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Geophysical Survey as a useful Instrument for Determining Subsurface Lithology in Igarra, Edo State, Nigeria

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Abstract

The investigation of direct current probing of sea level for subsurface lithology in Igarra area of Edo State, Nigeria was carried out using electrical resistivity method based on schlumberger array of vertical electrical sounding (VES).

The need to carry out this research became imperative in view of the fact that subsurface lithologies are of economy importance to mankind for development. Ten (10) VES, uniformly distributed was carried out at four (4) different stations. A computer iterative method of interpretation was employed using the IP12WIN and win rest software. The results were correlated with geologic and lithological data/log acquired from the survey area to obtain the desired lithologies or rock types. The various subsurface lithologies encountered were topsoil, sandstone, wet sand, sand and clay with resistivities varying from (60-300) ohm-m, (200-400) ohm-m, (200-500) ohm-m (300-600) ohm-m, (70-130)ohm – m respectively, thicknesses raying from (0.2-2.00)m, (0.4-2.00)m, (3.50-6.50) m (25-55)m and (1.0-3.0) m respectively, depths varying from (0.2-2.0)m, (0.6-4.0)m, (4.10-10.50m), (29.10-65.50)m and (30.10-68.50)m. These results agreed very well with available borehole records of the area.

1.0 Introduction

The movement and production of individual minerals arising from subsurface lithologies for the use of variable industries is an issue that has received adequate entrepreneurial attention in Nigeria [1]. The study of the earth's resistivity is commonly used in shallow depth investigation. Although previous researchers have employed geophysical prospecting as a mean of investigating the electrical properties of rocks and soil, this was not covered over a wide range [2].

Geophysical survey as a viable tool based on electrical exploration method utilizes artificial electric currents to explore the properties of the earth's interior and to search for natural resources such as water, clay oil, and other mineral arising from various subsurface lithologies [3].

Previous researchers have shown that the search for oil and solid minerals was confirmed to deposits directly observable on the surface in the form of seeps and outcrops or other exposures [4]. When all accumulation in an area that could be discovered by such simple methods had been found, it became imperative to deduce the presence of subsurface lithologies indirectly by downward projection of geophysical survey information observable on the earth's surface [5]. This involves measurements on the earth's surface that could give information on the structure or composition of concealed rock types or lithologies that might be useful for locating desired mineral deposits [6].

2.0 Brief Local Geology of the Study Area

The study area was Igarra in Edo State of Nigeria. It is located in the northern part of Edo State and lies approximately within latitude $7^{0}17$'N and longitude $6^{o}18$'E with an elevation of 30m[7].

It is underlain by the Ameki formation which consist mainly of a series of cross-bedded sandstone, clays pebbly grit silt stone [2].

3.0 Experimental Work

The geophysical survey was carried out in Igarra, Edo State of Nigeria with the aid of SAS (signal averaging system) ABEM 300 digital terrameter and its 2000 booster [8] vertical electrical sounding (VES) was carried out using the

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schlumberger array in the survey area, with the current electrode (AB/2) spacing ranging from 2m-1000m. This spacing depends on the number of points per decade, which is usually n= 6, giving a spread of $10^{1/n}$.

The resulted to spread of 1.0m, 1.47m, 2.15m, 3.16m, 4.64m, 6.81m, 10.0m, 14.7m, 21.5m e.t.c (g) [9]

Measurements were taken at increasing current electrode distances so that the electric current introduced into the ground penetrated greater depths. In places, where the ground was dry, small amount of water was applied to the ground for easy penetration of current electrode into the ground which made good contact with the ground [10]

The current electrodes were expanded at six points per decade while the potential electrodes remained fixed. A decrease in the potential difference across the potential electrodes necessitated a new potential electrode spacing in accordance with schlumberger field condition of AB$\geq$5MN where A and B are current electrodes, M and N are potential electrodes [11].

For easy reference, a table of semi current electrode spacing AB/2 and respective apparent resistivites for the four covered stations is shown in table 5.1.

4.0 Theoretical Analysis

The fundamental theory behind geo-electrical survey was analysed completely by Maillet and other researchers [15], [16]. In a homogeneous isotropic medium, the potential due to a single point current source such as the current electrode, satisfy laplace's equation arising from the equipotential hemispherical surface so that

$$E = -\nabla V \qquad (4.1)$$

and from ohm's lenv

$$J = \sigma E \qquad (4.2)$$

Where ∇represents del operator

V= electric potential, E= electric field intensity

σ= electrical conductivity, J = Current density

For a single point current source $\Delta . J = O$ (4.3)

Using (4.1) and (4.2), we have

$$\nabla \sigma E = \nabla . \sigma (-\nabla V) = 0 \qquad (4.4)$$

$$:. -\sigma \nabla^2 V = 0$$

$$:. \nabla^2 V = O \text{ for } r >> O \qquad (4.5)$$

Where ∇^2 (del squared) is called lapacian operator. The exact solution to equation (4.5) have been documented in previous research work of the researcher [1], [4], [8], [9], [10],[11]. The solution lead to the calculated apparent resistivity (ℓ_a) according to schlumberger array condition of AB$\geq$ SMN given as

$$\ell_a = \pi \left[\frac{\frac{(AB)^2}{2} - \frac{MN^2}{2}}{MN} \right] \frac{\Delta V}{I} \qquad [11] \qquad (4.7)$$

AB = current electrode spacing in meter

MN = Potential electrode spacing in meter

ΔV = potential difference in volts, I = electric current in

5.0 Results And Discussion

After the geophysical field survey that produced the readings above, the apparent resistivity values in ohm-m were plotted against half current electrode spacing with both axis in a log scale to obtain the various sounding curves. The sounding curves shown in figures 5.1-5.4 were then interpreted using IP12WIN and Win rest software to provide a model showing the thicknesses and resistivities of the various subsurface lithological layers, [12] shown in table 5.5

The results and field/theoretical sounding curves obtained are presented in tables 5.2-5.4 and figures 5.1-5.4. The analysis of the resistivities of various lithologically formation is usually ambiguous because it is possible for different rock types (lithology) to have the same resistivity [1]. However for the avoidance of doubt, we usually integrate the approximate ranges for electrical resistivities standard table of rocks and soil [13] with a nearby borehole lithology/driller's log [14] to obtain the various subsurface lithologies shown in the last column of table 2 above. The various curve typed exhibited in figures 5.1-5.4 indicate the sandy nature of the area and hence aquifer or water bearing formations as seen from the low resistivities values in tables 5.1 and 5.2.

Table 5.1: apparent resistivities, values for typical stations.

S/N	AB/2 (m)	App. Resist for Station 1 (ohm-m)	App. Resist for Station 2 (ohm-m)	App. Resist for Station 3 (ohm-m)	App. Resist for Station 4 (ohm-m)
1	1.00	307.49	213.66	140.21	210.59
2	1.47	215.18	185.46	151.57	278.64
3	2.15	117.00	175.98	156.96	384.79
4	3.16	54.99	181.19	152.53	538.93
5	4.64	35.88	190.35	140.95	747.30

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6	6.81	36.60	199.14	127.01	1017.28
7	10.00	40.93	213.55	112.08	1356.62
8	14.70	46.15	244.19	95.29	1770.51
9	21.50	54.14	297.40	78.13	2245.45
10	31.60	67.76	376.00	65.20	2788.56
11	46.40	86.10	476.10	62.12	3412.47
12	68.10	119.68	591.73	70.32	4108.69
13	100.0	161.84	715.30	87.53	4713.84
14	147.00	219.44	837.57	110.49	4903.89
15	215.00	-	-	-	4487.06
16	316.00	-	-	-	3713.42
17	464.00	-	-	-	3115.70

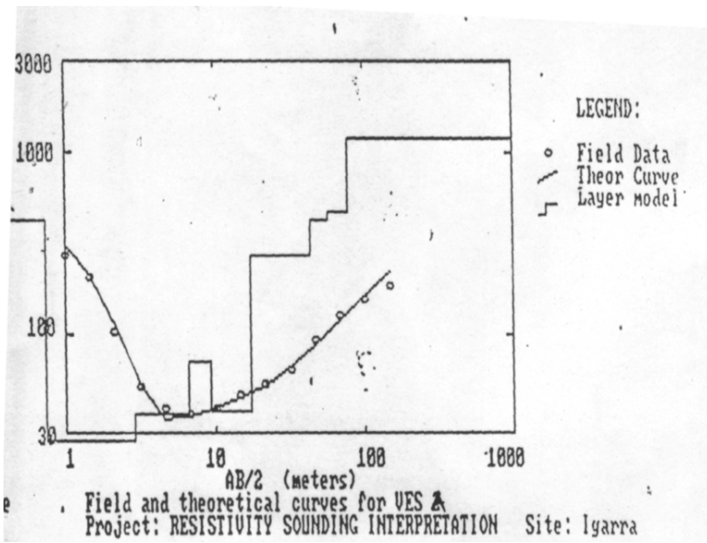

Fig 5.1 Iterated Sounding Curve for Station 1

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	330.85	0.16	0.16
2.00	430.00	0.58	0.74
3.00	26.88	2.14	2.88
4.00	37.91	3.80	6.68
5.00	71.70	2.64	9.32
6.00	38.95	8.10	17.42
7.00	270.00	25.81	43.23
8.00	417.00	13.95	57.18
9.00	470.25	19.34	76.52
10.00	1184.40	infinity	infinity

Field data & computer interpretation by:
OKODUGHA Ehizele C

Table 5.2 Lithology for Station1

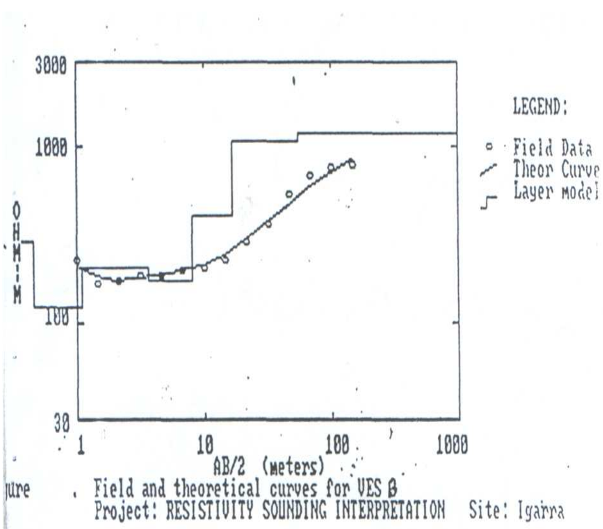

Fig 5.2 Iterated Sounding Curve for Station 2

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK
1.00	293.00	0.45	0.45
2.00	126.03	0.64	1.09
3.00	207.00	2.60	3.69
4.00	172.57	4.41	8.10
5.00	412.00	8.53	16.63
6.00	1044.09	38.17	54.80
7.00	1187.92	infinity	infinity

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Table 5.3 Lithology for Station 2

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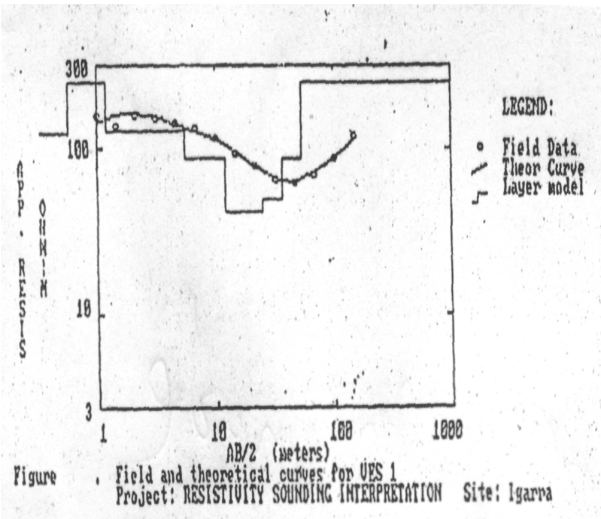

Fig 5.3 Iterated Sounding Curve for Station 3

LAYER PARAMETERS OF MODEL

LAYER	RESISTIVITY	THICKNESS	CUM THICK.
1.00	120.48	0.58	0.58
2.00	235.05	0.64	1.20
3.00	123.00	4.39	5.59
4.00	66.70	6.42	12.01
5.00	41.30	12.58	24.59
6.00	46.00	11.53	36.12
7.00	85.40	16.95	53.07
8.00	238.00	infinity	infinity

Field data & computer interpretation by:
MARERE Omamode

Table 5.4 Lithology for Station 3

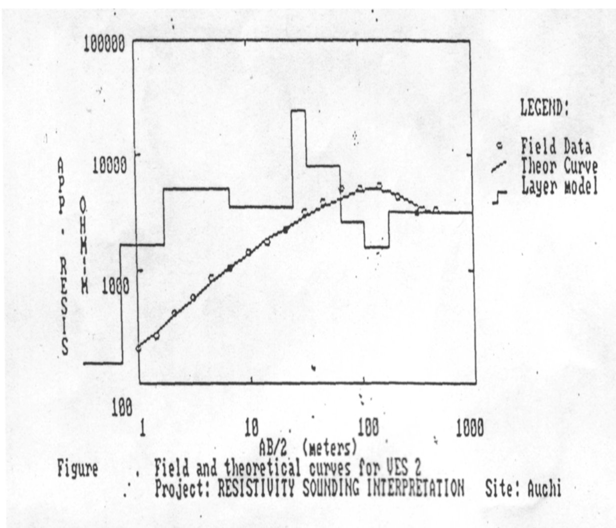

Fig 5.4 Iterated Sounding Curve for Station 4

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Stations	Layers Resistivity (ohm-m)	Layer thickness (m)	Depth (m)	Subsurface lithology
1	330.85	0.16	0.16	Top soil
	430.00	0.58	0.74	Sandstone
	26.88	2.14	2.88	Wet sand
	37.91	3.80	6.68	Wet clay
	71.70	2.64	9.32	Wet clay
	38.95	8.10	17.42	Wet clay
	270.00	25.81	43.23	Sand
	417.00	13.95	57.18	Sand
	970.25	19.34	76.52	Basalt
	1184.40	Infinity	Infinity	Fresh basement
2	293.00	0.45	0.45	Top soil
	126.03	0.64	1.09	Clay Soil
	207.00	2.60	3.69	Loose sand
	172.57	4.41	8.10	River Sand
	4120.00	8.53	16.63	River sand
	1044.09	38.17	54.80	Sand
	1187.92	Infinity	Infinity	Sand
3	120.48	0.56	0.56	Clay Sand
	235.05	0.64	1.20	Loose sand
	123.60	4.39	5.59	Clay
	66.70	6.42	12.01	Clay
	41.30	12.58	24.59	Sand stone
	46.00	11.53	38.12	Sand stone
	85.40	15.95	54.07	Sand
	236.00	Infinity	Infinity	Sand
4	145.0	0.71	0.71	Wet top soil/clay
	1606.50	1.09	1.80	Sandy soils
	5060.00	5.09	6.89	Sandy soils
	3456.00	18.48	25.37	Sand
	2640.09	8.32	33.69	Sand
	7767.56	32.73	66.42	Sandstone
	2571.43	39.79	106.21	River sand
	1532.00	70.28	176.49	River sand
	8122.00	Infinity	Infinity	Dry sand

Table 5.5: various subsurface lithologies encountered for typical stations.

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6.0 Conclusion

Geophysical survey based on electrical resistivity method of schlumberger array or configuration is very reliable and successful in exploring subsurface lithologies or rock types in Igarra, Edo State of Nigeria. The various subsurface lithologies encountered which are topsoil. Sandstone, wet sand, sand and clay agreed very well with available bore-hole/lithological log/drillers log record of the area. These subsurface lithologies are of economy importance to mankind for development for example one of the subsurface lithologies which is clay falls into one of the industrial minerals that are needed for the manufacturing of industrial product. Also sand deposit means aquifer or water bearing formations geophysically which can serve as a guide to competent bore-hole driller for pure water production e.t.c.

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