc. Hence, there are SP logs, Resistivity logs, Sonic logs, Density logs, etc. Wireline logs are quite useful because the borehole samples usually collected during drilling and used to construct a litho log are not precise and accurate records of formations encountered. Wireline geophysical logging is recorded when the drilling tools are no longer in the hole (Rider 1986).

Geophysical logs can be classified into three groups viz:

- **Reservoir thickness logs**
  These are gamma ray and Spontaneous Potential (SP) logs. These logs discriminate reservoir from non – reservoir.
- **Porosity logs**
  These are density, neutron and sonic logs. They are used to calculate porosity, identify lithologies and differentiate oil from gas.
- **Resistivity logs**
  In this group are laterolog, induction and microresistivity logs. In conjunction with porosity logs, they are used to calculate hydrocarbon saturations.

In the water industry, only SP and resistivity logs are commonly used to identify aquifers. Applications of other logs like neutron, sonic, density, etc are restricted to the oil industry because of the financial involvement.
The main objective of geophysical logging exercise carried out at this location was to identify the best aquifer zone where screens could be installed in order to get good quality and much groundwater.

Summary of the Geology of the Study Area
Okwudor is located within these coordinates; Latitude 5^0 43″ 3′, Longitude 7^0 00″ 50′. It falls within the Benin Formation (Fig.1).

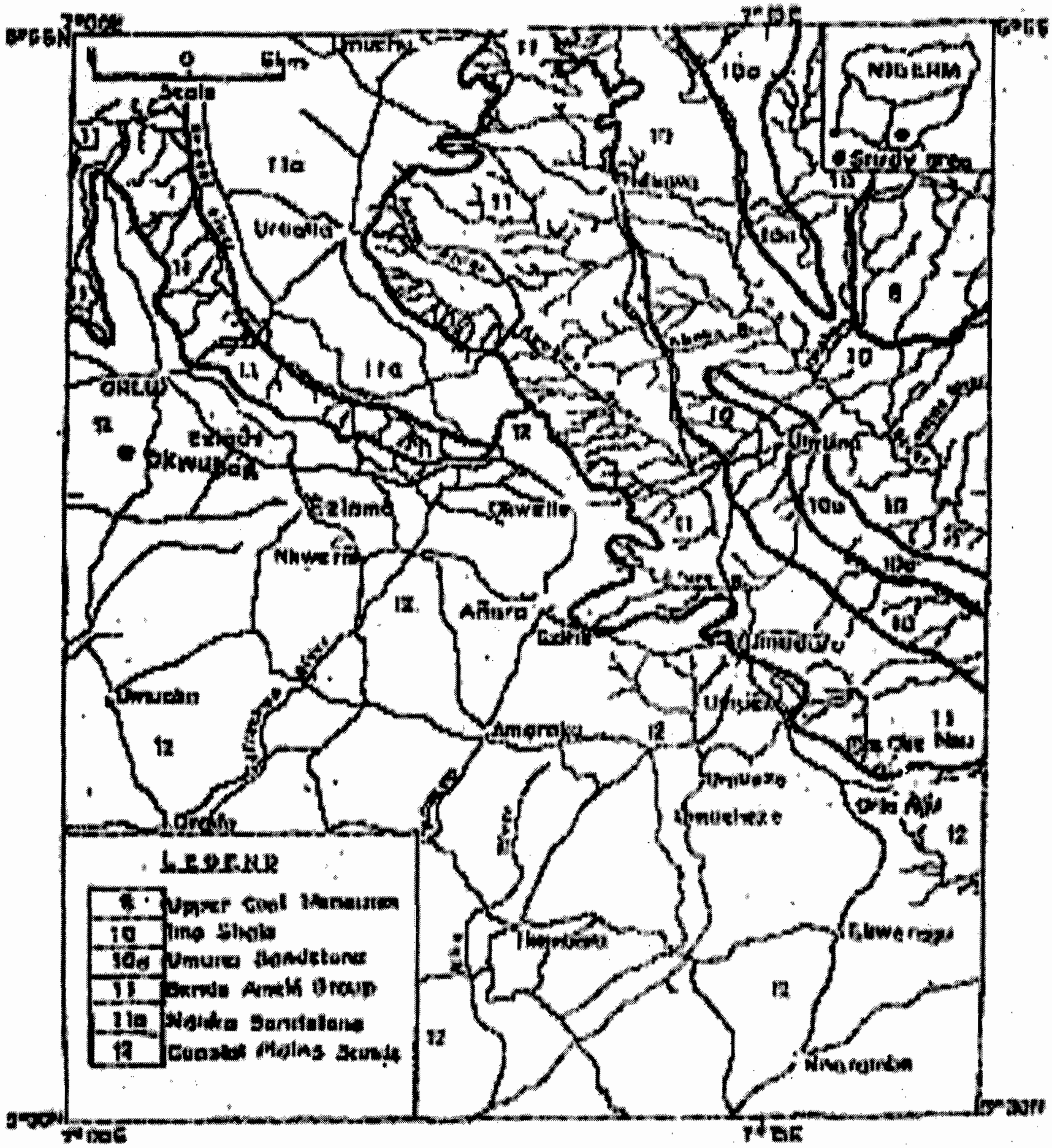

Fig. 1: Geological map of the study area

The Benin Formation represents the coastal and delta – top sands and gravels, poorly sorted and often cross – bedded with clay lenses (Wright et al., 1985). It extents from the west across the whole Niger delta area and southward beyond the present coastline. It is over 90% sandstone with shale intercalations. It is coarse grained, sub-angular to well rounded and bears lignite streaks and wood fragments. It is a continental deposit of probable upper deltaic depositional environment (Asseez, 1976).
Various structural units (point bars, channel fills, natural levees, back swamp deposits, oxbow fills) are identifiable within the formation, indicating the variability of the shallow water depositional medium. In the subsurface, it is of Oligocene age, in the north becoming progressively younger southward. In general, it ranges from Miocene to Recent. The thickness is variable but generally exceeds 1830 metres. Very little hydrocarbon accumulation has been associated with the formation.

Geophysical Logging Exercise

A rotary rig machine was used for the drilling operation. The most widely used drilling fluid is a suspension of bentonitic clay in water known as drilling mud (Freeze and Cherry, 1979). Bentonite plus other additive chemicals like CMC were used for the drilling at this location. The geophysical logging took place when drilling had stopped because the specified depth had been reached. The SP log was run as the cable of the logging system was being lowered into the well at an interval of three metres until the bottom of the borehole was reached. As the cable was being withdrawn from the well, the resistivity logs (Normal 16" and Normal 64") were run. This procedure is in line with the directive which instructs that SP logging measurements should be taken in a separate run to avoid electrode polarization effects that occur during resistivity measurements (ABEM, 1999).

Instrumentation

The equipment used for the logging exercise was ABEM Terrameter SAS system. It is a family of instruments for surveying of Resistivity, Self Potential and Temperature (ABEM, 1999). The Terrrameter SAS 300 is a complete transmitter/receiver system in one single box which can be used alone or as master for the following peripherals:

- The Terrameter SAS 2000 is a booster transmitter for the extension of the voltage and current ranges of the SAS 300.
- The Terrameter SAS LOG 200 is a well logging unit for resistivity, Self Potential and temperature.

In summary, the SAS LOG 200 measures six logs viz: self potential, temperature, resistivities (short normal 16", long normal 64" and long lateral 18ft) and fluid resistivity.

Origin of the SP Currents

Three factors are necessary to provoke an SP current: a conductive fluid in the borehole, a porous and permeable bed surrounded by an impermeable formation and a difference in Salinity (or pressure) between the borehole fluid and the formation water (Rider, 1986). SP currents originate principally through the electrochemical effects of Salinity differences between the borehole fluid (in fact mud filtrate) and the formation water, Fig. 3. These differences create spontaneous currents, either when the fluids themselves come into contact through a porous medium (the diffusion potential) or else when they come into contact through a shale which acts as a semi-permeable membrane (the shale potential). These and other potentials have been discussed by Telford et al., 1990. These two effects for the same solution create exactly opposite polarities. The actual SP currents, which are measured in the borehole are as a result of the combination of the two electrochemical effects mentioned earlier.

Results and Discussion

Figure 2 shows the standard format for the interpretation of SP signatures. The vertical line on the positive side is the shale line while the second line on the negative side indicates the sand line. The SP signatures move between these two lines: excursions toward the shale base line implies a shaly Formation which is invariably impermeable whereas excursion toward the sand line shows sandy Formation which is permeable. The raw field data are shown in Table I. The processed data were plotted on the appropriate graph sheet and presented on the standard log format as shown in Fig. 4. It can be observed that the Self Potential (SP) readings started as negative numbers and continued to be negative decreasingly until a depth of about seventy four metres (74 metres) where the readings changed to positive numbers.

Table 1: Field data of the wire – line logs from Okwudor

DEPTH (m)	SP mV	N16″ ρ (Ωm)	N64″ ρ (Ωm)	DEPTH (m)	SP mV	N16″ ρ (Ωm)	N64″ ρ (Ωm)
20	-432	1887	3780	89	+1.7	1146	2350
23	-429	1960	5310	92	+1.7	1050	1635
26	-415	1914	4360	95	+1.9	1024	1920
29	-397	1570	2390	98	+2.0	1010	1670
32	-371	1588	2210	101	+2.2	967	1469
35	-350	1754	2780	104	+2.2	940	1080
38	-332	1825	4400	107	+2.3	916	829
41	-321	1851	4460	110	+2.3	968	1252
44	-321	1694	4450	113	+2.4	993	1427
47	-307	1685	3740	116	+2.4	1032	1302
50	-304	1696	3270	119	+2.4	1061	1327
53	-303	1602	2770	122	+2.4	1093	1465
56	-293	1143	3740	125	+2.5	1146	1638
59	-189.2	1210	4330	128	+2.5	1128	1605
62	-57.1	1178	4810	131	+2.5	1082	1587
65	-52.0	1251	4890	134	+2.52	1004	1587
68	-21.3	1278	4800	137	+2.53	988	1568
71	-2.6	1309	5270	140	+2.54	1050	1773
74	+1.1	1267	6350	143	+2.52	1115	1800
77	+1.1	1270	6950	147	+2.53	1184	1691
80	+1.2	1278	3650	150	+2.53	1202	1596
783	+1.4	1234	3210				
86	+1.5	1197	2940				

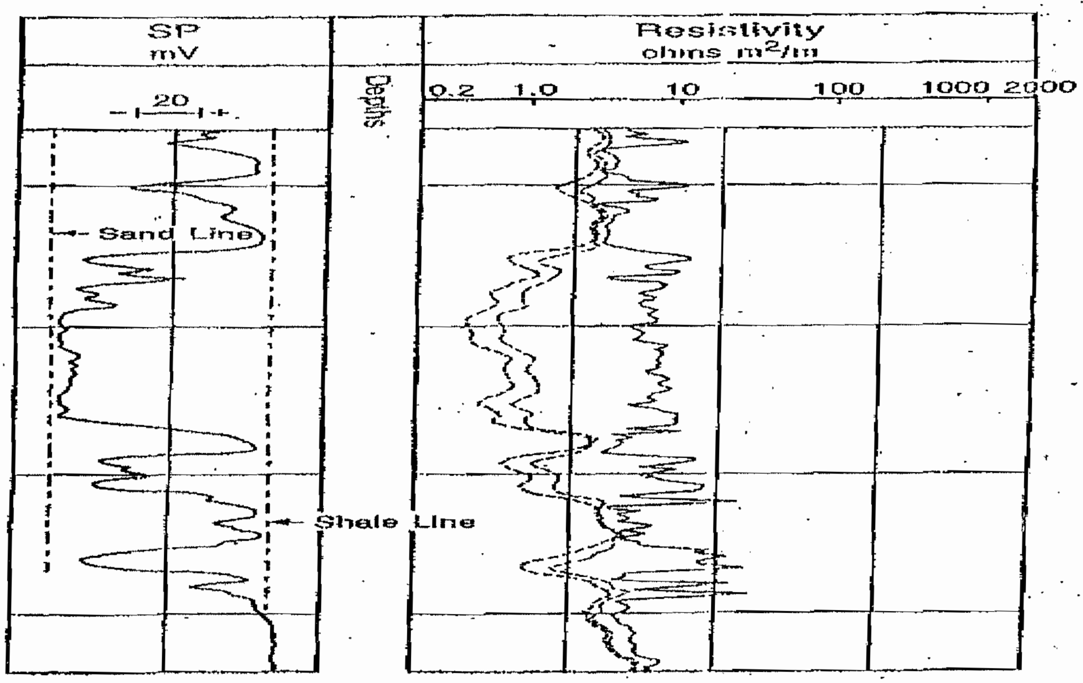

Fig. 2: SP log in a sand – shale series (Schlumberger, 1990)

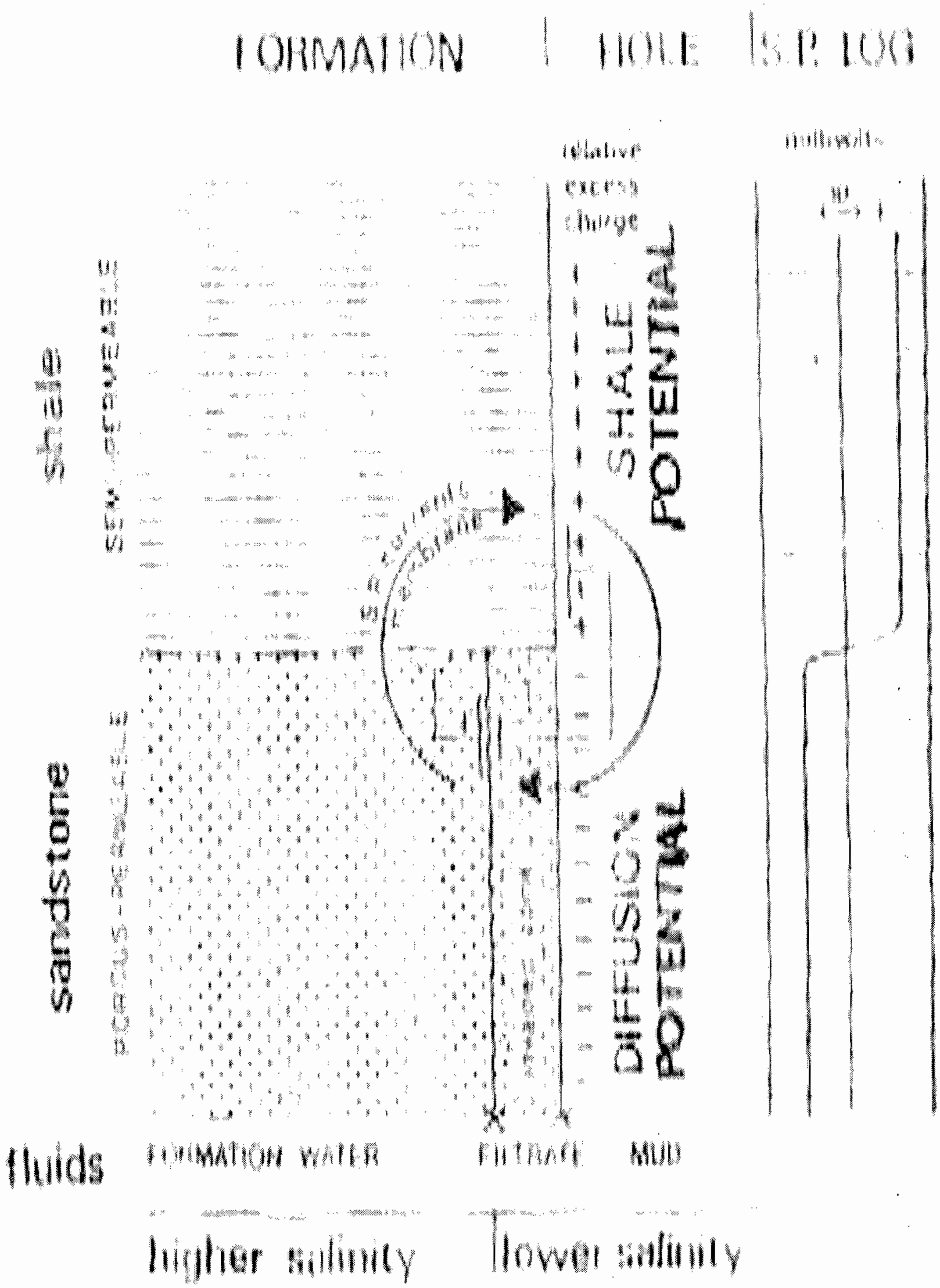

Fig. 3: Origin of SP current in a borehole (Rider, 1980)

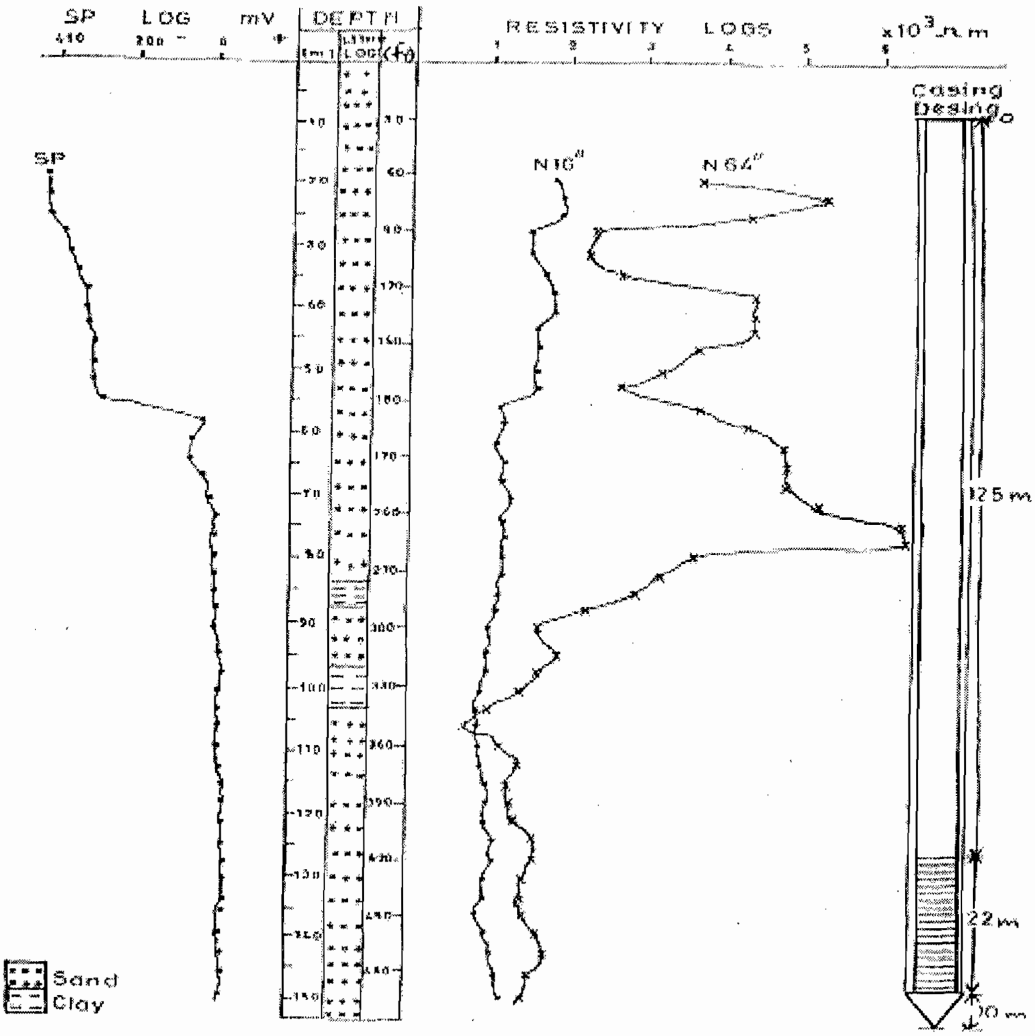

Fig. 4: The electric logs from Okwudor water well

The interpretation that can be deduced from the SP curve is that permeable lithologic units exist between a depth of 20 metres and 71 metres where the SP data are negative, Fig. 4. From 72 metres down to 150 metres, the geologic units are becoming impermeable i.e. the impermeability of the beds increases with depth. These are the interpretation that can be given to the SP field curve obtained from Okwudor, Fig. 4, based on the basic principles of SP currents as shown Fig. 3. The resistivity logs (N16" and N64") indicate the presence of sand units between 110 metres and 150 metres in contrast to shale units which SP log tries to infer. The litho log constructed from the borehole samples, Fig. 4, also shows the presence of sand between 110 metres and 150 metres. It can be observed that the SP interpreted results differ from both resistivity and litho logs. These divergent SP results from other logs can be considered to be anomalous. Most of the data acquired from many logging exercises in places like Port Harcourt, Orlu, Owerri, Aba, etc. conformed with this standard format and it was easy to use the results of both Spontaneous potentials (SP) and resistivity to sketch a casing design. For example, the SP data obtained from the Abiriba borehole (Selemo, 1998) showed excursions to both positive and negative sides of the zero origin, Fig. 5 which are indications of permeability of the lithologic units. The resistivity and the SP logs have the same interpretation. Likewise, the logging results from Uba – Umuaka (Selemo, 2000) also conformed with the conventional practice of positive SP signatures depicting impermeable beds while negative values imply porous units. Fig. 6. More case studies can be cited where SP and resistivity data never gave contradicting interpretations. The present case in question can then be regarded as an anomaly which may arouse the interest of geoscientists and professionals that are involved in geophysical logging. Therefore, the SP log was ignored when considering the appropriate zone for screening. After a thorough examination of the resistivity and litho logs, the screens were installed between 125 metres and 147 metres and the water yield of the well was prolific.

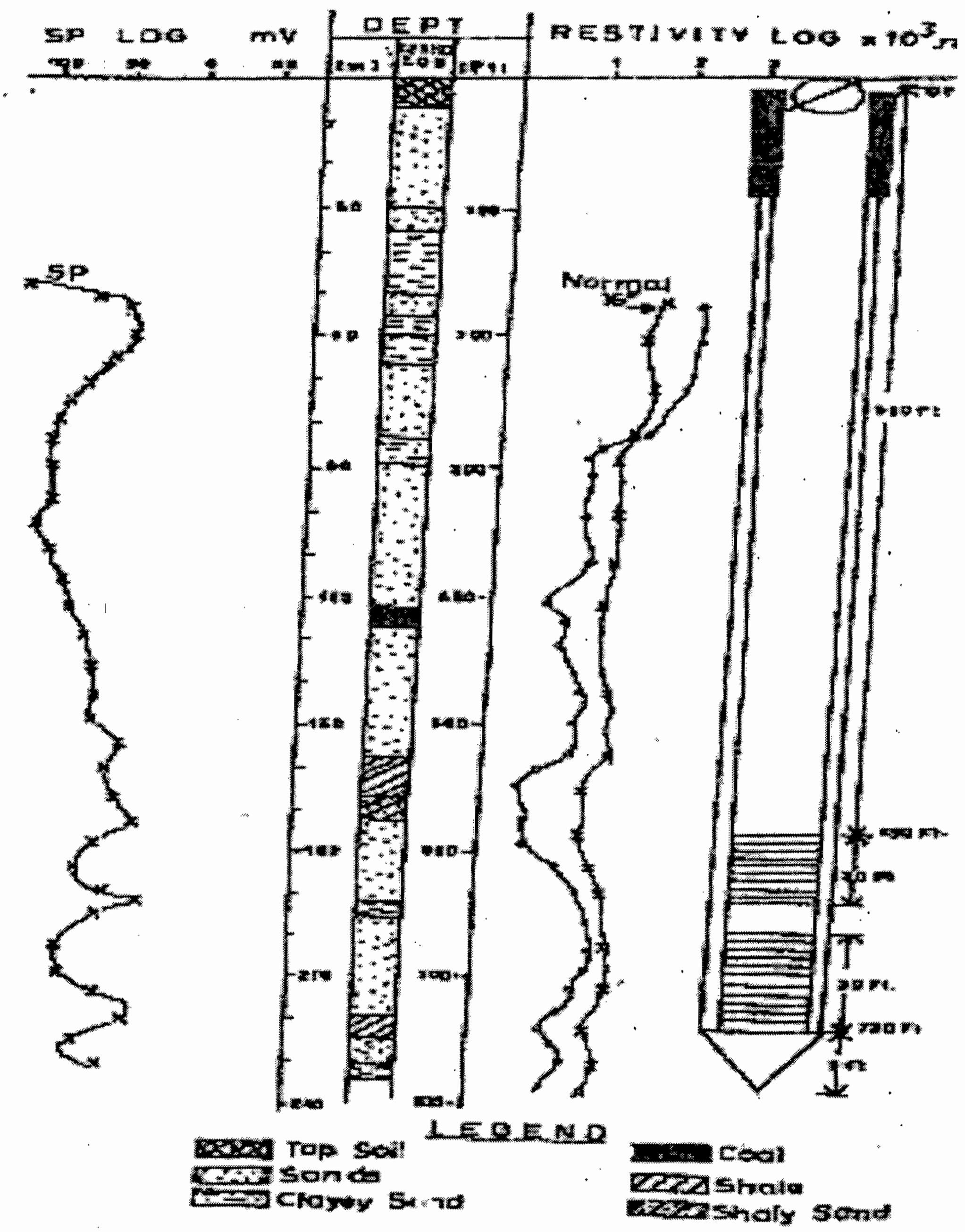

Fig. 5: The electric logs from Abiriba water well

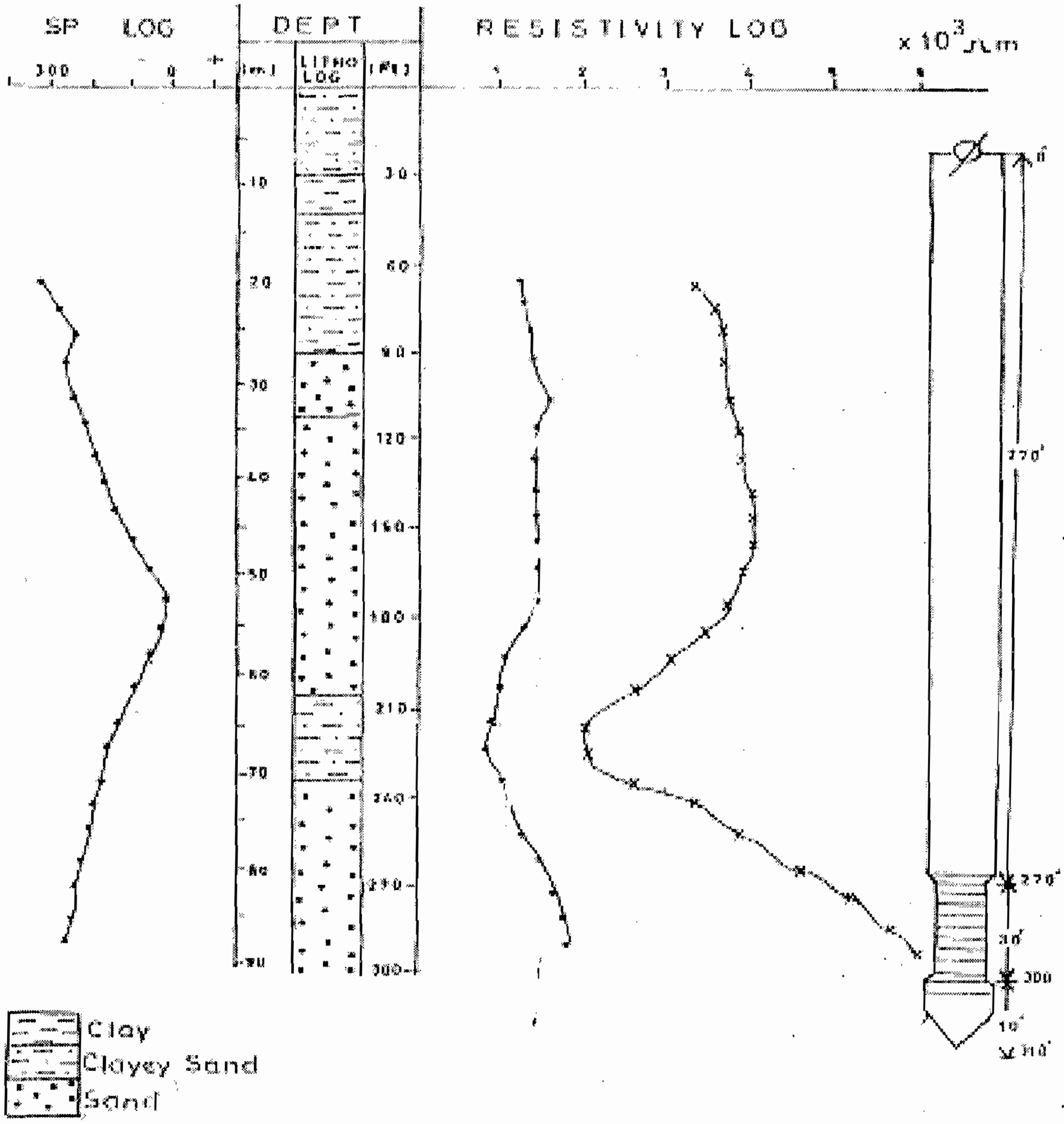

Fig. 6: The electric logs from Uba – Umuaka water well

The issue now is the apparent misleading signatures of the SP log that tend to indicate the presence of impermeable units beyond 75 metres. Other logs gave different results which were used to achieve a successful borehole.

How can one explain these anomalous responses from the SP log? Going back to the origin of SP currents, Fig. 3, the salinity of the formation water might be higher than that of the mud, hence the SP currents could probably flow in the clockwise direction. If a situation should arise whereby the mud salinity becomes higher than that of the formation (probably due to excessive introduction of chemicals into the mud) there could be a reversal in the flow of SP currents. This could lead to this anomalous observation.

Conclusion

The essence of geophysical logging especially in the water industry is to assist in locating porous and permeable layers within the subsurface where the sand screens can be installed so that groundwater may easily enter the borehole through them. The prominent logs that are good indicators are SP and resistivity logs. But in this case study, the SP signatures gave results that are contradicting to those of the resistivity logs. The SP log portrays the screening zone as impermeable while the resistivity logs indicate that the same zone is permeable. In a situation like this where there are conflicting interpretations from SP and resistivity logs, another log especially the litho log should be considered. Unfortunately logs like gamma ray, density etc are not used in the water industry because of the financial implications. In this study case, the results from resistivity logs and that of the litho log agree. Thus they were used to sketch the casing design for the well and it became productive.

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