ISSN 2229-5518

Delineation of Subsurface Lithology using Two-Dimensional Geoelectrical Resistivity Imaging in Ologbo Area of Edo State, Nigeria.

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Abstract - In this research work, subsurface lithology in Ologbo area of Edo state was delineated using two-dimensional geoelectrical resistivity imaging technique. The Petrozenith earth resistivity meter equipment was employed using the Wenner-Schlumberger electrode configuration. Two locations were investigated within the study area which includes Near Pipeline Route, off NNPC Road (line 11) and Lonestar Area (line 18). A total of seventy-eight Wenner-Schlumberger sounding were obtained in each of the area, while the data was inverted using the Zondres 2D software. The results show the presence of laterite, sand and gravel in the area.

Index Terms – NNPC (Nigerian National Petroleum Corporation), 2D (Two Dimensional). 2D resistivity imaging, inversion, lithology, Ologbo and pseudosection.

1 INTRODUCTION

The importance of rock types and minerals cannot be over-emphasized as they form the basis of all economic activities of a nation. The geology of an area is critical in assessing its suitability for the type of building to be erected, the type of road to be constructed, the type of dam to be constructed for the generation of electricity, e.t.c. Near-surface soil may consist of expansive clay that expands or shrinks as a result of change in moisture content [1]. Movement of foundation may occur if the clay moistening and drying is not uniform. Subsurface geological features such as fractures, voids, small depth of bedrock, near – surface depth to water table are among the common constraints to building constructions, especially to their foundations. The use of electrical resistivity imaging to address a wide variety of hydrological, environmental and geotechnical problems is increasingly becoming very popular [2]. One of the many direct ways in which geophysical investigation aids the general economy is in the delineation of subsurface lithologies or rock types which give rise to oil/ mineral, gas and other valuable products of different kinds [3]. This delineated rock types such as clay deposit, sandstone deposit, limestone deposits, shales and even aquiferous sand deposits are of a high economy value in the world's economy [4]. Clay for example has been indispensable in architecture, in industry, and in agriculture. Sandstone on the other hand has been used for domestic construction and house-wares since pre-historic times, and continues to be used. Again sand is used for agricultural, acquaria, artificial reefs, artificial islands, beach nourishment, brick, cob, mortar, concrete, glass and paint. Gravel and laterite are used for road construction.

Ologbo is a border town located between Edo and Delta states of southern Nigeria, approximately 3km from Benin City, with geographical coordinates of about, 6° 3' North, 5° 40' East. The geology of the study area is characterized by deposits laid during the tertiary and cretaceous periods. The area is underlain by sedimentary rock constituting part of the Benin formation which is made up of over 90% massive, porous, coarse sand with clay/shale interbeds having high groundwater retention capacity. The topography of the area is generally flat [5].

2 THEORY

The electrical resistivity method involves the measurement of the apparent resistivity of soils and rock as a function of depth. It is expressed in ohm-meters. The resistivity of soils is a complicated function of permeability, ionic content of the pores fluids, clay mineralization and porosity. Using maxwell's equations in a form relating to electric and magnetic field vectors [6]:

$$\nabla \times E = -\frac{\partial B}{\partial t} \qquad (1)$$

$$\nabla \times H = J + \frac{\partial D}{\partial t} \qquad (2)$$

Taking the divergence of "(1)"

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$$\nabla \cdot \nabla \times E = -\nabla \cdot \frac{\partial B}{\partial t} = -\frac{\partial}{\partial t}(\nabla \cdot B) \quad (3)$$

But the divergence of a curl is zero, hence

$$\nabla \cdot \nabla \times E = -\nabla \cdot \frac{\partial B}{\partial t} = -\frac{\partial}{\partial t}(\nabla \cdot B)$$
$$= 0$$
$$\therefore \ \nabla \cdot B = 0 \quad (4)$$

Similarly

$$\nabla \cdot \nabla \times H = \nabla \cdot J + \nabla \cdot \frac{\partial D}{\partial t} = \nabla \cdot J + \frac{\partial}{\partial t}(\nabla \cdot D) = 0 \quad (5)$$

The divergence of current density is equivalent to the rate of accumulation of charge density Q

Hence

$$\nabla \cdot J = -\frac{\partial Q}{\partial t} = -\frac{\partial}{\partial t}(\nabla \cdot D)$$
$$\therefore \ \nabla \cdot D = Q \quad (6)$$

In the regions of finite conductivity, charge does not accumulate to any extent during current flow, hence Q=0

$$\therefore \ \nabla \cdot J = 0 \quad (7)$$

Ohm's law states that the current density is proportional to electric field strength

$$J = \sigma E \quad (8)$$

But the electric field is the gradient of a scalar potential

$$E = -\nabla V \quad (9)$$

Hence

$$J = -\sigma \nabla V \quad (10)$$

Using "(7)"

$$\nabla \cdot (\sigma \nabla V) = 0 \quad (11)$$

$$\nabla \sigma \cdot \nabla V + \sigma \nabla^2 V = 0 \quad (12)$$

If σ is constant throughout, it reduces to Laplace's equation.

$$\nabla^2 V = 0 \quad (13)$$

At this point, solution may be developed for a particular earth model by selecting a co-ordinate system to match the geometry of the model and by imposing appropriate boundary conditions.

3 METHODOLOGY

The data for this research was acquired using the Petrozenith earth resistivity meter. The Wenner-Schlumberger hybrid array was adopted. This enabled the build-up of a pseudosection. With the geometric factor K for the array used, the resistance value readings were converted to apparent resistivity.

The geoelectric images were interpreted geologically using knowledge of geology of the survey area, resistivities of sediments, rocks and minerals available in literatures.

4 RESULTS

The 2D survey displayed the image of the subsurface vertically and laterally thus enhancing continuity. The data was inverted using the ZONDRES 2D software to obtain a 2D true resistivity model of the subsurface. The resistivity results obtained for lines 11 and 18 are shown in tables 1 and 2 below:

Table 1: Line 11 Data Sheet

2D ELECTRICAL RESISTIVITY IMAGING FIELD DATA REPORT SHEET						
ARRAY TYPE		Wenner-Schlumberger	DATE	4-04-2014		
INSTRUMENT USED		Petrozenith Earth Resistivity Meter	STATE	Edo		
LOCATION		Near Pipeline Route, off NNPC Road	LGA	Ikpoba Okha		
LINE NUMBER		L11	Town	Ologbo		
OBSERVER		JUSTICE EFAM ADAGBON				
BEGIN COORDINATE/ALTITUDE		N6o 04.954' , E0050 39.553' / 22.7m				
END COORDINATE/ALTITUDE		N6o 04.943' , E0050 39.496' / 22.8m				
GEOMETRICAL FACTOR : 31.42		ELECTRODES SPACING : 5m				
S/No	C1	P1	P2	C2	R (Ω)	ℓa (Ωm)
1	0	5	10	15	69.85	2194.687
2	5	10	15	20	64.81	2036.33
3	10	15	20	25	65.48	2057.382
4	15	20	25	30	66.75	2097.285
5	20	25	30	35	56.19	1765.49
6	25	30	35	40	62.35	1959.037
7	30	35	40	45	65.8	2067.436
8	35	40	45	50	62.97	1978.517
9	40	45	50	55	69.32	2178.034
10	45	50	55	60	64.7	2032.874
11	50	55	60	65	70.63	2219.195

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12	55	60	65	70	65.26	2050.469
13	60	65	70	75	65.45	2056.439
14	65	70	75	80	56.85	1786.227
15	70	75	80	85	57.91	1819.532
16	75	80	85	90	64.61	2030.046
17	80	85	90	95	57.05	1792.511
18	85	90	95	100	65.19	2048.27
	GEOMETRICAL FACTOR: 94.26	ELECTRODES SPACING : 10m				
1	0	10	15	25	29.93	2821.202
2	5	15	20	30	26.55	2502.603
3	10	20	25	35	29.6	2790.096
4	15	25	30	40	23.33	2199.086
5	20	30	35	45	26.36	2484.694
6	25	35	40	50	27.42	2584.609
7	30	40	45	55	25.08	2364.041
8	35	45	50	60	29.96	2824.03
9	40	50	55	65	23.46	2211.34
10	45	55	60	70	30.03	2830.628
11	50	60	65	75	24.16	2277.322
12	55	65	70	80	26.45	2493.177
13	60	70	75	85	22.18	2090.687
14	65	75	80	90	25.16	2371.582
15	70	80	85	95	25.24	2379.122
16	75	85	90	100	24.57	2315.968
	GEOMETRICAL FACTOR : 188.52	ELECTRODES SPACING: 15m				
1	0	15	20	35	16.02	3020.09
2	5	20	25	40	15.38	2899.438
3	10	25	30	45	14.12	2661.902
4	15	30	35	50	15.67	2954.108
5	20	35	40	55	15.62	2944.682
6	25	40	45	60	13.93	2626.084
7	30	45	50	65	13.67	2577.068
8	35	50	55	70	13.92	2624.198
9	40	55	60	75	16.86	3178.447
10	45	60	65	80	14.7	2771.244
11	50	65	70	85	13.52	2548.79
12	55	70	75	90	12.95	2441.334
13	60	75	80	95	11.87	2237.732
14	65	80	85	100	14.47	2727.884
	GEOMETRICAL FACTOR : 314.2	ELECTRODES SPACING: 20m				
1	0	20	25	45	11.3	3550.46
2	5	25	30	50	9.19	2887.498
3	10	30	35	55	9.14	2871.788
4	15	35	40	60	10.29	3233.118
5	20	40	45	65	7.89	2479.038
6	25	45	50	70	9.74	3060.308
7	30	50	55	75	7.87	2472.754
8	35	55	60	80	11.06	3475.052
9	40	60	65	85	8.72	2739.824
10	45	65	70	90	10.53	3308.526
11	50	70	75	95	7.46	2343.932
12	55	75	80	100	7.46	2343.932

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	GEOMETRICAL FACTOR : 471.3	ELECTRODES SPACING 25m				
1	0	25	30	55	6.47	3049.311
2	5	30	35	60	7.12	3355.656
3	10	35	40	65	6.09	2870.217
4	15	40	45	70	6.38	3006.894
5	20	45	50	75	6.49	3058.737
6	25	50	55	80	6.27	2955.051
7	30	55	60	85	6.13	2889.069
8	35	60	65	90	6.87	3237.831
9	40	65	70	95	6.21	2926.773
10	45	70	75	100	6.91	3256.683
	GEOMETRICAL FACTOR : 659.82	ELECTRODES SPACING : 30m				
1	0	30	35	65	4.85	3200.127
2	5	35	40	70	5.12	3378.278
3	10	40	45	75	4.43	2923.003
4	15	45	50	80	4.79	3160.538
5	20	50	55	85	3.85	2540.307
6	25	55	60	90	5.22	3444.26
7	30	60	65	95	3.93	2593.093
8	35	65	70	100	4.13	2725.057

Table 2: Line 18 Data Sheet

2D ELECTRICAL RESISTIVITY IMAGING FIELD DATA REPORT SHEET						
	ARRAY TYPE	Wenner-Schlumberger	DATE	7-04-014		
	INSTRUMENT USED	Petrozenith Earth Resistivity Meter	STATE	Edo		
	LOCATION	Lonestar Area	LGA	Ikpoba Okha		
	LINE NUMBER	L18	Town	Ologbo		
	OBSERVER	JUSTICE EFAM ADAGBON				
	BEGIN COORDINATE/ALTITUDE	N6o 03.927′ , E0050 38.744′ / 18.8m				
	END COORDINATE/ALTITUDE	N6o 03.936′ , E0050 38.692′ / 18.9m				
	GEOMETRICAL FACTOR : 31.42	ELECTRODES SPACING : 5m				
S/No	C1	P1	P2	C2	R (Ω)	ℓa (Ωm)
1	0	5	10	15	40.78	1281.308
2	5	10	15	20	33.79	1061.682
3	10	15	20	25	46.58	1463.544
4	15	20	25	30	41.43	1301.731
5	20	25	30	35	36.82	1156.884
6	25	30	35	40	50.33	1581.369
7	30	35	40	45	41.12	1291.99
8	35	40	45	50	61.34	1927.303
9	40	45	50	55	48.49	1523.556
10	45	50	55	60	63.04	1980.717
11	50	55	60	65	66.89	2101.684

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12	55	60	65	70	55.18	1733.756
13	60	65	70	75	60.53	1901.853
14	65	70	75	80	51.56	1620.015
15	70	75	80	85	60.44	1899.025
16	75	80	85	90	55.2	1734.384
17	80	85	90	95	75.74	2379.751
18	85	90	95	100	69.4	2180.548
	GEOMETRICAL FACTOR : 94.26	ELECTRODES SPACING : 10m				
1	0	10	15	25	10.46	985.9596
2	5	15	20	30	17.69	1667.459
3	10	20	25	35	16.39	1544.921
4	15	25	30	40	21.18	1996.427
5	20	30	35	45	13.36	1259.314
6	25	35	40	50	21.73	2048.27
7	30	40	45	55	18.33	1727.786
8	35	45	50	60	13.99	1318.697
9	40	50	55	65	19.92	1877.659
10	45	55	60	70	23.52	2216.995
11	50	60	65	75	12.89	1215.011
12	55	65	70	80	22.34	2105.768
13	60	70	75	85	15.15	1428.039
14	65	75	80	90	20.56	1937.986
15	70	80	85	95	20.43	1925.732
16	75	85	90	100	25.97	2447.932
	GEOMETRICAL FACTOR : 188.52	ELECTRODES SPACING: 15m				
1	0	15	20	35	8.33	1570.372
2	5	20	25	40	8.97	1691.024
3	10	25	30	45	8.17	1540.208
4	15	30	35	50	8.16	1538.323
5	20	35	40	55	9.32	1757.006
6	25	40	45	60	9.18	1730.614
7	30	45	50	65	8.92	1681.598
8	35	50	55	70	10.72	2020.934
9	40	55	60	75	11.91	2245.273
10	45	60	65	80	9.66	1821.103
11	50	65	70	85	10.82	2039.786
12	55	70	75	90	9.25	1743.81
13	60	75	80	95	9.91	1868.233
14	65	80	85	100	11.22	2115.194
	GEOMETRICAL FACTOR : 314.2	ELECTRODES SPACING: 20m				
1	0	20	25	45	5.83	1831.786
2	5	25	30	50	5.93	1863.206
3	10	30	35	55	4.32	1357.344
4	15	35	40	60	5.4	1696.68
5	20	40	45	65	4.9	1539.58
6	25	45	50	70	4.46	1401.332
7	30	50	55	75	5.59	1756.378
8	35	55	60	80	10.36	3255.112
9	40	60	65	85	5.63	1768.946
10	45	65	70	90	6.52	2048.584
11	50	70	75	95	4.25	1335.35
12	55	75	80	100	6.91	2171.122

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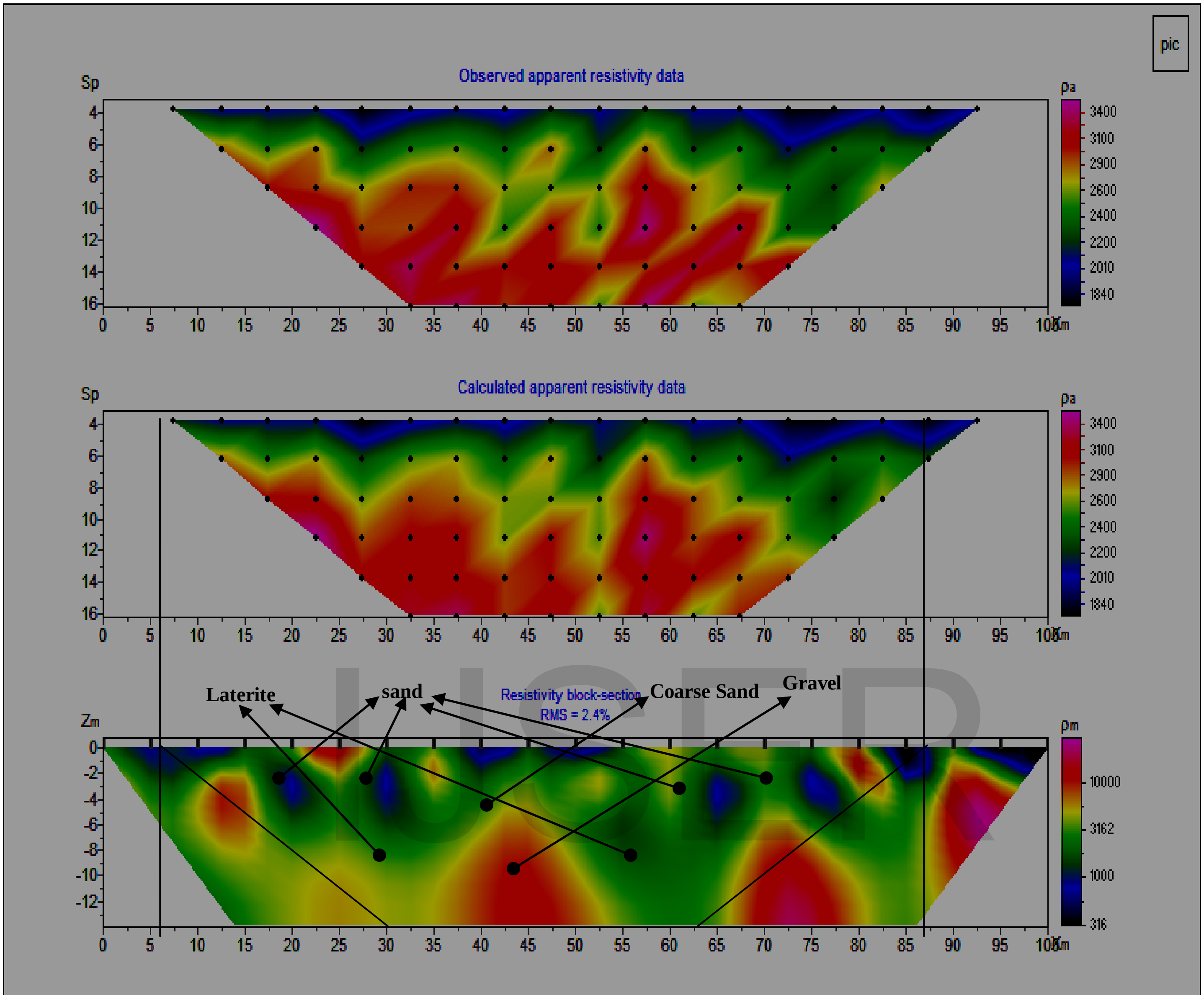
	GEOMETRICAL FACTOR : 471.3	ELECTRODES SPACING 25m				
1	0	25	30	55	257.9	121548.3
2	5	30	35	60	2.78	1310.214
3	10	35	40	65	3.37	1588.281
4	15	40	45	70	3.5	1649.55
5	20	45	50	75	3.05	1437.465
6	25	50	55	80	3.57	1682.541
7	30	55	60	85	4.53	2134.989
8	35	60	65	90	3.46	1630.698
9	40	65	70	95	4.03	1899.339
10	45	70	75	100	2.86	1347.918
	GEOMETRICAL FACTOR : 659.82	ELECTRODES SPACING : 30m				
1	0	30	35	65	2.07	1365.827
2	5	35	40	70	2.77	1827.701
3	10	40	45	75	2.67	1761.719
4	15	45	50	80	2.6	1715.532
5	20	50	55	85	2.8	1847.496
6	25	55	60	90	4.57	3015.377
7	30	60	65	95	2.44	1609.961
8	35	65	70	100	2.51	1656.148

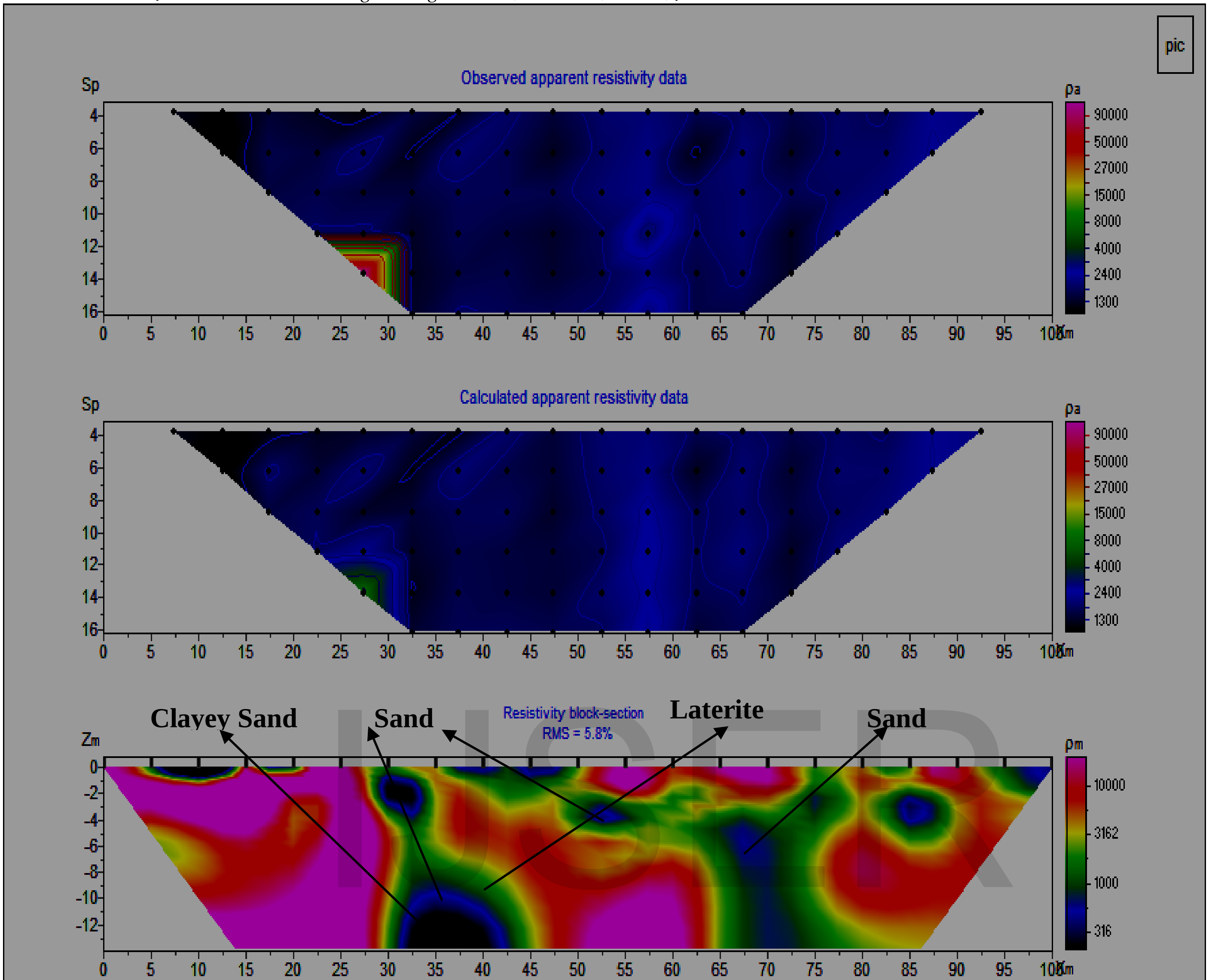
Traverse Line 11, runs S-W. It has four isolated sand bodies with resistivity value of 570Ωm and gravel with high resistivity value of about 8290Ωm encased within medium laterite soil with resistivity value of 2081Ωm. Coarse medium dry sand with resistivity value of 4871Ωm surrounds the gravel. The sand body exists at a depth of about 4.50m with a thickness of about 2.50m and a lateral extent of 3.50m. While the gravel have a depth of about 14.00m, a thickness of about 7.20m and a lateral extent which measures about 10.00m.

Survey Line 18, runs S-E. It has two well defined isolated sand bodies with varying apparent resistivity values. These comprises of a clayey sand body and a non clayey sand body whose resistivities are 200Ωm and 570Ωm respectively, and exists within a lateritic medium with a resistivity value of about 2081Ωm. The clayey sand is bounded by a non-clayey sand body. The clayey sand has a depth and thickness which measures about 14.00m and 3.00m respectively, with a lateral extent measuring about 10.00m. The elongated sand (right) has a measured depth and thickness values of 14.00m and 9.50m respectively. It has a lateral extent of about 3.80m.



Survey Aim: To delineation subsurface lithologies	**Survey Date**: 4/04/2014
Survey Line No./ Length/Direction:11/100m/S-W	**Equipment Used:** Petrozenith Earth Resistivity Meter
Site Description: Near Pipeline Route, off NNPC Road	**Array/Software Used:** Wenner-Schlumberger/Zondres2d
State/Town/ LGA: Edo/Ologbo/Ikpoba Okha	**Begin /End Coordinates:** N 6.083°,E5.659°/N6.082°,E

Fig. 1. Subsurface geologic image of line 11



Survey Aim: To delineation subsurface lithologies	**Survey Date**: 7/04/2014
Survey Line No./ Length/Direction:18/100m/S-E	**Equipment Used:** Petrozenith Earth Resistivity Meter
Site Description: Lonestar Area	**Array/Software Used:** Wenner-Schlumberger/Zondres2d
State/Town/ LGA: Edo/Ologbo/Ikpoba Okha	**Begin /End Coordinates:** N 6.065°,E5.646°/N6.066°,E 5.645°

Fig. 2. Subsurface geologic image of line 18

5 CONCLUSION

In this research study, we have been able to delineate the subsurface lithology as consisting of sand, laterite and gravel. Variations in their resistivities, depths and lateral extents occurred due to the nature of the subsu rock and mode of deposition.

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