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Geophysical Determination of Construction Clay Deposit Using 2-Dimensional Resistivity Imaging In Ologbo Area of Edo State

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Abstract

Geophysical exploration based on a two-dimensional electrical resistivity survey was carried out to determine the presence of construction clay deposits in Ologbo Area of Edo State, Nigeria. Begin and end co-ordinates for line 1 were N6°05.585′, E005°39.686′ and N6°05.541′, E005°39.652′ and N6°03.754′, E005°39.029′ and N6°03.700′, E005°39.054′ for line 2. The survey technique utilized was Wenner-Schlumberger array in the two explored areas to justify the operation of assembling apparent resistivity data. Significantly, clay finds its use in the steel industry where it is used to make refractories. Petrozenith earth resistivity meter, 21 electrodes, 4 cables cases and a GPRS device comprised the field equipment. The data recorded after prospecting with maximum current electrode spacing of 100.0 meters was interpreted using Zondres2D computer program to produce true resistivity models. Geologic interpretation of the survey revealed that clay and clayey soil were present intermingled with pure silt and traces of fine sand deposits. The depths of clay formations were measured at 4 meters and 12 meters for survey line 1 and survey line 2, respectively. Areas of probable clay formations have been identified especially for future exploitation.

Keywords*: 2-D resistivity survey, construction clay, refractories, pseudosection.*

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INTRODUCTION

Clay minerals are layer-typed aluminosilicates, ubiquitous on our planet in geologic deposits, terrestrial weathering environments and marine sediments [1]. Clay minerals precipitated from seawater in near shore depositional environments can similarly influence the geochemical cycles of metals. In engineering settings, clay mineral swelling plays a significant role in petroleum extraction serving as lubricants and as industrial catalyst for synthesis of many organic compounds [2]. Clay is found in three forms: surface clay, shale and fireclay. Most bricks are made from surface mined clays that reside near the surface of the earth and are striped-mined. Shales are clays that have been subjected to high pressures causing them to be hardened [3]. Fireclays are found at deeper formations and have more uniform physical and chemical properties. They can withstand higher temperatures and are used to produce firebricks for high temperature applications such as refractories [4].

Extracted clay contains a variety of minerals. The color varies depending on the amount of iron oxide from a buff, red or salmon color when burned.

GEOLOGY OF THE AREA

The Niger Delta basin is situated in the continental margin of the Gulf of Guinea in Equatorial West Africa, between latitude 3° and 6° N and longitude 5° and 8° E. It ranks among the world’s most prolific petroleum producing tertiary deltas [5].

An upper delta-top lithofacies, the Benin formation consists of massive continental sand and gravel. These deposits are graded downwards into, or overlie unconformably with delta-front lithofacies, the Agbada formation which comprises mostly shore face and channel sand with minor shales in the upper part and an alternation of sand and shale in equal proportion in the lower part [6]. Akata formation occurs deeper in the section.

Ologbo town is located within the Benin formation characterized by loose fresh-water bearing sand with alternating lignite and clay beds downwards [7] (Figure 1).

Ologbo formation is aquiferous in nature due to its very low percentage of shaly layers having a depth of about 2,445 meters with no overpressure.

RESISTIVITY THEORY

Resistivity values were appropriately recorded according to the electrode spacing employed during the survey. A further step was taken to convert these resistivity values into apparent resistivity values of the subsurface formations [8]. The resistivity meter measured a resistance value $R = \frac{v}{I}$, so in practice, the apparent resistivity value was calculated by $\rho_a = RK$, where, K is called the geometric factor relative to the electrode spacing and the array used in the survey [9]. For the Wenner-Schlumberger array employed in this survey, it is assumed that the geometric factor can be calculated as follows (Figure 2).

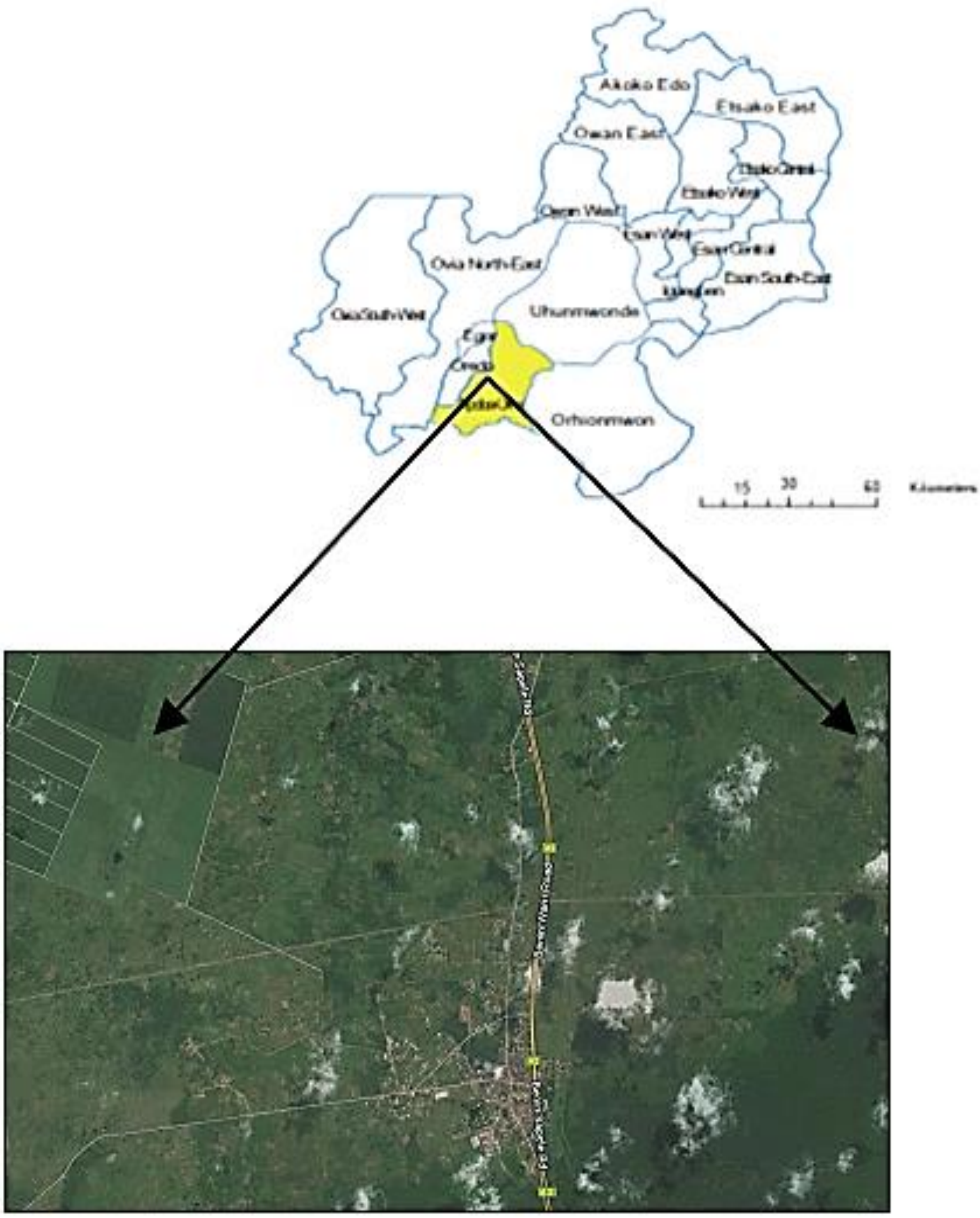


***Fig. 1**: Satellite image of Ologbo area [7].*

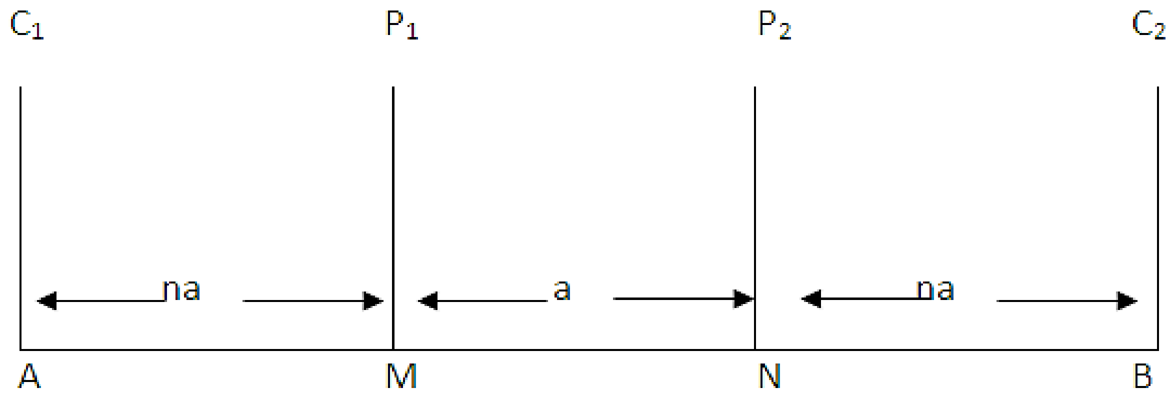


Fig. 2*: Diagram of Wenner-Schlumberger field configuration.*

$$\rho a = R\pi MN[= (\frac{L}{MN})^2 - 0.25]$$

Since $\rho a = RK$

$$K = \pi MN[(\frac{L}{MN})^2 - 0.25]$$

But $L = \frac{AB}{2}$

From the diagram above,
AB = 2na + a

Therefore

$$K = \pi MN\left[(\frac{2na+a}{2} \div \frac{MN}{1})^2 - 0.25\right]$$

From the Diagram,
MN = a

Thus;

$$K = \pi a\left[(\frac{2na+a}{2} \div \frac{a}{1})^2 - 0.25\right]$$
$$K = \pi a\left[(\frac{2na+a}{2a})^2 - 0.25\right]$$
$$K = \pi a\left[(\frac{2n+1}{2})^2 - 0.25\right]$$
$$K = \pi a\left[(\frac{2n+1}{4})^2 - 0.25\right]$$
$$K = \pi a\left[\frac{4n+4n+1}{4} - 0.25\right]$$
$$K = \pi a\left[\frac{4n+4n+1-1}{4}\right]$$
$$K = \pi a\left[\frac{4n+4n}{4}\right]$$
$$K = \pi an[n+1] \qquad (3.1)$$

This geometric factor (K) is multiplied with the resistivity reading **(R)** from the field to obtain the apparent resistivity. The value of **a** represents the 5 meters of the electrode spacing while *n* varies from 1, 2, 3, 4, 5 and 6 as observed in the field survey.

Maximum depth of penetration is given by:
d = 0.217 x L
$d = 0.217 \times (2na + a)$ (3.2)

FIELD ARRAY METHOD

The Wenner-Schlumberger array is a new hybrid between the Wenner and Schlumberger arrays arising out of relatively recent work with electrical imaging surveys [10]. A modified form of this array so that it can be used on a system with the electrodes arranged with a constant spacing is shown above (Figure 2). Note that the 'n' factor for this array is the ratio of the distance between the $C_1 - P_1$ (or $C_2 - P_2$) electrodes to the spacing between the $P_1 - P_2$ potential pair. Note also that the Wenner array is a special case of this array when the 'n' factor is equal to 1.

The Wenner-Schlumberger array has a slightly better horizontal coverage compared with the Wenner array. For the Wenner, each deeper data level has 3 data points less than the previous data level, while for the Wenner-Schlumberger array, there is a loss of two data points with each deeper data level [11]. The data 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. Two locations were investigated in Ologbo Area of Edo State each of 100 m in length. A total of seventy-eight Wenner-Schlumberger soundings were done in each of the areas (Figure 3).

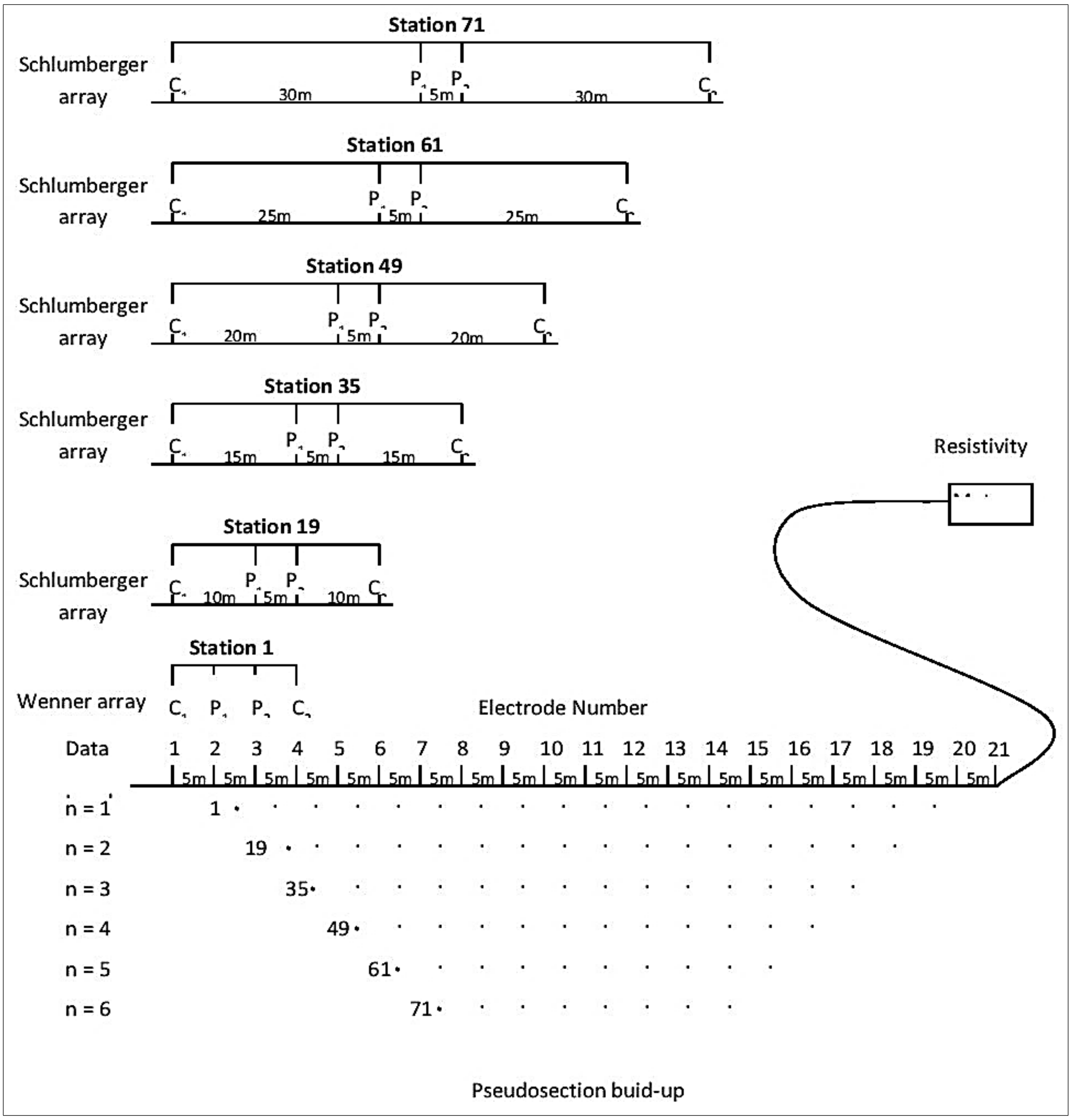


***Fig. 3**: Spread showing electrode spacing [12].*

RESULTS, ANALYSIS AND INTERPRETATION

Resistivity values were appropriately recorded according to the electrode spacing employed during the survey [13]. A further step was taken to convert these resistivity values into apparent resistivity values of the subsurface formations. The resistivity meter measured a resistance value R $=\frac{v}{I}$. So in practice, the apparent resistivity value was calculated by $\rho_a = RK$ where, K is called the geometric factor relative to the electrode spacing and the array used in the survey. The calculated apparent resistivity values (**ℓa**) of each measurement for survey line 1 and survey line 2 are shown in Tables 1 and 2, respectively.

Determination of clay deposit, estimation of its depth of occurrence, its lateral extent and thickness can be easily calculated using the resistivity data acquired in the survey area.

The geo-electric images were interpreted geologically using knowledge of geology of the survey area, borehole log around the survey area, resistivity values of sediments, rocks and minerals available in literatures. Table 3 shows resistivity values of some earth materials (Figure 4).

Table 1: *Resistivity field data for line 1.*

2D ELECTRICAL RESISTIVITY IMAGING FIELD DATA REPORT SHEET						
	ARRAY TYPE	**Wenner-Schlumberger**	**DATE**	**5-04-2014**		
	INSTRUMENT USED	Petrozenith Earth Resistivity Meter	STATE	Edo		
	LOCATION	Imasabor Primary School Football Field	LGA	Ikpoba Okha		
	LINE NUMBER	L1	Town	Ologbo		
	OBSERVER	AISABOKHAE JOSEPH EHIMARE				
	BEGIN COORDINATE/ALTITUDE	N6°05.585′, E005°39.686′/28.7 m				
	END COORDINATE/ALTITUDE	N6°05.541′, E005°39.652′/26.3 m				
	GEOMETRICAL FACTOR: 31.42	ELECTRODES SPACING: 5 m				
S/No	**C1**	**P1**	**P2**	**C2**	**R (Ω)**	**ℓa (Ωm)**
1	0	5	10	15	23.18	728.3156
2	5	10	15	20	28.1	882.902
3	10	15	20	25	38.88	1221.61
4	15	20	25	30	44.85	1409.187
5	20	25	30	35	44.16	1387.507
6	25	30	35	40	60.32	1895.254
7	30	35	40	45	55.81	1753.55
8	35	40	45	50	50.77	1595.193
9	40	45	50	55	48.24	1515.701
10	45	50	55	60	39.37	1237.005
11	50	55	60	65	42.69	1341.32
12	55	60	65	70	31.93	1003.241
13	60	65	70	75	44	1382.48
14	65	70	75	80	32.16	1010.467
15	70	75	80	85	31.53	990.6726
16	75	80	85	90	52.33	1644.209
17	80	85	90	95	5740	180350.8
18	85	90	95	100	20.69	650.0798
	GEOMETRICAL FACTOR: 94.26	**ELECTRODES SPACING: 10 m**				
1	0	10	15	25	10.86	1023.664
2	5	15	20	30	16.56	1560.946
3	10	20	25	35	15.38	1449.719
4	15	25	30	40	12.99	1224.437
5	20	30	35	45	14.21	1339.435
6	25	35	40	50	21.69	2044.499
7	30	40	45	55	17.82	1679.713
8	35	45	50	60	14.32	1349.803
9	40	50	55	65	14.28	1346.033
10	45	55	60	70	16.84	1587.338
11	50	60	65	75	12.38	1166.939
12	55	65	70	80	14.08	1327.181
13	60	70	75	85	12.44	1172.594
14	65	75	80	90	11.3	1065.138
15	70	80	85	95	14.74	1389.392
16	75	85	90	100	10.07	949.1982

	GEOMETRICAL FACTOR: 188.52	**ELECTRODES SPACING: 15 m**				
1	0	15	20	35	10.28	1937.986
2	5	20	25	40	8.41	1585.453
3	10	25	30	45	6.81	1283.821
4	15	30	35	50	8	1508.16
5	20	35	40	55	9.31	1755.121
6	25	40	45	60	8.34	1572.257
7	30	45	50	65	9.03	1702.336
8	35	50	55	70	2.9	546.708
9	40	55	60	75	7.36	1387.507
10	45	60	65	80	7.43	1400.704
11	50	65	70	85	6.12	1153.742
12	55	70	75	90	6.88	1297.018
13	60	75	80	95	6.11	1151.857
14	65	80	85	100	9.07	1709.876
	GEOMETRICAL FACTOR: 314.2	**ELECTRODES SPACING: 20 m**				
1	0	20	25	45	5.78	1816.076
2	5	25	30	50	4.8	1508.16
3	10	30	35	55	5.27	1655.834
4	15	35	40	60	6.44	2023.448
5	20	40	45	65	4.6	1445.32
6	25	45	50	70	7.2	2262.24
7	30	50	55	75	5.04	1583.568
8	35	55	60	80	5.11	1605.562
9	40	60	65	85	3.85	1209.67
10	45	65	70	90	6.64	2086.288
11	50	70	75	95	4.35	1366.77
12	55	75	80	100	4.21	1322.782
	GEOMETRICAL FACTOR: 471.3	**ELECTRODES SPACING 25 m**				
1	0	25	30	55	3.4	1602.42
2	5	30	35	60	3.96	1866.348
3	10	35	40	65	3.65	1720.245
4	15	40	45	70	3.59	1691.967
5	20	45	50	75	3.3	1555.29
6	25	50	55	80	3.62	1706.106
7	30	55	60	85	3.43	1616.559
8	35	60	65	90	2.68	1263.084
9	40	65	70	95	3.32	1564.716
10	45	70	75	100	2.94	1385.622
	GEOMETRICAL FACTOR: 659.82	**ELECTRODES SPACING: 30 m**				
1	0	30	35	65	3.24	2137.817
2	5	35	40	70	3.42	2256.584
3	10	40	45	75	3.01	1986.058
4	15	45	50	80	2.54	1675.943
5	20	50	55	85	2.78	1834.3
6	25	55	60	90	2.59	1708.934
7	30	60	65	95	1.89	1247.06
8	35	65	70	100	2.9	1913.478

Table 2: *Resistivity field data for line 2.*

2D ELECTRICAL RESISTIVITY IMAGING FIELD DATA REPORT SHEET						
	ARRAY TYPE	**Wenner-Schlumberger**	**DATE**	**8-04-2014**		
	INSTRUMENT USED	Petrozenith Earth Resistivity Meter	STATE	Edo		
	LOCATION	Auntie Julie Secondary School Football Field	LGA	Ikpoba Okha		
	LINE NUMBER	L2	Town	Ologbo		
	OBSERVER	AISABOKHAE JOSEPH EHIMARE				
	BEGIN COORDINATE/ALTITUDE	N6°03.754′, E005°39.029′/25.6 m				
	END COORDINATE/ALTITUDE	N6°03.700′, E005°39.054′/23.0 m				
	GEOMETRICAL FACTOR: 31.42	ELECTRODES SPACING: 5 m				
S/No	**C1**	**P1**	**P2**	**C2**	**R (Ω)**	**ƪa (Ωm)**
1	0	5	10	15	50.3	1580.426
2	5	10	15	20	95.98	3015.692
3	10	15	20	25	64.36	2022.191
4	15	20	25	30	96.83	3042.399
5	20	25	30	35	61.51	1932.644
6	25	30	35	40	67.51	2121.164
7	30	35	40	45	49.72	1562.202
8	35	40	45	50	55.87	1755.435
9	40	45	50	55	66.68	2095.086
10	45	50	55	60	58.58	1840.584
11	50	55	60	65	58.77	1846.553
12	55	60	65	70	49.85	1566.287
13	60	65	70	75	50.66	1591.737
14	65	70	75	80	41.79	1313.042
15	70	75	80	85	40.86	1283.821
16	75	80	85	90	42.42	1332.836
17	80	85	90	95	29.66	931.9172
18	85	90	95	100	39.82	1251.144
	GEOMETRICAL FACTOR: 94.26	**ELECTRODES SPACING: 10 m**				
1	0	10	15	25	21.61	2036.959
2	5	15	20	30	21.14	1992.656
3	10	20	25	35	23.07	2174.578
4	15	25	30	40	18.29	1724.015
5	20	30	35	45	22.96	2164.21
6	25	35	40	50	16.58	1562.831
7	30	40	45	55	19.25	1814.505
8	35	45	50	60	21.76	2051.098
9	40	50	55	65	19.79	1865.405
10	45	55	60	70	14.23	1341.32
11	50	60	65	75	15.58	1468.571
12	55	65	70	80	13.32	1255.543
13	60	70	75	85	15.43	1454.432
14	65	75	80	90	11.95	1126.407
15	70	80	85	95	15.81	1490.251
16	75	85	90	100	8.76	825.7176

	GEOMETRICAL FACTOR: 188.52	**ELECTRODES SPACING: 15 m**				
1	0	15	20	35	8.84	1666.517
2	5	20	25	40	12.6	2375.352
3	10	25	30	45	8.57	1615.616
4	15	30	35	50	9.73	1834.3
5	20	35	40	55	4.05	763.506
6	25	40	45	60	274.47	51743.08
7	30	45	50	65	9.63	1815.448
8	35	50	55	70	7.91	1491.193
9	40	55	60	75	7.2	1357.344
10	45	60	65	80	6.73	1268.74
11	50	65	70	85	7	1319.64
12	55	70	75	90	6.36	1198.987
13	60	75	80	95	4.49	846.4548
14	65	80	85	100	6.31	1189.561
	GEOMETRICAL FACTOR: 314.2	**ELECTRODES SPACING: 20 m**				
1	0	20	25	45	6.38	2004.596
2	5	25	30	50	5.43	1706.106
3	10	30	35	55	4	1256.8
4	15	35	40	60	3.94	1237.948
5	20	40	45	65	3.76	1181.392
6	25	45	50	70	4.95	1555.29
7	30	50	55	75	4.96	1558.432
8	35	55	60	80	3.6	1131.12
9	40	60	65	85	3.5	1099.7
10	45	65	70	90	3.57	1121.694
11	50	70	75	95	3.99	1253.658
12	55	75	80	100	2.07	650.394
	GEOMETRICAL FACTOR: 471.3	**ELECTRODES SPACING 25 m**				
1	0	25	30	55	2.7	1272.51
2	5	30	35	60	3.05	1437.465
3	10	35	40	65	2.82	1329.066
4	15	40	45	70	2.34	1102.842
5	20	45	50	75	1.99	937.887
6	25	50	55	80	2.5	1178.25
7	30	55	60	85	2.12	999.156
8	35	60	65	90	2.46	1159.398
9	40	65	70	95	2.16	1018.008
10	45	70	75	100	1.89	890.757
	GEOMETRICAL FACTOR: 659.82	**ELECTRODES SPACING: 30 m**				
1	0	30	35	65	1.68	1108.498
2	5	35	40	70	1.36	897.3552
3	10	40	45	75	1.33	877.5606
4	15	45	50	80	1.54	1016.123
5	20	50	55	85	1.54	1016.123
6	25	55	60	90	1.2	791.784
7	30	60	65	95	1.21	798.3822
8	35	65	70	100	1.33	877.5606

***Table 3**: Resistivity of some common rocks [14].*

ROCK/MATERIAL	RESISTIVITY (Ωm)
Basalt	20–20000
Wet Clay	10–200
Copper	Approx 2000000000
Gabbros	1000–500000
Galena	0.001–100
Gold	Approx 240000000
Igneous rock	100–1000000
Iron	Approx 0.0000001
Kaolinite	10–100
Limestone (porous)	100–10000
Magnetite	0.01–1000
Metamorphic rock	50-100000000
Sandstone	200-10000
Sea water	Approx 0.15
Smectite	1–100
Top soil	5–1000
Zinc blende	1.5–12000

The resistivity value of clay varies from about 5.0 ohm.meter to 225 ohm.meter [15].

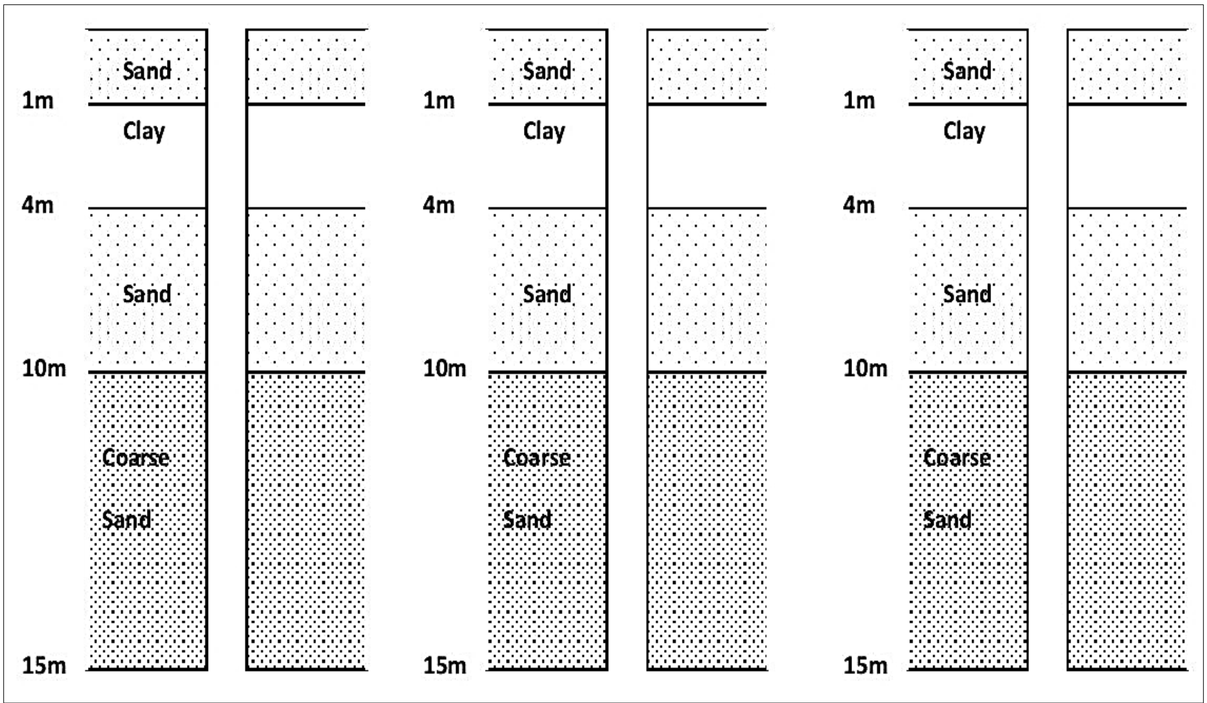
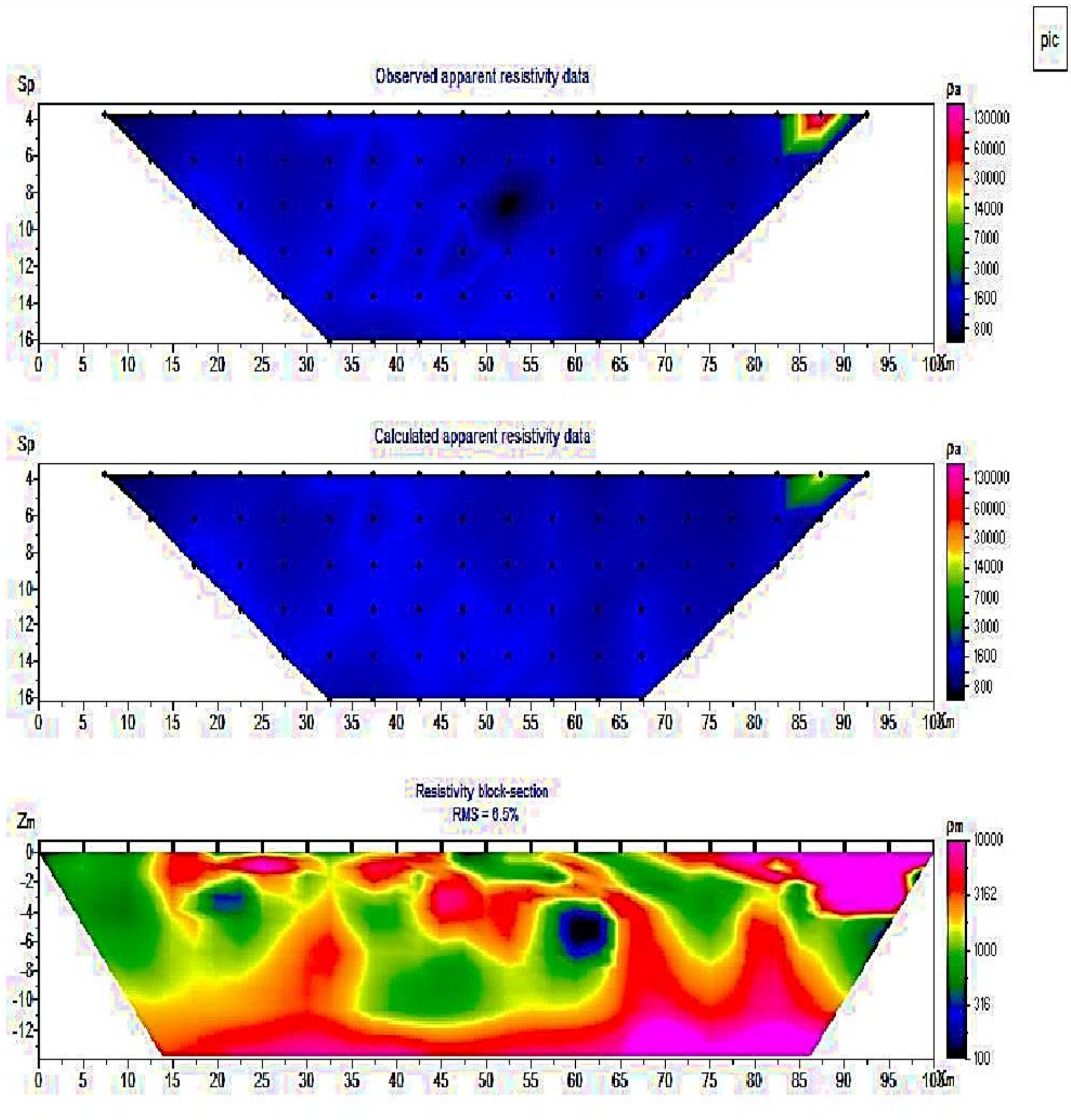


***Fig. 4**: Borehole log around project area.*
Source: Description of the Existing Environment - Baseline Data. Available from https://www3.opic.gov/environment/eia/greenfields/Chapter%205%20-%20Description%20of%20the%20Existing%20Environment%20-%20Baseline%20Data.pdf [Accessed on June 2016].

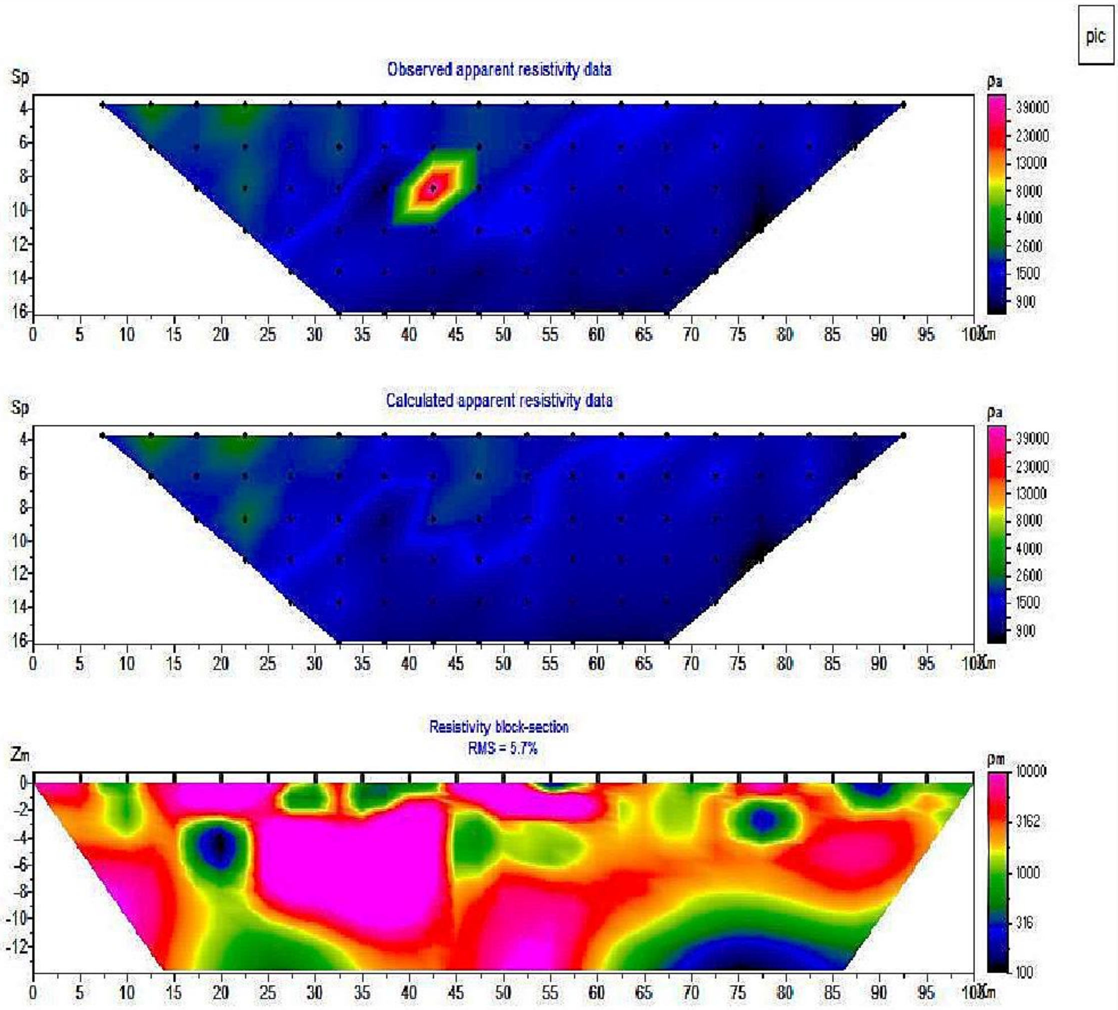
The resistivity images for survey line 1 and survey line 2 are shown in Figures 5 and 6, respectively.



Survey Aim: DETERMINATION OF CLAY DEPOSIT	Survey Date: 5/04/2014
Survey Line No./ Length/Direction: L1/100m/S-E	Equipment Used: Petrozenith Earth Resistivity Meter
Site Description: Imasabor Primary School Premises	Array/Software Used: Wenner-Schlumberger/Zondres2d
State/Town/ LGA: Edo/Ologbo/Ikpoba Okha	Begin /End Coordinates: N 6.093°,E5.661°/N6.092°,E5.661°

Fig. 5*: Resistivity imaging for survey line 1.*

Survey Line 1 has a rounded isolated low resistivity deposit of between 100 Ωm and 300 Ωm within a low resistivity lateritic environment. The depth to the top and bottom of the isolated rock is 4.0 m and 6.5 m respectively with 2.5 m in thickness. This rock body occurs between 57.0 m to 64.5 m in horizontal distance, which gives lateral extent of 7.5 m. Survey Line 2 has a deep-seated isolated low resistivity deposit of between 100 Ωm and 300 Ωm below a low resistivity lateritic environment. The depth to the top of the deep-seated isolated rock is 11.0 m with its thickness and depth to bottom largely unknown due to its occurrence beyond the capture of the survey. This rock body occurs between 68.0 m and 85.0 m in horizontal distance, which gives lateral extent of 17.0 m.



Survey Aim: DETERMINATION OF CLAY DEPOSIT	**Survey Date**: 8/04/2014
Survey Line No./ Length/Direction: L2/100m/S-E	**Equipment Used:** Petrozenith Earth Resistivity Meter
Site Description: Auntie Julie Secondary School Premises	**Array/Software Used:** Wenner-Schlumberger/Zondres2d
State/Town/ LGA: Edo/Ologbo/Ikpoba Okha	**Begin/End Coordinates:** N 6.063°,E5.651°/N6.062°,E5.652°

***Fig. 6**: Resistivity imaging for survey line 2.*

INTERPRETATION

The data provided the model for the different layer thickness and resistivity values, which were then integrated with a standard table of electrical resistivity values.

It is pertinent to state in geophysical terms that clay exists in both stations of the area. In survey line 1, clay exists sparsely at depth of about 4 meters with thickness of about 2.5 meters at about 60-meter mark from the base of the survey line. This portion is marked with low resistivity corresponding to values similar to clay formations. In survey line 2, clay exists at depth of about 12 meters with lateral extent from about 70 to 85 meters from the base of the survey line.

CONCLUSION

In conclusion, the resistivity surveys carried out in order to determine clay formation depth and thickness in Ologbo town of Edo State, using Wenner-Schlumberger array showed two resistivity images.

The images showed the presence of gravel, sandstone and clay with the clay deposit occurring at about 4 meters and about 12 meters for survey line 1 and survey line 2, respectively.

The resistivity data paints a picture of an area predominantly sand with sparse deposits of clay having resistivity values ranging from about 20 Ωm to 1000 Ωm.

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