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GEOPHYSICAL STUDY OF BRINE DEPOSITS USING ELECTRICAL RESISTIVITY TECHNIQUE IN AWE, AWE LOCAL GOVERNMENT AREA OF NASARAWA STATE IN NIGERIA

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ABSTRACT
Forty-five (45) Vertical electrical sounding (VES) were carried out in Awe brine field Awe LGA, Nasarawa State, with the aim of providing valuable information on the geology of the area, and delineating the brine deposits and their subsurface configuration. The VES result(curves) obtained showed a dominant trend of decreasing resistivity with depth which indicates increase in salinity with depth. The result also revealed four distinct geoelectric layers. The first layer which constitutes the top soil showed resistivity values ranging between 4.2 Ωm and 282.5 Ωm; and the thickness ranging from 0.276 m to 19m; the second layer has resistivity values which vary between 11 Ωm and 650Ωm with the thickness ranging from 0.502m to 22.47m. The third geoelectric layer is interpreted as the brine zone. The resistivity of this layer is generally low at most locations. Its values vary from 0.12Ωm to 97Ωm with thickness ranges between 0.210 m to 21.56m. The low resistivity of the layer confirmed the presence of brine deposit within it. The geoelectric section revealed the occurrence of brine deposit between the depth interval of 4 and 38m in the study area. The fourth layer show resistivity values which vary between 15 Ωm and 34568 Ωm and thickness between 5.34 m to 44.78m. The layer revealed very high resistivity in most VES locations however, some points showed low resistivity which may be because of infiltration of brine from the upper layer.

Key words: *Brine Field, Vertical Electrical Sounding (VES), Geoelectric section, Resistivity, Delineation*

INTRODUCTION

Brine is saline or salty water, particularly a highly concentrated solution of common salt (sodium chloride). Naturally, brine occurs as underground salt lakes formed when water accumulates in a topographic depression. The occurrence of brine-springs in the Benue Valley has attracted considerable attention (Obaje, 2009). Awe brine field in Awe LGA area of Nasarawa State is one of the brine fields located within Benue brine field. According to Offodile, (1992), the salt deposits in the area occur in form of underground brine coming from the western flanks of Keana anticline. It appears to come from the interbedded shale of fractured sandstone of Awe formation.

The economic importance of brine in Nigeria being a country that imports more than ninety percent (90%) of its common salt and allied chemicals cannot be over-emphasized. Hence, the need to carry out a geophysical study to ascertain the economic viability of the brine field.

This study, however, intends to use Electrical resistivity prospecting technique (vertical electrical sounding) with a view to delineate the depth, geometry, and distribution of salt deposit within the study area and to ascertain the nature of subsurface geological Formations. The method has been chosen for this work because it had been proven to be a quick and effective tool for geoelectrical mapping and characterization of mineral deposits. For instance; Adeoti *et al.*, (2010), carried out a geophysical investigation of saline water intrusion into freshwater aquifer using vertical electrical sounding. There result revealed that the method is effective for delineating saline water intrusion. Saad(2006), investigated phosphate deposits in OuladAbdoun, Morocco using electrical resistivity. Badmus *et al.,* (2009), also carried out geoelectric mapping and characterization of limestone deposits of Ewekoro Formation, southwestern Nigeria. The method can be used to determine the nature, geometry and the thickness of the geological formation (Telford *et al.*, 1977 and Oteri, 1977).

Awe Brine field in Awe LGA area of Nasarawa State, is one of the brine fields located within the Benue Brine field in the Benue Trough. The area lies between latitude 8° 05′ N and 8° 07′ N, and longitudes 9° 05′ E and 9° 10′ E and it covers the area of approximately 12km^2 (Fig. 2). It is situated within the tropical sub-humid climatic belt and is characterized by Guinea savannah vegetation type with daily temperature ranging from 26^{o}C to 32^{o}C, a mean rainfall of 1248 mm and relative humidity of 60% to 80% (Binbol, 2006; NiMet, 2017). The topography is gentle and the elevation range from 100m to 145m.

According to (Obaje *et al.,* 2006 and Offodile, 2002), Awe Brine field is underlain by the following geological formations; Ezeaku, Keana, saliferous Awe and Asu River formations. The sedimentary formations listed above are underlined by the Basement complex of Precambrian age. The detailed stratigraphy of the area is shown in Figure 1.

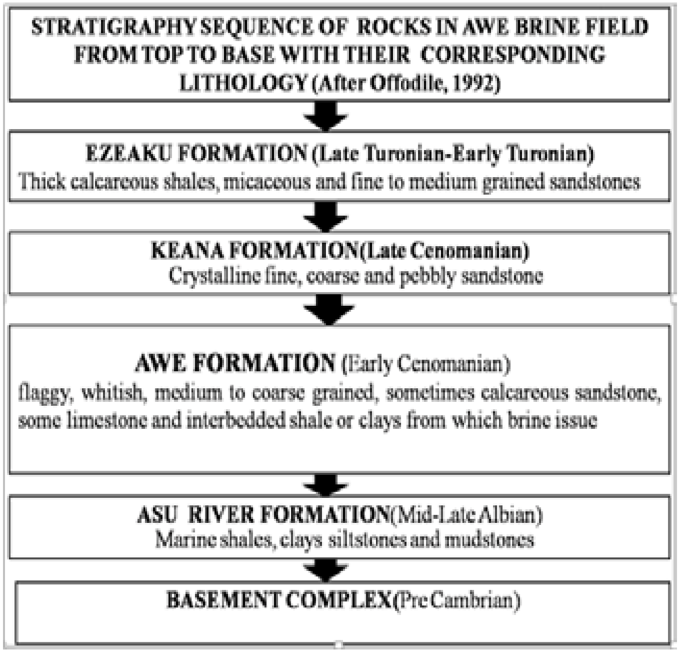


Figure1: Stratigraphy of Rocks in Awe Brine Field

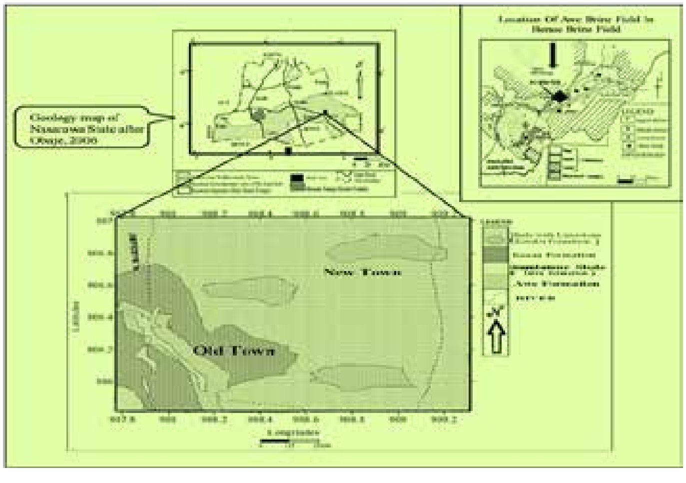


Figure 2: GeologicalMap of the Study Area (after Offodile, 1983)

MATERIALS AND METHODS

The geophysical survey to study the distribution of brine deposit in Awe brine field was conducted using electrical resistivity method. SAS 4000 resistivity meter with electrode spacing ranging between 1 to 80m was used for the data acquisition. During the field work, the VES stations were established along some selected streets within the study area. These streets were used as profiles on which VES data were collected. The profiles and VES station are shown in figure 3. Forty-five VES were conducted along four profiles, and they are: Profile 1 (VES 7, 8, 9,10,11,12, 13,15,18, 20,21, 22, 23, 24, 25, 26, 27, 28, 33, 34, 44, and 45); Profile 2 (VES 2, 3, 14, 17, 29, 30, 31, 32, 36,and 37); profile 3 (VES 1, 5,6, 38, 39, 40, 41,42, and 43): and 4(VES 4, 16, 19, and 35).

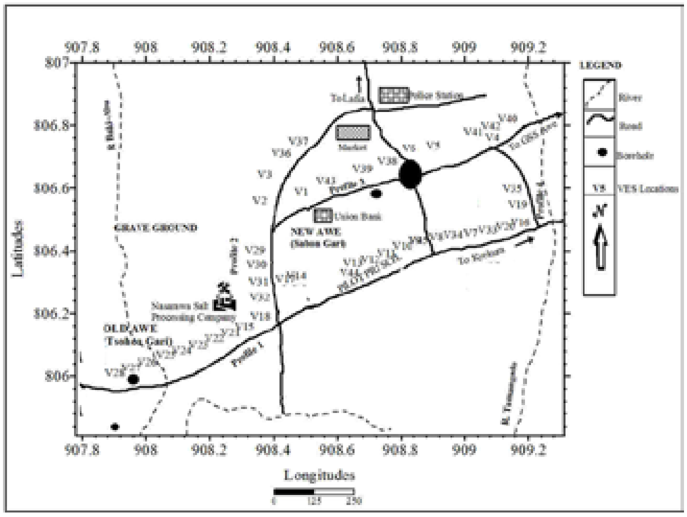


Fig. 3: A Data Acquisition Map Showing VES Location

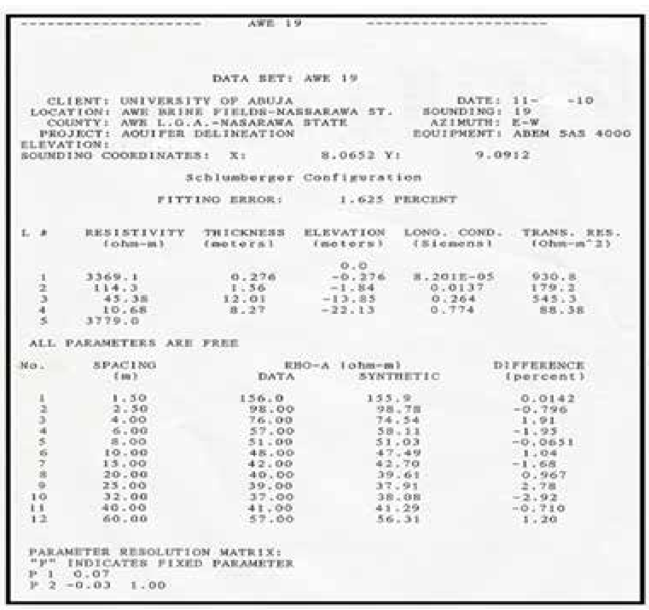
RESULTS AND DISCUSSION

The sets of VES data collected at each location were interpreted using computer (1-D inversion) program modeling which makes use of the interactive program (Offix). The curves were interpreted with a minimum number of layers that are deemed necessary. Most of the interpreted results revealed the presence of 4 geoelectric layers, while only a few revealed the presence of 5 or 6 geoelectric layers. Some typical VES curves of the area are shown in figure 4a and 4b below. The inversion of the interpreted field resistivity data was carried out with the aim of delineating the subsurface geologic sequence and determines their geoelectrical parameters (layer thicknesses and resistivities).

Forty-five (45) VES stations were established across Awe brine field in Awe LGA, Nasarawa state. The interpretation of the result shows that all the forty-five depth soundings curves are characterized by a steep descent from the dry unsaturated top soil to the saltwater saturated sediment. This decrease in electrical resistivity could be attributed to increasing in porosity, fluid content, possibly conductivity arising from saline water intrusion from the nearby brine bearing formation. Since porosity is the major control of the resistivity of rocks (Kearey *et al.,* 2002). Computer modeling for some selected VES stations are shown in Fig. 4a and 4b below. The shape of the curves indicates alternation of saline and freshwater horizons. The interpreted resistivity depth sounding data in Awe brine field are presented as geoelectric section, Isopach map, and resistivity contour maps. The maps were produced using computer software, "Surfer". From the analysis of the result of the study, major top fresh, brine and underlying layers were delineated.

Contour Maps

Contour mapping is one of the techniques that can be used for interpretation of resistivity data. Brine distribution of the study area was contoured using computer software, "Suffer"



AWE 19

DATA SET: AWE 19

CLIENT: UNIVERSITY OF ABUJA — DATE: 11- -10
LOCATION: AWE BRINE FIELDS-NASSARAWA ST. — SOUNDING: 19
COUNTY: AWE L.G.A.-NASARAWA STATE — AZIMUTH: E-W
PROJECT: AQUIFER DELINEATION — EQUIPMENT: ABEM SAS 4000
ELEVATION:
SOUNDING COORDINATES: X: 8.0652 Y: 9.0912

Schlumberger Configuration

FITTING ERROR: 1.625 PERCENT

L. #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			0.0		
1	3369.1	0.276	-0.276	8.201E-05	930.8
2	114.3	1.56	-1.84	0.0137	179.2
3	45.38	12.01	-13.85	0.264	545.3
4	10.68	8.27	-22.13	0.774	88.38
5	3779.0				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	156.0	155.9	0.0142
2	2.50	98.00	98.78	-0.796
3	4.00	76.00	74.54	1.91
4	6.00	57.00	58.11	-1.93
5	8.00	51.00	51.03	-0.0651
6	10.00	48.00	47.49	1.04
7	15.00	42.00	42.70	-1.68
8	20.00	40.00	39.61	0.967
9	25.00	39.00	37.91	2.78
10	32.00	37.00	38.08	-2.92
11	40.00	41.00	41.29	-0.710
12	60.00	57.00	56.31	1.20

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER
P 1 0.07
P 2 -0.03 1.00

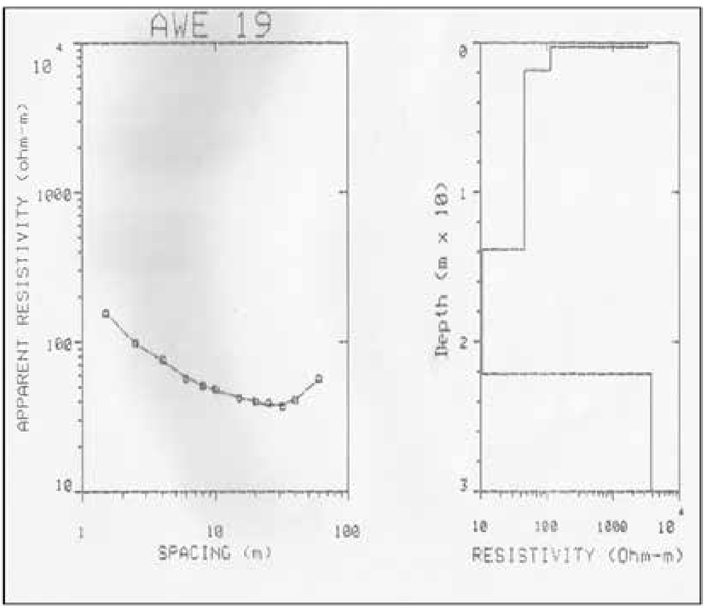
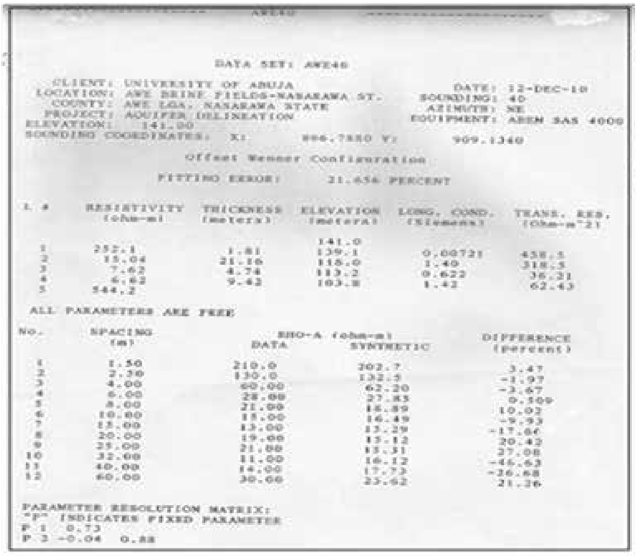


Figure 4a: A typical interpreted 1D resistivity data of VES 19



DATA SET: AWE40

CLIENT: UNIVERSITY OF ABUJA   DATE: 12-DEC-10
LOCATION: AWE BRINE FIELDS-NASARAWA ST.   SOUNDING: 40
COUNTY: AWE LGA, NASARAWA STATE   AZIMUTH: NE
PROJECT: AQUIFER DELINEATION   EQUIPMENT: ABEM SAS 4000
ELEVATION: 141.00
SOUNDING COORDINATES: X: 806.7550 Y: 909.1340

Offset Wenner Configuration

FITTING ERROR: 21.656 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)	ELEVATION (meters)	LONG. COND. (Siemens)	TRANS. RES. (Ohm-m^2)
			141.0		
1	252.1	1.81	139.1	0.00721	458.5
2	15.04	21.16	118.0	1.40	318.5
3	7.62	4.74	113.2	0.622	36.21
4	6.62	9.43	103.8	1.42	62.43
5	544.2				

ALL PARAMETERS ARE FREE

No.	SPACING (m)	RHO-A (ohm-m) DATA	SYNTHETIC	DIFFERENCE (percent)
1	1.50	210.0	202.7	3.47
2	2.30	130.0	132.5	-1.97
3	4.00	60.00	62.20	-3.67
4	6.00	28.00	27.85	0.509
5	8.00	21.00	18.89	10.03
6	10.00	15.00	16.49	-9.93
7	15.00	13.00	13.29	-17.66
8	20.00	19.00	15.12	20.42
9	25.00	21.00	15.31	27.08
10	32.00	11.00	16.12	-46.63
11	40.00	14.00	17.73	-26.68
12	60.00	30.00	23.62	21.26

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER
P 1 0.73
P 2 -0.04 0.88

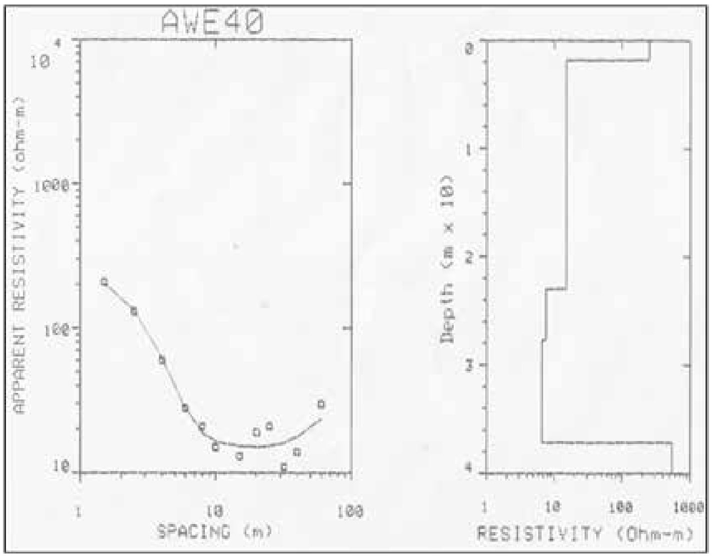


Figure 4b: A typical interpreted 1D resistivity data of VES 40

The Upper Layer

This layer forms the surface material overlying Awe brine field. Fig 5a and b are the contour maps of surface material overlying the brine layer. The layer showed clearly the depth of the brine across the area. The resistivity values of this layer range between 4280Ωm on VES 14 to 14Ωm on VES 3. The high resistivity values of the layer may be due to the dried nature of the superficial deposits and high compaction because of overburden weight. The resistivity contour map indicates high resistivity around South-western to southern part while east to east-western portion was overlain by materials of average resistivity. The analyses of isopach (iso-thickness) map showed that the layer is relatively thin with the thickness ranging from 0.276m on VES 19 to 2.87m on VES 13. Since overburden thickness composed of all materials above the brine deposited bed, it shows that brine deposit appears at various depths along the study area. However, correlating the resistivity with the geology of the area, it can be suspected that the layer is clayey sand Ezeaku formation, which is the youngest rock formation in the area.

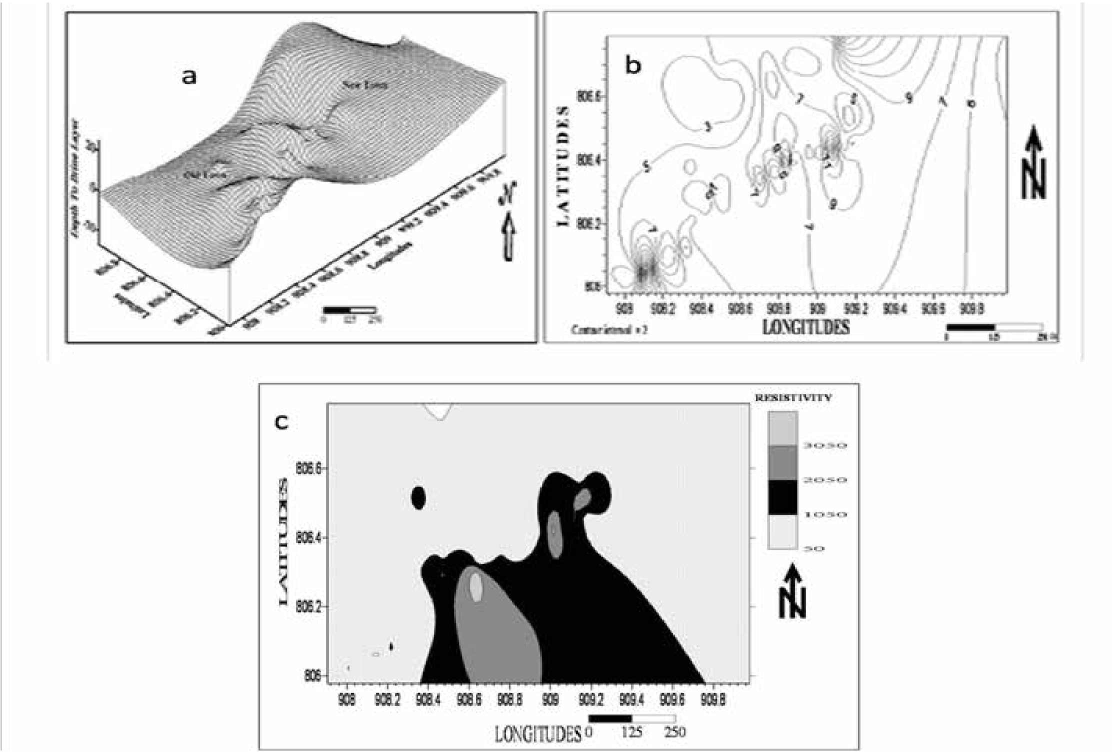
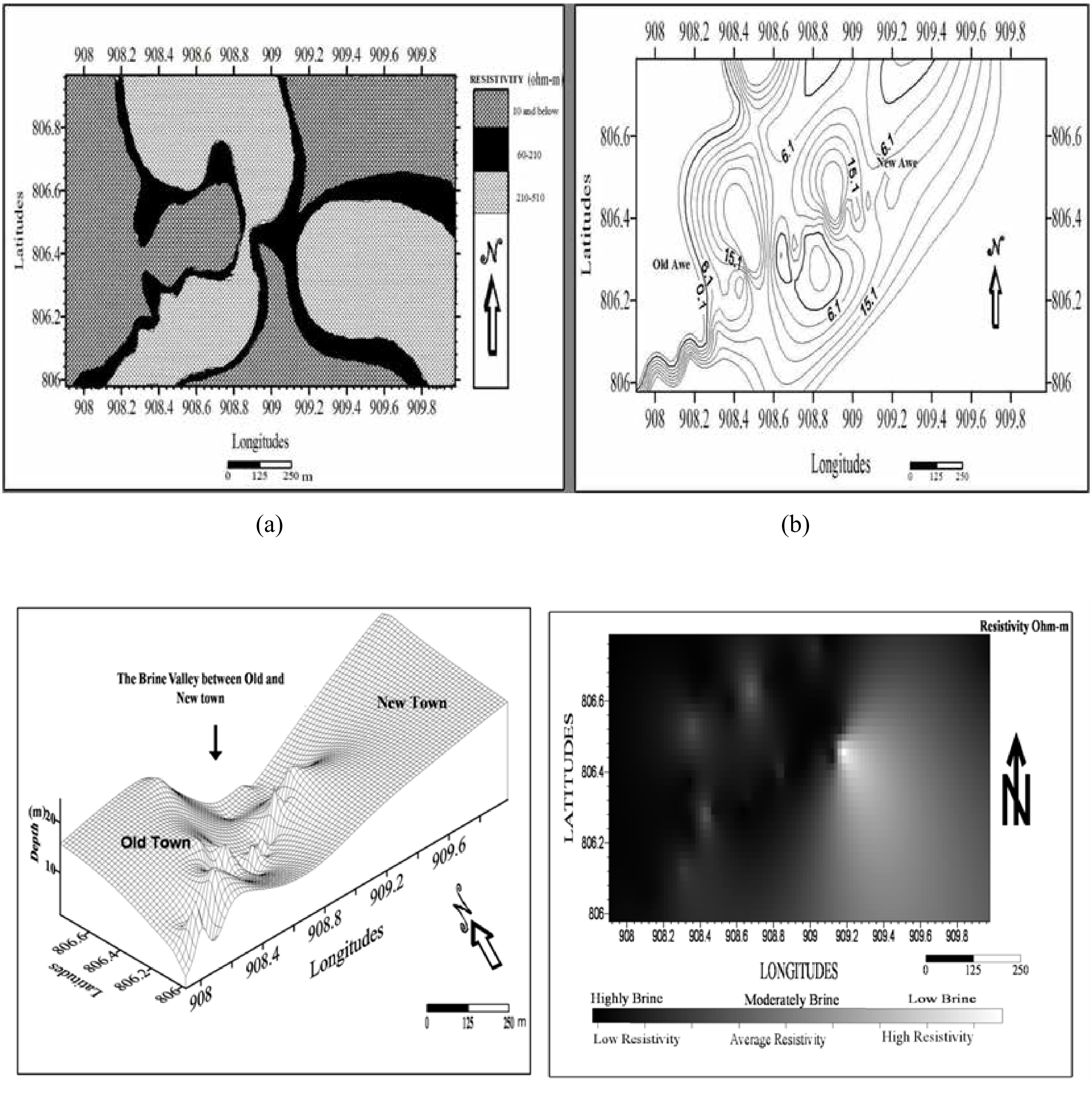


Figure 5: (a) Thickness of The First Layer (b) First LayerIsopach(Isothickness) Map
(c) Isoresistivity Zoning map of the upper layer

The Middle (Brine) Layer

The resistivity values interpreted from this layer range from 674Ωm on VES 41 to 0.12Ωm on VES 5, which indicates that the resistivity values vary greatly from one location to another. This variation can be clearly distinguished on the resistivity contour map (Figure 6a). The dominant part of this layer is overlain by the geological formation of low resistivity, however, small portions around the west and southern part of the study area showed high resistivity values. The low resistivity of the layer is attributed to the effect of strong brine within the layer. Based on the resistivity values, the layer can be inferred to be the saline sand of Awe Sedimentary Formation. The thickness of the layer ranges from 0.210 on VES 44 to 21.56m on VES 9. The 3-Dimensional representation of the layer is shown in Figure (8b). It can be observed that in Figure (8a), there is depression (valley) which formed the brine pond in between old town and new town.



(a) (b)

(c) (d)

Figure 6: (a) Resistivity Zoning Map of Brine layer (b) Third LayerIsopach (Isothickness) Map
(c) Thickness of Brine Layer (d) A map showing distribution of Brine across the area

The Lower Layer

The analysis of resistivity zoning and isopach maps (Fig. 6a and b) of this layer was carried out with the view of gaining information about the lateral variations in the apparent resistivity and thickness of the layer. It is evident that the resistivity of the layer varies from 34568Ωm on VES 2 to 15Ωm on VES 35. The iso-resistivity contour map of the layer (Fig. 7a) Showed that the rock materials that occupy the north and southern through the central part of the study area have significantly low resistivity values compare to the east and western portion which revealed high resistivity value. The low resistivity shown by some locations is an indication of saline water intrusion into the layer from overlying formation (brine layer). Also, the isopach map (Fig. 7b) indicates that the thickness of this layer varies from 44.78m to 5.34m on VES 33 and 45 respectively.

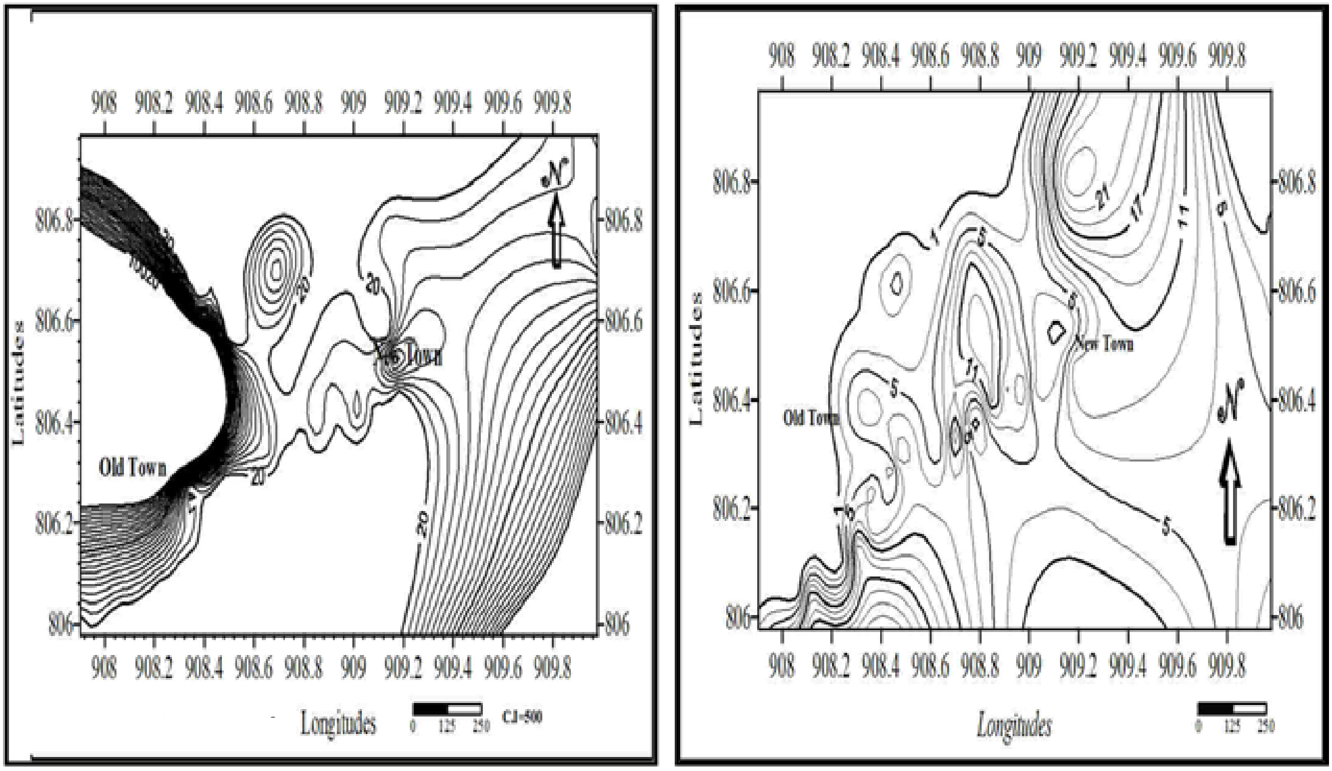


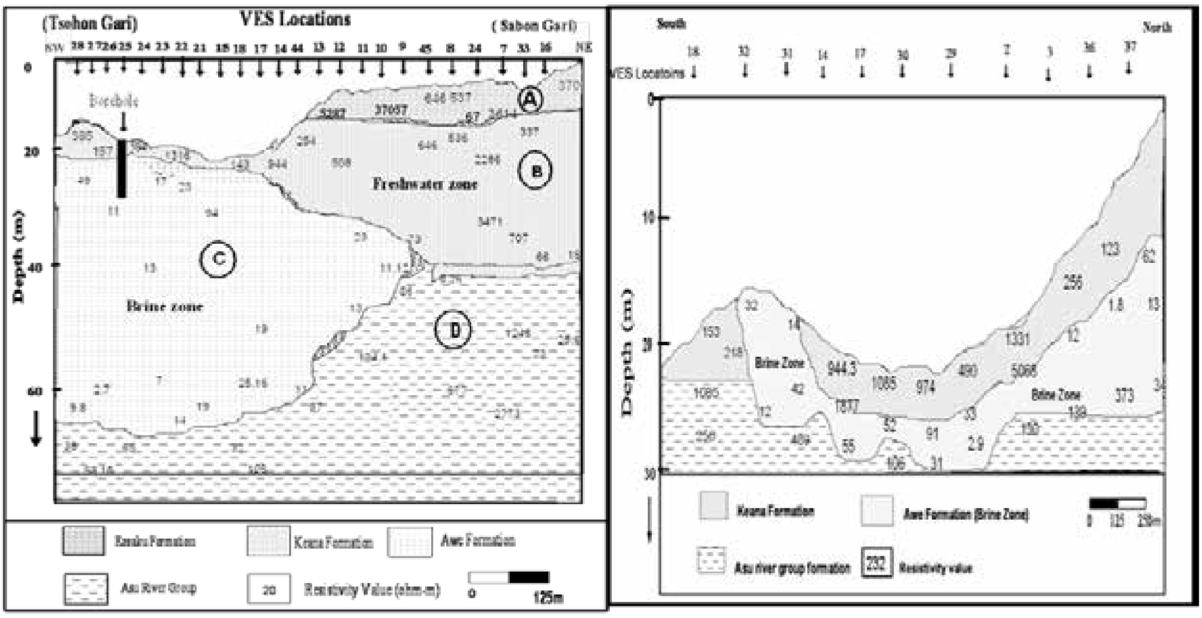
Figure 7: (a) Third Layer Resistivity Contour Map (b) Third LayerIsopach(Isothickness) Map

Geoelectric Section

The geoelectric-sections along two major surveyed profiles were constructed. The first and second profiles run along southwest-northeast and north-south directions respectively. The two geoelectric sections revealed to a large extent a good quantity of brine deposit, which is of economic importance in mining and industrial purposes.

Twenty-two VES points are situated on the first geoelectric profile (VES 7, 8, 9,10,11,12, 13,15,18, 20, 21, 22, 23, 24, 25, 26, 27, 28, 33, 34, 44, and 45). The sections (Fig.8a) revealed the presence of three major distinct layers. The first and second layers under this section form the overburden. The materials within the layer revealed a very high resistivity values ranges from 67 Ωm and 3747 Ωm and the thickness which varies from 1.13 m to 23.47m. The high resistivity can be attributed to low brine composition, high compaction and dry nature of materials within the layer. The third layer delineated under this profile is interpreted as brine layer. It has resistivity values that vary from 0.14 Ωm to 97Ωm and thickness which ranges between 6 m to 37m. The low resistivity values recorded from this layer is an indication of brine deposit.

The second geoelectric section (Fig. 8b) runs across the second survey profile. Nine VES were established along this profile (VES 2, 3, 14, 17, 29, 30, 31, 32, 36, and 37). Three subsurface layers were delineated under this profile. The first layer constitutes the topsoil and its resistivity values range between 123Ωm and 5068Ωm. The thickness of the layer varies between 0.4m to 10.0m. The high resistivity value of this layer confirmed that the layer is composed of saline free material. The second layer under this section revealed a resistivity value that ranges from 2.9Ωm to 91Ωm and its thickness varies between 0.14 m to 5m. Due to low resistivities of the layer, it is delineated as brine horizon. The third layer delineated under this section showed high resistivity values as occurred to the first geoelectric section. Its resistivity and thickness vary between 106 Ωm and 1005Ωm and 5.6 m to 17m respectively. Though in some locations as can be seen from figure 8b, the layer revealed low resistivity value. The geoelectric sections showed a brine concentration around south-western to the central part of the area. The thickness of brine layer decreases toward the central part of the area until it disappears before reaching New Awe town area.



(a) (b)

Fig: 8:(a) Geoelectric section along first survey profile (b) Geoelectric section along second survey profile

CONCLUSION

Vertical electrical sounding (VES) survey was conducted in the Awe brine field in Awe LGA, Nasarawa State, with the aim of providing valuable information on the geology of the area, and delineating the brine deposits and their subsurface configuration. Forty-five resistivity depth soundings data were acquired in the study area. The subsurface structure composed mainly of alternation of highly saline and saline-free horizons. From the study, four distinct geoelectric layers were delineated. The upper layer showed very high resistivity value and it is presumed to saline free horizons. However, the third layer is interpreted as brine zone (C). Its resistivity values range from 2.7Ωm 97Ωm. The layer reflects the area of high brine concentration whose depth varies gradually across the profile. The research work further showed the occurrence of vast deposits of brine deposits, which can be of economic importance in mining and industrial purposes. The interpreted results show brine deposits where they occur mostly in south-western part of the area investigated. It indicates brine deposit between depth interval of 4m and 38m in the study area. The results also showed the effectiveness and usefulness of electrical resistivity in mapping brine deposits. Toexplore the brine in highly economic quantity, it is therefore recommended that integrated geophysical and geological study of that environment should be carried out.

REFERENCES

Adeoti, L Alile, O.M., and Uchegbulam. O. (2010).Geophysical investigation of saline water intrusion into freshwater aquifers: A case study of Oniru, Lagos State, *Scientific Research and Essays (SRE) Academic Journal Vol. 5*(3) pp 248-259.

Badmus B. S. and OlatinsuO. B. (2009).Geoelectric mapping and characterization of limestone deposits of Ewekoro Formation, southwestern Nigeria. *Journal of Geology and Mining Research Vol. 1(*1) pp. 008-018.

Binbol, N.L. (2006), a climate of Nasarawa state, Report of geographical prospective on Nasarawa State, Department of Geography Nasarawa State University.

Kearey, P., Brooks, M., and Hill, I. (1996), An Introduction to Geophysical Exploration 3rd edition, Blackwell Science Publishing Ltd. Pp 183-184.

Nigeria Meteorological Agency (NiMet) (2017). Seasonal Rainfall Prediction (SRP). Pp 45-62.

Obaje, N.G. (2009). Geology and Mineral Resources of Nigeria, Lecture Notes in Earth Sciences Springer-Verlag Berlin Heidelberg, pp. 148-150.

Obaje. N .G, Lar, U.I, Moumouni A, Chaanda, M.S and Goki, N.G (2006). Geology and Mineral Resources of Nasarawa State, A Preliminary Investigation, Report of geographical prospective on Nasarawa State, Department of Geography Nasarawa State University.

Offodile M.E. (1992). The Geology and Tectonic of Awe Brine Fields, *Journal of African Earth Sciences vol*. 2(3) pp.191-202,

Offodile M.E. (2002). An approach to groundwater study and development in Nigeria 2nd Edition Mecon Publishing, pp. 240.

Oteri, A.U (1988). Electric Log Interpretation for the evaluation of salt water intrusion in the eastern Niger Delta. *Hydrological Sciences Journal, 33* (2), pp. 19-30.

Sa'ad, B. (2006).A resistivity survey of phosphate deposits containing hardpan pockets in OuladAbdoun, Morocco Geofísica International, Vol. 45(1), pp. 73-82

Telford; W. H., Gilbert, L. P. and Sherif, R. E., (1977). *Applied geophysics.* Cambridge University Press London.Pp. 522-534.