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Application of Self-potential Geophysical Method in Investigation of Pb-Zn Sulphide deposits in Enyigba and Environs, South Eastern Nigeria

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ABSTRACT

The self potential (SP) method has been used to investigate lead-zinc sulphide ore deposit veins in Enyigba area, in Ebonyi State, south eastern Nigeria. The study area lies between latitude $6^0 09^1 00^{11}$N to $6^0 14^1 00^{11}$N and $08^0 05^1 00^1$E to $08^0 10^1 00^1$E. The entire area is situated about 13km south of Abakaliki. The lithologic units of the formation are mainly shales. It is underlain by the Abakaliki shale formation of Asu-River Group. The ABEM SAS 1000 was used to measure Sp values values. The results were plotted using computer software. The data were interpreted qualitatively. The sp values gotten were both positive and negative. The positive values range from +0.15mV to +70.38mV while the negative values range from -0.1mV to -110.25mV. The results obtained from SP data were plotted using surfer 11.0 software to get the picture of iso-potential distribution of Pb-Zn sulphide veins in the surveyed area. This enables comparison of anomalies across the data sets. The data show fairly good comparison. Based on the qualitative interpretation, the negative sp anomaly is most diagnostic. This is indicative of sulphide ore deposit. The results indicate the possible existence of mineralized veins with different orientation. The majority of the veins trend in NW-SE directions. The self-potential survey results suggest possible existence of lead-zinc sulphide ore deposits. However, a better check to this investigation is by integrating other geophysical methods like Gravity or Magnetics and Electromagnetic or combining SP with resistivity method. This will provide a clearer picture of the ore deposit and pattern of deposition.

Keyword: Self-potential, Enyigba, Lead-zinc, Mineralization, Veins

INTRODUCTION

The search for mineral resources has been the interest of mankind for many decades. Many developed world, based their development on the extraction and utilization of mineral resources. The deposits of Pb-Zn sulphide in Nigeria has been known long time but have only been exploited in the past on a very small scale. The Lead-Zinc field is over 48,000 sq.km in extent with Lead-Zinc minerals at many centres. Deposits are localized in Cretaceous sediments along 600 km long belt within the Benue Trough, a sediment-filled intracratonic basin extending from Ishiagu (South of Abakaliki) north eastwards to Gombe (Farrington, 1952; Olade, 1976 and

Orazulike, 1994). Deposits occur in a variety of sedimentary host rocks ranging from shales in Abakaliki area, carbonate in Arufu-Akwana and to sandstone in Zwark, and they are structurally controlled.

The occurrence of Lead-Zinc in the Benue valley has attracted a lot of attention. Mining of the ore in Enyigba has been carried out a long time by both the natives for local use as cosmetics and foreign companies, for export. The major ore minerals are galena and sphalerite, with siderite, chalcopyrite, pyrite, barites, calcite and quartz as associated gangue minerals.Production of the ore was first recorded in 1925 (Offodile, 1976) but commercial production started in 1947 (Kogbe, 1989). Production has since died down due to poor price of the minerals from a peak value of 180.22 tones in 1975 through 503.74 tonnes in 1976, 221.73 tonnes in 1981 to very low production volume of 5 tonnes in 1984 (Kogbe, 1989 and RMRDC, 1998). The discovery of the Pb-Zinc elsewhere in Benue trough was due to geological field mapping (Coswarth, 1949; Bogue, 1952 and Farrington, 1952). Since the discovery and mining Pb-Zn deposits in Abakaliki and its environs in the early 1900s, not much data exists on the geophysical survey of the area.Some published geophysical investigations in the Benue Trough have been the gravity (Cratchely and Jones, 1965), resistivity and magnetic survey (Mamah et al, 2000). The above surveys either focused on the evolution, structure or estimation of the ore reserves in the trough.

The study involved using geophysical approach for Pb-Zn ore deposits exploration, using self-potential method. It is a geophysical method was used to locate the zone of mineralization. Geophysical method was carried out in the summit area of Enyigba and its environs (fig. 1), which is one of the mineralized zones of Lower Benue Trough. The self-potential (sp) method is a passive geophysical method based on the natural occurrence of electrical fields on the earth's surface. It is natural electrical field method where the field is time stationary (Gallas et al, 2011). The source for the phenomena is buried in the subsurface. The self-potential (sp) method has been used for a long time in the field of mineral exploration for buried ore bodies (Sarma, 2014). Sp surveys are especially useful for locating sulphide ore.

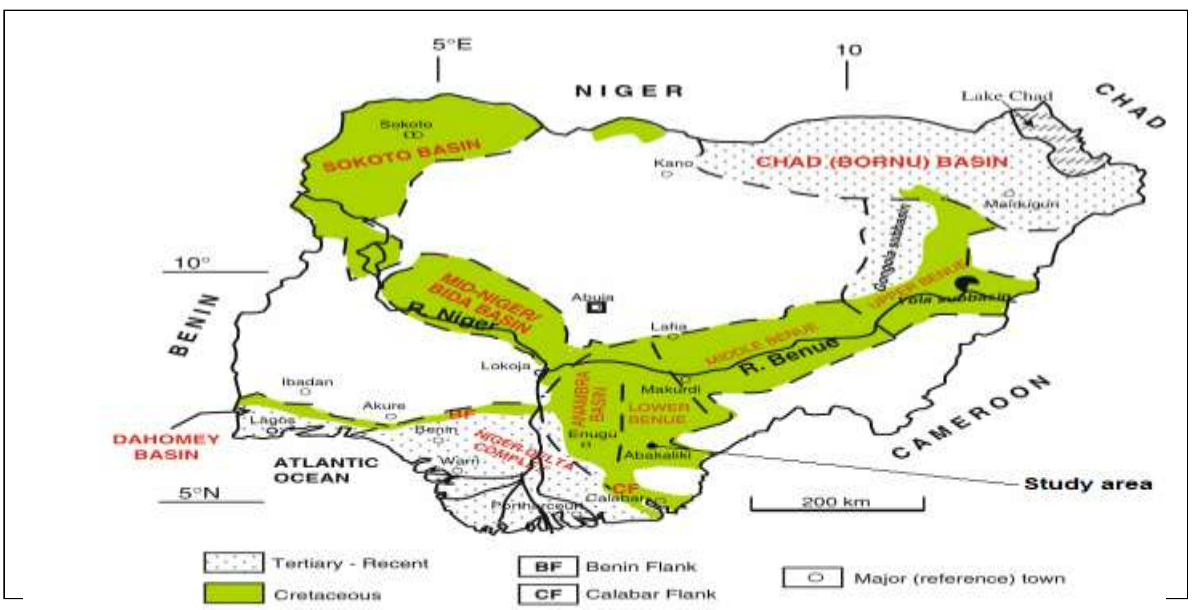

Figure:1: Sedimentary Basins of Nigeria (Modified after Obaje, 2009) showing the study area

Physiography

In the study area, the topography is undulating plain alternating with running of ridges and hill from east to west. The plain terrains are underlain by shale and some mudstones. Lead-Zinc deposits are generally in closely spaced steeply dipping fractures which trend NW-SE.The drainage system of the study area is dendritic in pattern, which is a function of lithologic control (Fig 1). The study area is mainly drained by Ebonyi River and Akpara River. The minor tributaries include two streams; the Iyinu stream and the Ikpete stream. All these, both the major and minor drainage system flow eastward to join the Cross river, somewhere outside the study area.

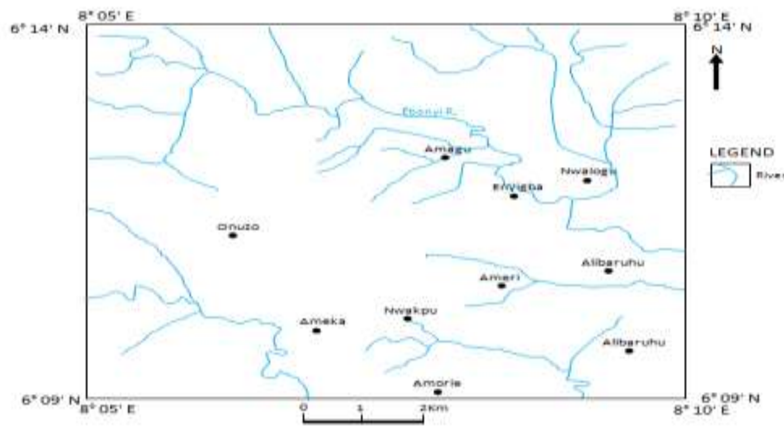

Figure 2: Map of the study area showing the drainage pattern.

Geology

The Abakaliki Shale formation underlies the study area (figure 3). Only sedimentary rocks, the Albian Shales are exposed in the study area. The sedimentary rocks are predominantly black carbonaceous shale with occasionally intercalation of hard mudstone and sandstone that are highly jointed and faulted. The shale formations belong to the Asu-River Group of the Albian Cretaceous sediments. The ASu-River Group is Middle Albian sediment and consists of very thick marine dark, grey shales, siltstones, and minor limestone. The sediments consist of poorly bedded sandy shales known as Abakaliki shales with sandstone and sandy limestone lenses (Kogbe, 1981). Reyment (1965) includes Arufu Limestone and Ulomba Formation to this group. Reyment (1965) also noted Ngbo Sandstone and Nkebeligwe Sandstone as its lateral equivalence. The Asu-River group of sediments in most cases lies unconformable on the basement complex (Offodile, 1976). From field observation, the rocks of the study area consist of variable coloured (black and reddish brown) shales and mudstones that have been included in the lead-zinc vein mineralization, baked shale as well as ironstone along the vein. The baked shales are concentrated at Onu-Ebonyi NE of Enyigba mine. The ironstone occurs as inter beds within the shale and vein fillings. The shale ranges from dark at depth to dark-gray and reddish-brown up the sequence. The mineralization is hosted in the dark shale.

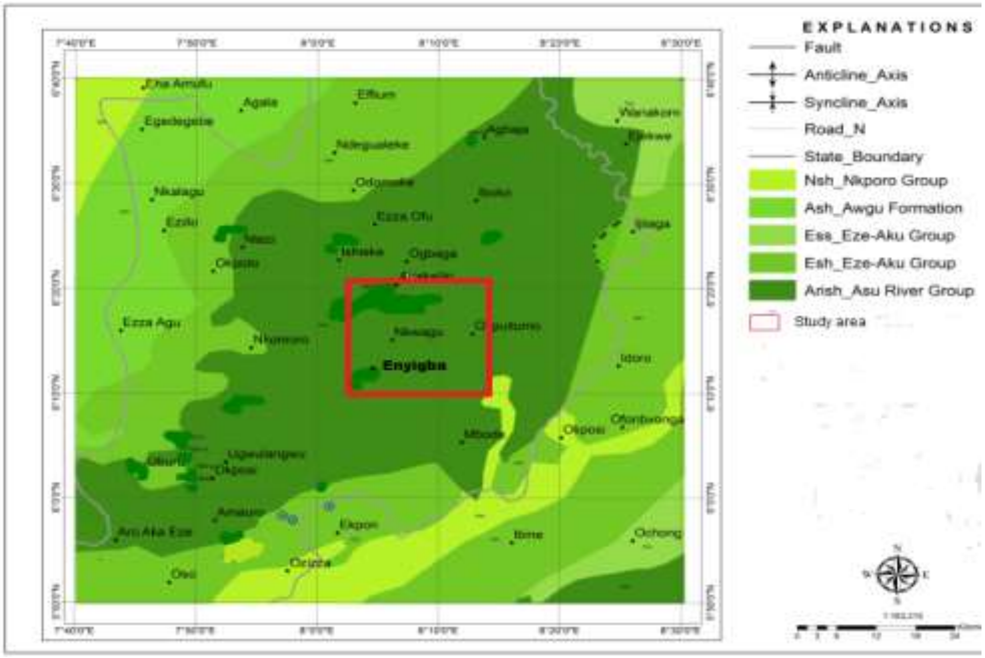

Figure 3: Geological map of Abakaliki, showing the study area

MINERALIZATION IN ENYIGBA

Mineralization in the study area is localized in faults and gently dipping vein (Orazulike, 1994). The mineralization veins at Enyigba dip between 10^0 -75^0 to the west (Orajaka, 1965) (Figure 4).Sulphide of lead-zinc (galena and sphalerite) associated with smaller amounts of copper from the Enyigba and its environs, (Lower Benue Trough), forming echelon lodes and vein infilling open fractures. The normally occupy the axes of anticlinal structures and are characterized by numerous vugs and cavities. Trends of the individual lodes and veins ranges from N-S to NW-SE. They are steeply dipping and varying in length from a few metres to two kilometers, and in width from a few centimeters to several meters. Their vertical extent appears not to exceed 150 meters. The lead-zinc mineralization in the area is structurally controlled and localized within a series of steeply dipping veins. The deposits at Enyigba are composed mainly of galena (PbS) and Sphalerite (ZnS). Siderite ($FeCO_3$) is also present and in appreciable quantity. Siderite and quartz form the gangue minerals. Chalcopyrite ($CuFe_2$) is also present but in minor quantities and its alteration results in the formation of azurite [$Cu_3(CO_3)_2OH_2$] and malachite [$Cu_2CO_3(OH)$] in the veins (Figure6). Pyrite (FeS_2) is also a common mineral in the study area. The host rocks are mainly the black carbonaceous Abakaliki Shales. The rock has been deformed along NE-trending axes producing folds truncated by N-S and NW-SE trending fractures and vein systems. The ore occur in hydrothermal vein, and for many years has been mined. Production of Lead-Zinc from the ore of the Enyigba and environs has been sporadic and intermittent and has amounted to more than a few 100 tones annually. The total amount of ore probably does not much exceed a million tones or do, and the small mining operation. There is, at present, some scope for exploitation to meet local needs.

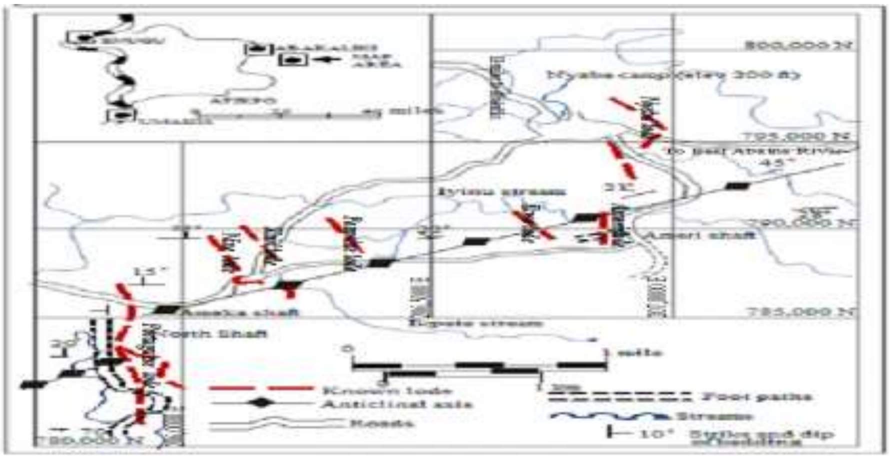

Figure 4: Geological map of lead-zinc deposits of Enyigba district, near Abakaliki, Lower Benue Trough. The area is underlain by shales (Modified fromOrajaka, 1965)

METHODOLOGY

Data Acquisition and Interpretation

The ABEM Terrameter (SAS 1000) equipment was used to acquire data for spontaneous potential. The self-potential measurements are made using the reference electrode method, whereby the base electrode is connected to a long spool of wire. Non-polarizing copper-copper (II) sulphate solution electrodes (Figure 5 and 6) are used for all self-potential measurement. Each station was assigned a unique identifier to facilitate further processing, and locations are recorded with a hand hold global positioning system (GPS) unit.

Eight SP profiles are drawn perpendicular to the advancing exploratory earthwork which is at N45^{0}W. The length of each profile is 200m and interval length of 5m. It is believed that this close grid would serve for extensive coverage of even minor vein/lode. Two non polarizing electrodes are used for self-potential survey. One of the electrodes is used as base station electrode while the other one is used as a roving electrode. One end of the wire is attached to the base station electrode. The wire is unreeled to the station one where the roving electrode is placed to a shallow hole in the ground. The voltage in the base station pot is always attached to the negative lead of the voltmeter (Terrameter) and the roving electrode wire attached to the positive side. After making the voltage measurement the roving electrode is picked up and more wire is unreeled to station two. The roving electrode is again placed in the earth and another voltage measurement is made. This method is repeated until the survey is completed. The reading will be taken at 5m interval. With this method, the total potential was measured directly at each station (Lowrie, 1997).

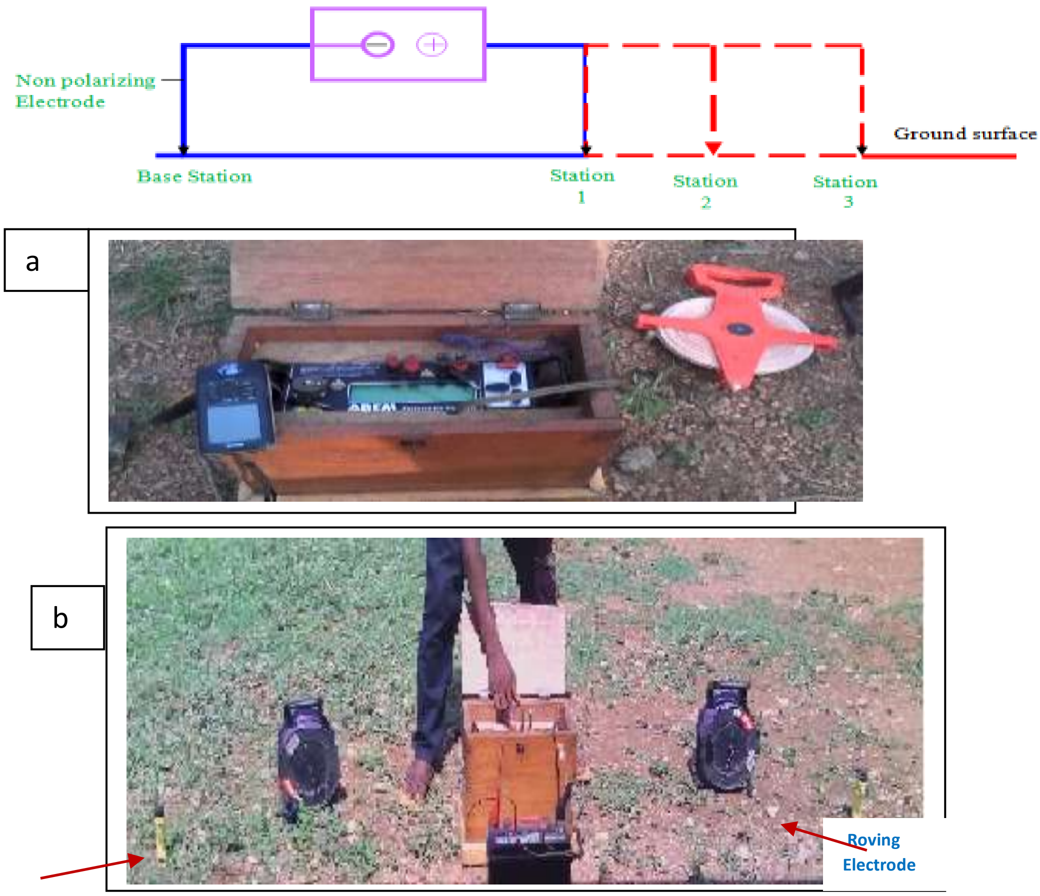

Fig 6: (a) Terrameter SAS 1000 and GPS (b) Field layout of SP survey at study area

RESULTS AND DISCUSSION

The self potential traverse, profile one to eight run parallel to each other in NE-SW direction. The profile one was carried out at the back of active mine in the study area to serve as a control for dictate SP values for anomalous Pb-Zn sulphide veins. The readings for this profile line was first plotted and three veins were dictated with the value range of -40 mV to -105.45 mV. After all data were acquired for the eight profile lines, the SP values were plotted using Microsoft-excel and surfer 11 computers software. The self-potential values gotten from the geophysical survey in the study area show both positive and negative sp anomalies. The results vary from -110.25 to 70.38mV throughout the study area. The interpretation was basically qualitative. Reynold, (1997. Interpreted self-potential anomalies values according to its source as follows: If the value of self-potential is negative of tens to hundred milivolts, then the source will likely besulphide ore deposits, deposits of graphite, magnetite and conductive minerals, coals or manganese. If the self-potential is positive of ten milivolts, then it is likely the source of quartz veins and pegmatite. If the self-potential value is less than 100 milivolts, it is probably due to chemical reactions. If the self-potential is negative of three hundred milivolts, it is probably as a result of bio-electric (trees and plants) (Reynold, 1997).

Visual inspection was used for all qualitative interpretation although the profile A serve as control, having dictated three veins with SP peak values as follows; -73.52 mV, -65.23 mV and -52.32 mV respectively (figure 6a). Plotted profiles (figure 6a-6h) and contour map variation (figure 7) is carefully observed for positive and negative anomaly closures. In the profile plots, profile A has three mineralized veins for Pb-Zn sulphide deposits as well as profile E and F. Profile C and D have 4 and 3 veins respectively while H has only one vein. Profile G, dictated no vein and all the SP values were all positive. This suggest absence of mineralized vein with that profile line. The negative closures and peak are most diagnostic. In the Abakaliki area, the negative closures had been interpreted to show the presence of pyrite (FeS_2) sulphide ore bodies (Chukwu 2013). The ore bodies are veins deposits and fractures that host the minerals. The generalized contour map for SP values in the eight profiles was constructed to view the lateral variation of SP anomalies across the mapped area.Contour maps of self-potential values for anomaly variation are constructed (figure 14). The maps show variation of positive and negative sp values. The negative sp values are indicative of sulphide ore deposits. The pink colour indicates negative peak anomaly, while the red colour indicates positive SP anomaly. Trend orientation of negative SP peak anomaly and normally occurred roughly NW-SE while brown colour represents positive SP peak.A general view of anomaly contour map suggest that the investigated area may be qualitatively interpreted to consist of several fault or fractured zones, which host the lead-zincsulphide mineralization in the study area.

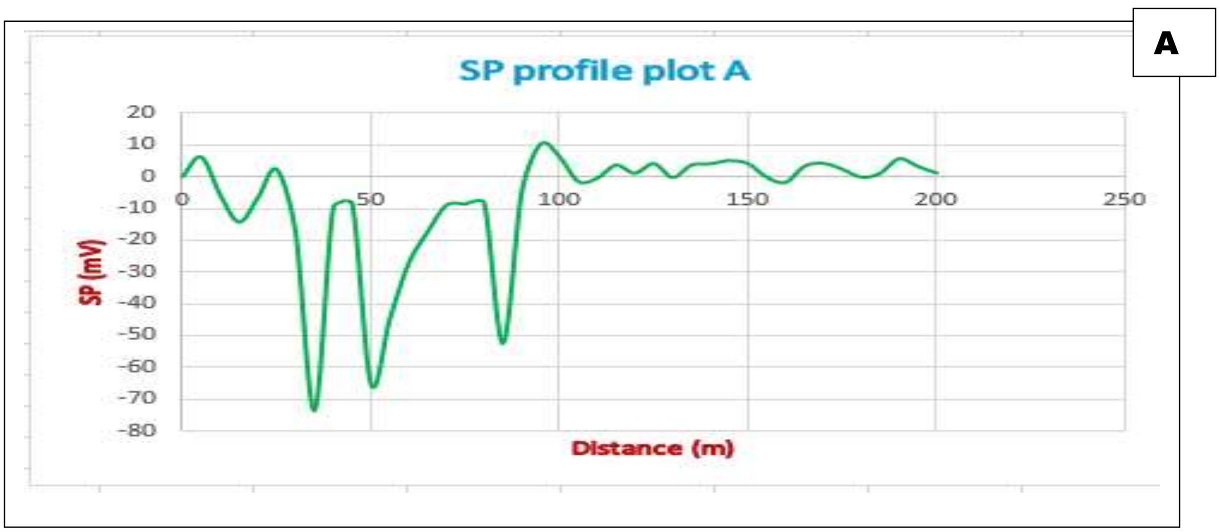

Figure 7: Self-potential profile plots for A

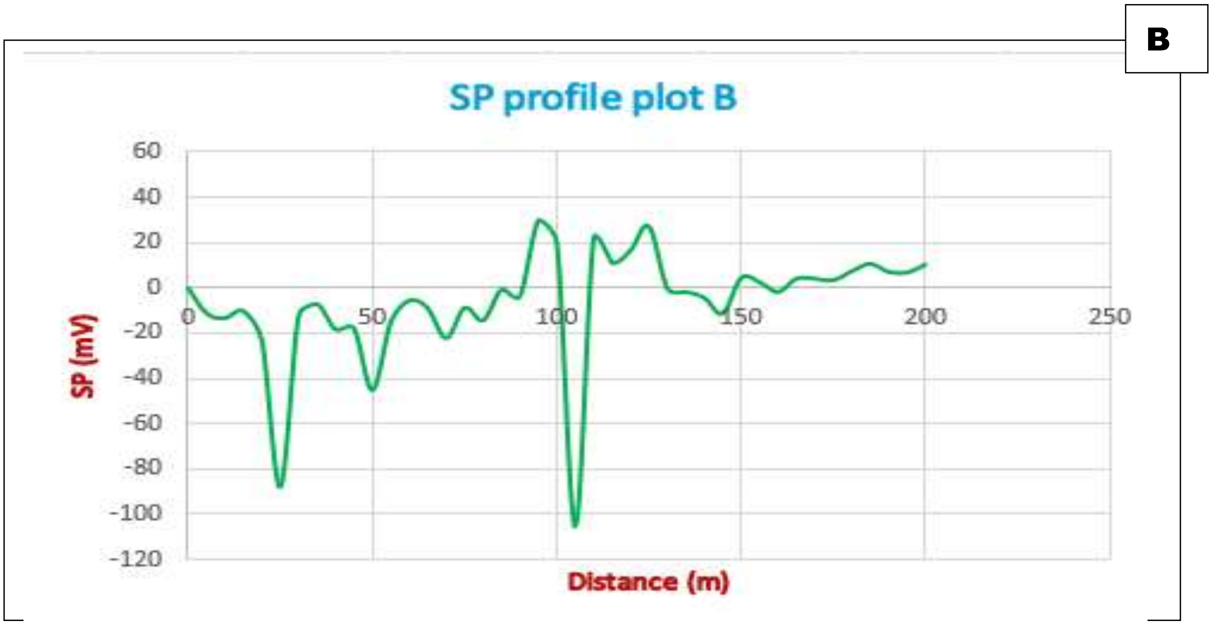

Figure 8: Self-potential profile plots for B

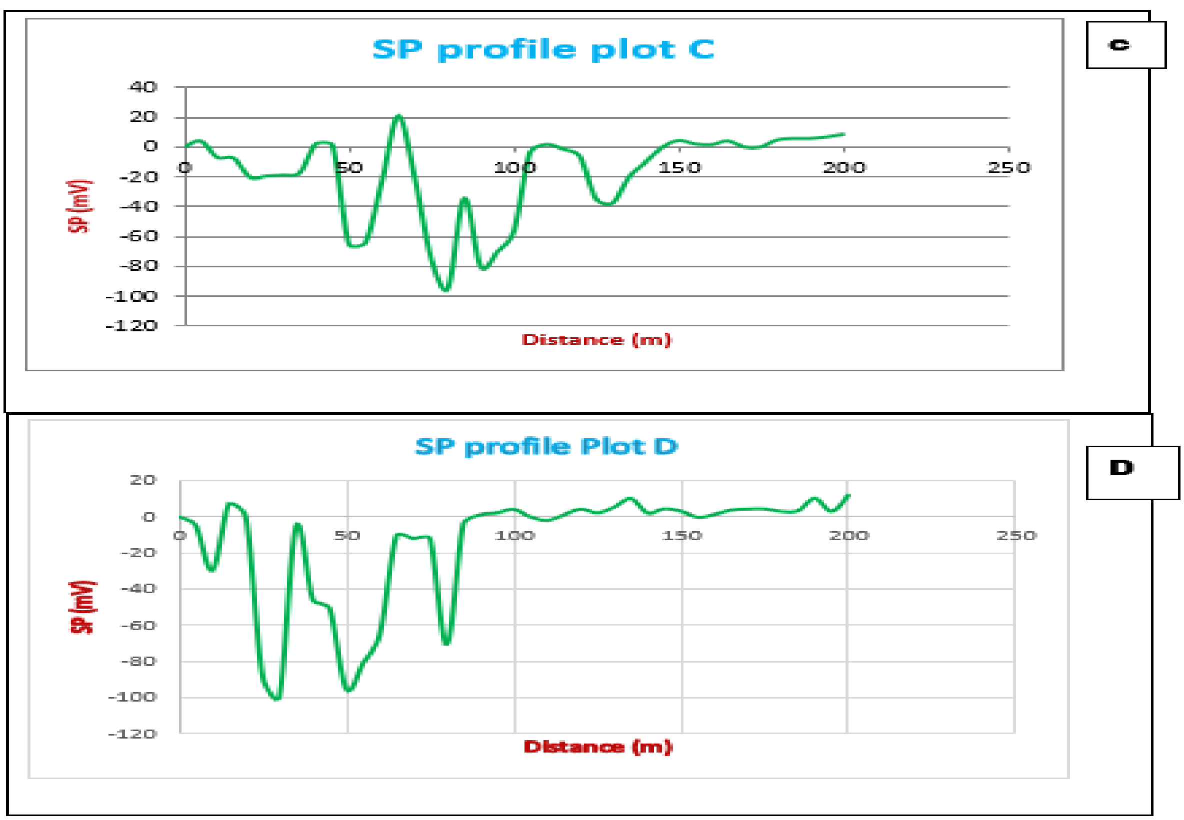

Figure 9: Self-potential profile plots for C and D

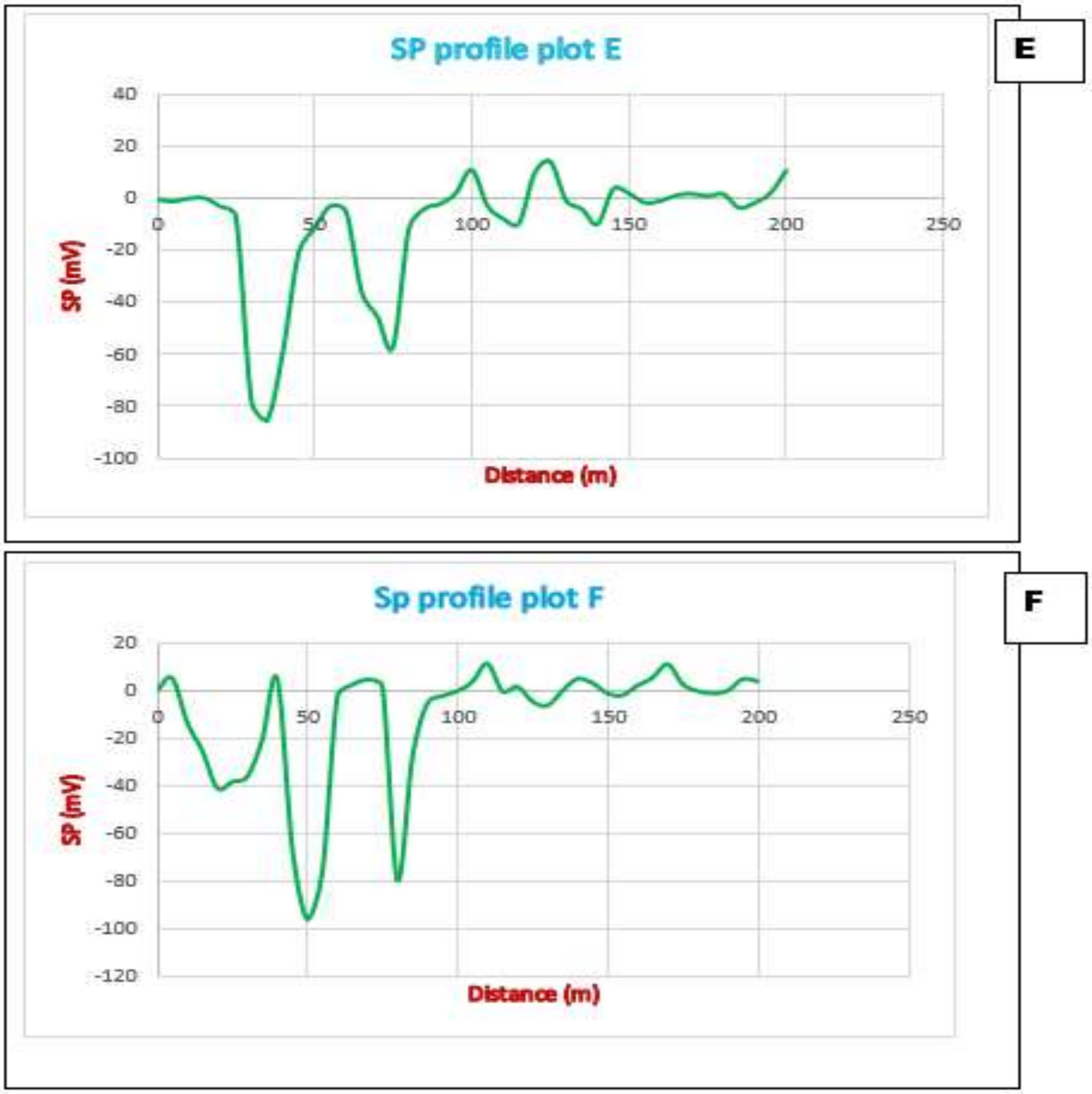

Figure 10: Self-potential profile plots for E and F

Figure11: Self-potential profile plots for E and F

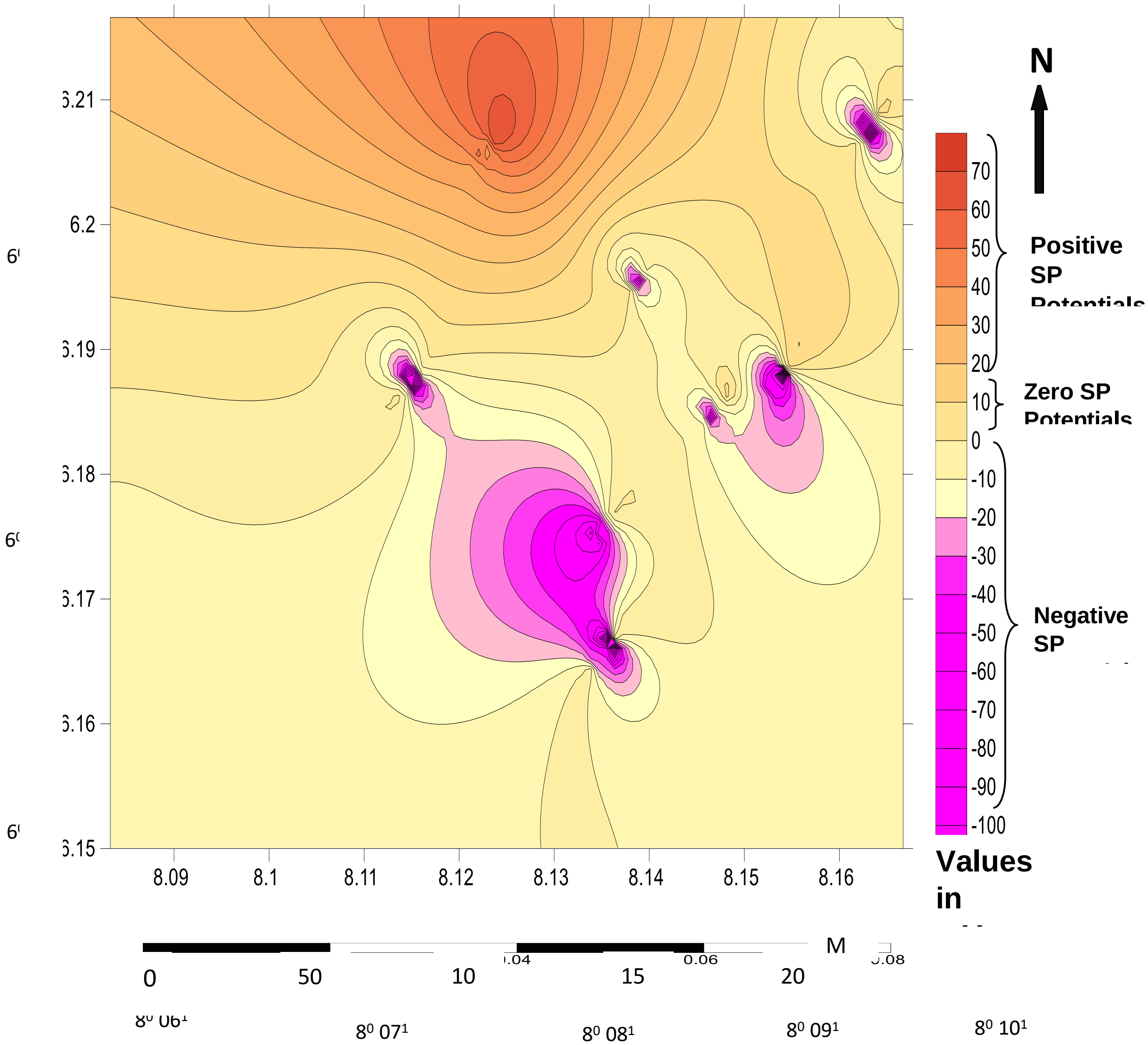

Fig. 12. Generalized Self Potential (SP) contour map of the study area

CONCLUSION

The detection of lead zinc sulphide ore deposit veins depends on whether or not the mineral has a physical contrast with the surrounding rock. Sufficient site coverage and spatial sampling are necessary to detect the vein bearing minerals and sufficient resolution is needed to define the target. Therefore, a higher density of station measurements or continuous measurements was needed by acquiring self potential data along closely spaced points. Regardless of the project objectives, site access actually limited where measurements could be made. The Self-Potential (SP) method is the cheapest and less cumbersome in term of the field procedure. In the SP anomaly variations, the negative SP anomalies were diagnostic as this indicates the presence Sulphide deposits in the study area. It is recommended that cautionary measures be carried out before commencement of any massive mining project in the study area. Professionals in mining sector should emphasize on the use of integrated geophysical exploration. This will reduce the incidence of abandoned mine fields and increase exploration and exploitation successes.

References

Bogue, R. G., (1952). The Lead-Zinc Deposits at Ishiagu, Ogoja Province, Nigeria: G.S.N. pp.1016.

Chukwu G. U .(2013). Characteristics of Self-Potential anomalies inAbakaliki Lower Benue Trough of Nigeria. Int. Res. J. Geo. Min. 3(7), 257-269.

Cotsworth, T. H. G., (1949). Lead occurrences in Ogoja Province. Unpublished report No. E/182/1. Mines Department, Enugu.

Cratchley, C. R., and Jones, J. P., (1965). An interpretation of the geology and gravity anomalies of the Benue Valley, Nigeria. Overseas Geol. Surv. Geophys, 1, pp. 26.

Farrington, J. L., (1952). A Preliminary Description of the Nigerian Lead-zinc Field. Econ. Geol, 47 (6), 583-608.

Gallas, J.D.F., Taioli, F., and W.M. Filho.,(2011). Induced polarization, resistivity, and self-potential: a case history of contamination evaluation due to landfill leakage, *Environmental Earth Science Journal*, 63, 251-261.

Kogbe, C. A., (1989). The Cretaceous and Paleogene Sediments of Southern Benue Trough Nig. In Geology of Nigeria, C. A. Kogbe (ed), Rock View (Nig) Ltd., Jos, pp. 325-334.

Lowrie, W., (1997). Fundamentals of geophysics. Cambridge University Press United Kingdom, pp. 209-212.

Mamah, L. I., Ezepue, M. C., and Ezeigbo, H. I., (2000). Integration of Geology and Geophysics in mineral Exploration in the Benue trough, Nigeria. The Onuahia Lead-zinc Deposit. A case study. Global J. Pure Appli. Sci.. 6 (2), 255-262

Obaje, N. G. (2009) Geology and mineral resources of Nigeria, Lecture Notes in Earth Sciences. *Springer Berlin Heidelberg*, 120, 77 -89.

Offodile, M. E. (1976). Stratigraphy of the Keana-Awe area of the Middle Benue region of Nigeria. Bull. of Geology Inst. of the Univ. of Uppsala N.S. 7, 37-66.

Olade, M. A. (1976). The genesis of lead-zinc deposits in Nigeria's Benue Rift (Aulocogen): A reinterpretation. Journal of Mining and Geology. 13, 20-27.

Orajaka, S., 1965, The Geology of Enyigba, Ameri and Ameka Lead-Zinc lodes Abakaliki; South-eastern Nigeria. A reconnaissance. J. Min. Geol. 2, 65-69.

Orazulike, D. M., 1994, The Mineralogy and Texture of Lead-zinc-Copper ores of Enyigba lode, Abakaliki, Nigeria. J. Min. Geol. 30 (1), 25-32.

Rayment, R. A., (1965). Aspects of Geology of Nigeria. University of Ibadan press, pp. 130

Reynolds, J. M., 1997, An Introduction to Applied and Environmental Geophysics. John Wiley and Sons, Inc., New York, USA.

RMRDC (1998). Raw materials: exportation of which is detrimental to the Nigerian economy. Update report, Raw Material Research and Development Council, Abuja.

Sarma V. S. (2014) Electrical Resistivity(ER), Self Potential (SP), Induced Polarisation (IP), Spectral Induced Polarisation (SIP) and Electrical Resistivity Tomography (ERT) prospection in NGRI for the past 50 years-A Brief Review. J. Ind. Geophys. Union 18, 245-272.