ISSN: 2819 - 3862
Volume 8, Number 3, 2023
Journal of International Physical Science

HYDROCARBON POTENTIAL EVALUATION USING PERMEABILITY AND POROSITY DATA FROM CONTROL SOURCE ELECTROMAGNETIC DATA IN MKPAT-ENIN LGA, AKWA IBOM STATE, NIGERIA.

[1]Ibim, D.F., [2]Frank, S.E.
[1&2]Department of Physics,
Ignatius Ajuru University of Education, Port Harcourt, Nigeria

Email: dagogo.ibim@iaue.edu.ng

ABSTRACT

Hydrocarbon potential evaluation using permeability and porosity data from control source electromagnetic (CSEM) data in Nkpat-Enin LGA, Akwa-Ibom State, Nigeria, was carried out to map out prospective areas for hydrocarbons exploration. High resolution CSEM data were obtained using the Bayesian methodology to ascertain the viability for hosting and exploring hydrocarbon potential in the study area. Evaluation of hydrocarbon potential is very important before drilling in order to know risk reduction, cost effectiveness and the best exploration method and tools to use for drilling without potential threat to life and property in the study area in the future. Permeability and porosity decreases as the magnetic susceptibility increases, suggestive of the direct proportionality of permeability to porosity. Results obtained suggest that, hydrocarbons will be drilled in the study areas when the initial prospect value is high and the initial probability value of hydrocarbon presence is high. Analysis made shows that there is a very good match between the data obtained from the geophysical parameters, particularly where the reservoirs are shallow as applicable to the study area. There are accumulations of hydrocarbon potentials in the study areas and they are readily suitable for exploration. The stable growth of active hydrocarbon reserves ensures their stable production consistently. The CSEM technology is suggestive of having significant potential to increase exploration efficiency, if applied correctly.

Key Words: Hydrocarbon, potential, exploration, Nkpat-Enin, Niger Delta

INTRODUCTION

The study area, "Nkpat-Enin" lies between latitude 4°4'5"N and longitude 7°44'56"E. (Akwa Ibom State Geonames, 2009). Nkpat-Enin is located in the south south region of Nigeria and is a town and a Local Government Area (LGA) of Akwa Ibom State. It sits at an altitude of approximately 185 m above sea level. Mkpat-Enin LGA has an area of 322.352 Km^2 and it's the second largest local government area in Akwa Ibom state. The LGA is located within the industrial belt extending from Eastern Obolo, Etinan, Oruk Anam, Onna, to Ikot Abasi. The population was 178,036 based on the 2006 census (Akwa Ibom State Geonames, 2009). The area is rich in oil and natural gas; oil was discovered in Ikot Akpa/Ekop as early as 1953 (Akwa Ibom State University of Technology, 2009). With higher and higher requirements on hydrocarbons exploration from oilfields, the integration of EM has become an effective approach to solving complicated problems especially in 3D EM and higher precision hydrocarbon detection methods. Electromagnetic method can show the presence of large geologic anomalies such as anticlines, fault blocks and salt domes, even though there may not be surface indications of their presence (Abubarkar and Habashy, 2005).

In recent years, hydrocarbon exploration has been more and more difficult, but poses a challenge and an opportunity for land-based CSEM techniques to explore in the world (Zheng *et al*., 2019; Zheng and Li, 2020; Safipour *et al*., 2018). One of the challenges is that traditional 2D EM cannot satisfy the current hydrocarbon exploration in the study area, thus, 3D acquisition and processing are required for the evaluation of hydrocarbon potentials using land-based CSEM data in the study area. Another challenge is the investigation of deep igneous rocks which requires the contribution of geophysical methods among which CSEM technique is one of the most important means for which the study is centered only on the evaluation of hydrocarbon potentials using CSEM data. Another challenge is detecting lithologic reservoirs in the study area.

An in-depth understanding of hydrocarbon generation and expulsion characteristics can effectively improve the accuracy of resource evaluation and the prediction of favorable exploration zones which are important for petroleum exploration and development of source rocks (Wang *et al*., 2020 &2012). Several methods of extraction and analytical determination for total petroleum hydrocarbon (TPHCs) have been reviewed in the study area using different geophysical methods but this work will bring to lamplight the importance of evaluating hydrocarbon potential using land-based CSEM which has the capacity of revealing the permeability and porosity of hydrocarbon present in the study area for exploration.

This study is therefore aimed at effectively using the land-based CSEM data to evaluate the hydrocarbon potential of the study area and to shed more light on sediment thickness which is crucial to hydrocarbon exploration. The objectives of this work are to map out the prospective areas for brine, oil and gas exploration, analyze the spectral depth estimation of petroleum based on elevation, latitude and longitude.

MATERIALS AND METHOD

Maxwell's four equations describe the electric and magnetic fields arising from distributions of electric charges and currents, and how those fields change in time. They were the mathematical distillation of decades of experimental observations of the electric and magnetic effects of charges and currents, plus the profound intuition of Michael Faraday (Chen and Xue, 2006; An and Di, 2016). The equations mainly give us the idea about how the electric and magnetic fields interacts with each other.

Equations that together form a complete description of the production and interrelation of electric and magnetic field are (Zheng *et al.,* 2019; Guo *et al*., 2016)

$$Gauss'law\ for\ electricity: \emptyset_E = \oint \vec{E} \cdot d\vec{A} = \frac{q_{enc}}{\varepsilon_0} \tag{1}$$

$$Gauss'law\ for\ magnetism: \emptyset_B = \oint \vec{B} \cdot d\vec{A} = 0 \tag{2}$$

$$Farady'law: \oint \vec{E} \cdot d\vec{s} = -\frac{d\emptyset_B}{dt} \tag{3}$$

$$Ampere - Maxwell\ law: \oint \vec{B} \cdot d\vec{s} = \mu_0 \varepsilon_0 \frac{d\emptyset_E}{dt} \tag{4}$$

where q = E.M charge, E = electric vector field, B = magnetic field, A is the area, and ε is the electric permittivity of free space or dielectric constant.

Equation (1) relates net electric flux to net enclosed electric charge, equation (2) relates net magnetic flux to net enclosed magnetic charge, equation (3) relates induced electric field to changing magnetic flux, and equation (4) relates induced magnetic field to changing electric flux and to current.

The study was conducted in Nya-Odiong, Ikot-Ekpa, Ikot-Etina and Asung all in Mkpat-Enin LGA of Akwa Ibom State, Nigera. The survey was carried out on 160 stations for high frequency passive land-based CSEM and 180 stations for CSAMT. The sites for both methods coincide. A STRATAGEMEH-4real-time system for passive source CSEM and two V6-A multipurpose receivers were used for data acquisition, including a T-30 system which was used for CSAMT transmitting. The STRATAGEMEH-4 records orthogonal electric and magnetic fields, which are used to obtain the tensor impedance for interpreting 2-D structures. This provides electrical conductivity imaging of the subsurface for depths between 10 m and 1,000 m. The electric field was measured by two pairs of titanium electrodes, while the magnetic field was measured by highly sensitive magnetic coils. The scalar survey mode was used in the CSAMT method. Seven C-C electrodes, a new kind of electrode made primarily from carbon, arranged in a line to cover six field sites, were used to record the data. To avoid the near-field effect, we chose the transmitter-receiver separation to be larger than 9km, which is about ten times the maximum depth of the tunnel.

Land-based controlled-source electromagnetic system may experience two weaknesses when exploring for deeper conductors: poor coupling with the target and small signal-to-noise ratios (S/Ns), both of which reduce the quality and interpretability of the area. These weaknesses were addressed by evaluating an oval time-domain EM procedure. The coupling weakness was addressed through multiple transmitter locations and multiple receiver locations, and the S/N was increased by spatial tacking of measurement (from the various transmitter-receiver combinations). A field test of this procedure was undertaken. Reciprocity data indicated that the noise levels of the vertical component data we acquired were about−0.004μV/Am^2. Spatial tacking of the data can reduce the noise levels by a factor of seven. This means that a small conductor previously only visible to 150 m could be seen to 275 m and a conductor visible to 300m could be seen to 575 m.

The time required to collect all the transmitter-receiver combinations could be a challenge to this procedure. This time can be reduced using the principle of reciprocity and not repeating approximately reciprocal measurements. Also, visualizing and interpreting the large volumes of data collected using the procedure could be a challenge. This has been partially addressed by creating equivalent-dipole depth sections. The Bayesian Methodology for integrating the use of land-based CSEM data for hydrocarbon exploration was adopted. However, computing the probability of hydrocarbon potential presence will be based on information obtained from the CSEM data. Meanwhile, the log interpretation will be obtained from the spectral depth estimation of CSEM data based on depths and GPS data.

RESULTS AND DISCUSSION

Table 1: Horizontal Plug Permeability, Mass Magnetic Susceptibility and Porosity in Low and High Fields of the Study Areas.

Horizontal Plug Permeability at Low Field	Mass Magnetic Susceptibility at Low Field	Horizontal Plug Permeability at High Field	Mass Magnetic Susceptibility at High Field	Porosity(%) at Low Field	Mass Magnetic Susceptibility at Low Field	Porosity (%) at High Field	Mass Magnetic Susceptibility at High Field
0.00001	-0.5	0.00001	-0.5	0	-0.5	0	-0.5
0.0001	-0.4	0.0001	-0.4	5	-0.4	5	-0.4
0.001	-0.3	0.001	-0.3	10	-0.3	10	-0.3
0.01	-0.2	0.01	-0.2	15	-0.2	15	-0.2
0.1	-0.1	0.1	-0.1	20	-0.1	20	-0.1
1	0.0	1	0.0	25	0.0	25	0.0
10	0.1	10	0.1	30	0.1	30	0.1
100	0.2	100	0.2	35	0.2	35	0.2
1000	0.3	1000	0.3	40	0.3	40	0.3
10000	0.4	10000	0.4	45	0.4	45	0.4
100000	0.5	100000	0.5	50	0.5	50	0.5

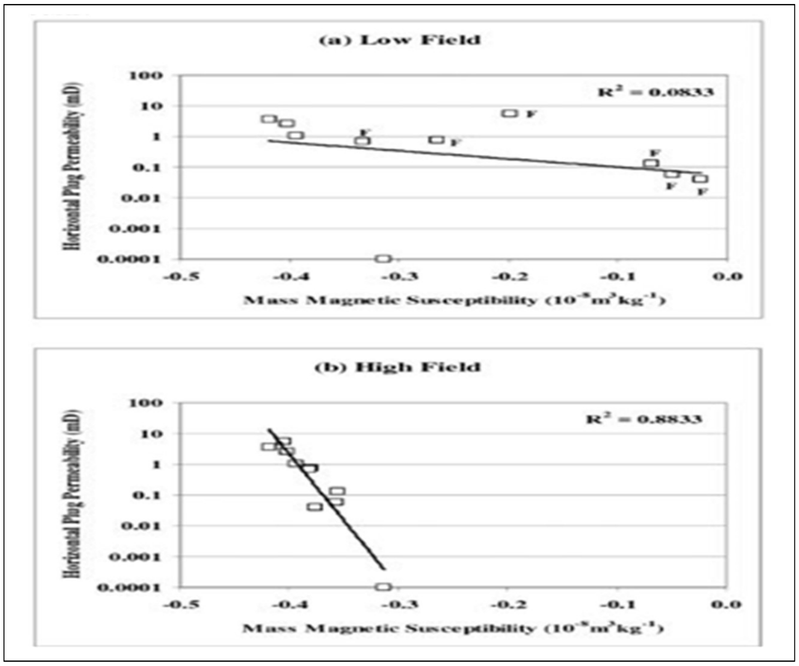

Figure 1: (a). Show the plot of Horizontal Plug Permeability versus Mass Magnetic Susceptibility in Low Fields of the Study Area. (b). Shows the plot of Horizontal Plug Permeability versus Mass Magnetic Susceptibility in High Fields of the Study Area.

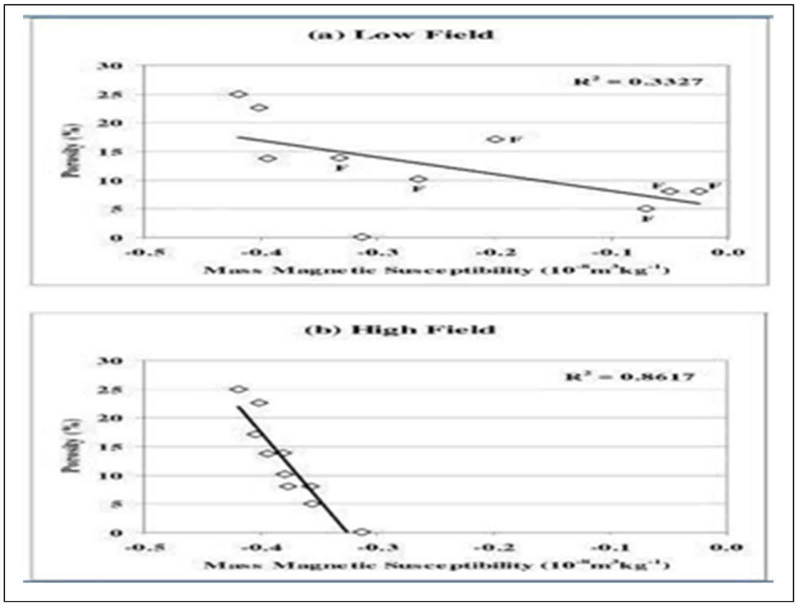

Figure 2: (a). Show the plot of Porosity and Mass Magnetic Susceptibility of the Low Fields in the Study Area. (b). Shows the Porosity and Mass Magnetic Susceptibility of the High Fields in the Study Area.

DISCUSSION

From the study, it showed that the success rate for multipurpose brine, oil and natural gas at Ikot-Akpa is far greater than the failure rate. Permeability and porosity decreases as the magnetic susceptibility increases, suggestive of the direct proportionality of permeability to porosity. The results obtained revealed that the risks update for CSEM line at Nya-Odiong is greater when considering the probability of success and distance compared to other study areas. Evaluation carried out depicts large probability of brine, oil and natural gas reservoir in Nya-Odiong, suggesting achievable exploration of hydrocarbon potentials in the study area.

Also, from our analytical view, it is predicted that the CSEM data depends on the price of drilling the prospect, the potential value and the initial estimate of the probability of hydrocarbon presence. Evaluations were interpreted as a result of comparing the Project Value, Prior Probability of Success and the Value of CSEM. Results obtained suggest that, hydrocarbons will be drilled in the study areas when the initial prospect value is high and the initial probability value of hydrocarbon presence is high. As such, the CSEM data will affect the decision because the prospect (brine, oil and natural gas) can be drilled and in such cases, in the middle zone, the value of CSEM data will be as large as 50 mUSD. There are accumulations of hydrocarbon potentials in the study areas and they are readily suitable for exploration.

CONCLUSION

Evaluation of hydrocarbon potential using land-based control source electromagnetic *(CSEM)* data in Nkpat-Enin LGA, Akwa-ibom State, Nigeria, was carried out to map out prospective areas for hydrocarbons. Evaluation of hydrocarbon potential is very important before drilling in order to know risk reduced, less expensive and the best exploration method and tools to use for drilling without potential threat to life and property on the study area in the future. The stable growth of active hydrocarbon reserves ensures their stable production consistently.
Probability of success or failure of brine, oil and natural gas in the study area was compared using the CSEM Phase and CSEM Offset. Analysis made revealed that there is a very good match between the data obtained from the geophysical parameters, particularly where the reservoirs are shallow as applicable to the study area.

In order to ensure accurate evaluation of hydrocarbons potential presence in the study area, resources should be moved to sources that are easier to locate but, are more difficult to exploit. Detailed estimation of petroleum reserves and resources should be carried out in the study area coupled with researchers carrying out works on the analysis of oil recovery factors, dynamics of oil and gas extraction in the study area and occasional re-evaluation of hydrocarbon reserves and resources with the involvement of new geological, geophysical, petro physical data, as well as using new methods should be adapted for research work on the study area.

Synthetic and real equivalent-dipole depth sections appeared very similar and illustrated that these images of the subsurface could be interpreted. However, better visualization techniques could be developed.

REFERENCES

Abubakar, A. & Habashy, T. M., (2005). A green function formulation of the extended born approximation for three-dimensional electromagnetic modelling. Wave Motion, 41(3), 211–227.

An, Z. & Di, Q. (2016). Investigation of geological structures with a view to HLRW disposal, as revealed through 3D inversion of aeromagnetic and gravity data and the results of CSAMT exploration. Journal of Applied Geophysics, 4(135), 204–211.

Chen, W.Y. &Xue, G.Q. (2006). Effective skin depth of whole EM field due to a grounded wire source. *Journal of Geophysics. 57 (7*), 2314–2320.

Zheng, Y.Z., Tang, J. & Cai, J.T. (2019). Deep electrical structure beneath the Sichuan Yunnan area in the eastern margin of the Tibetan plateau. Journal of Geophysics, 60 (6), 2425–2441.

Guo, Z., Dong, H. & Kristensen, Å. (2016). Electromagnetism regularized Maxwell equation. Journal of Geophysics. Eng, 13 (6), 858–867.

Kamureyina, P. & Sillitoe, R.H. (2010). Porphyry copper systems. *Economics Geology, 105 (1*), 3–41.

Safipour, R., Hölz, S., Jegen, M. & Swidinsky, A. (2018). A first application of a marine inductive source EM configuration with remote electric dipole receivers: Palinuro Seamount. Geophysical Prospecting, 66(5), 1415–1432.

Wang, C.Y. & Huang, J.L. (2020). Mantle transition zone structure around Hainan by receiver function analysis. *Chinese Journal of Geophysics, 55(6*), 1161–1167.

Wang, Q., Xu, Li, Z.X., Li, X.H., Li, J., Liu, Y., Long, W.G., Zhou, J.B., Wang, Joan, P.F. (2012). Temperature, pressure, and composition of the mantle source region of late cenozoic basalts in Hainan Island, SE Asia: a Consequence of a Young thermal mantle plume close to subduction zones. Journal of Petrol, 53(2), 177–233.

Zheng, S., Li, H.F. & Li, X. (2020). Three-dimensional FDTD modeling of TEM excited by a loop source considering ramp time. *Chinese Journal of Geophysics, 56 (3*), 1049–1064.