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GEOPHYSICAL INVESTIGATION OF POTENTIAL FELDSPAR DEPOSITS IN MOKWA, NIGERIA FOR ECONOMIC BENEFITS

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ABSTRACT

The geophysical technique of Electrical Resistivity in mineral rocks investigation has been found to be one of the very effective and convenient methods. It was therefore applied using Schlumberger configuration to investigate the location, depth and the economic viability of Feldspar mineral deposits at the study location in Mokwa, Niger State, Nigeria. This research is aimed at determining the location and economic viability of Feldspar deposits in Mokwa that can serve as Industrial fillers or induce the development and sustainability of both small and medium scale paint, plastic, rubber and adhesive Industries within and outside the study area. 30 Vertical Electrical Soundings (VES) were acquired in 6 profiles using ABEM SAS 4000 Terrameter with 50 m spacing in between each profiles. The results revealed that Profile 1 VES point 5, profile 2 VES point 2, profile 4 VES point 4 and profile 5 VES point 5 are underlined with rocks of Low electrical resistivity values which implied possible Feldspar deposits. The highest Feldspar Deposits with average thickness of 7.87 m was discovered in profile 1, while profile 4 exhibited the lowest deposits with thickness of 2.50 m. On the average, the depths of these minerals rocks from the surface fell in the interval of 0.06 m to 8.00 m. However, the discovered feldspar deposits are not of much economically viable for Industrial filler exploration capable of influencing any Industrial development in either small or medium scale capacity.

Keywords: Feldspar Deposits, Industrial filler, VES, Electrical Resistivity.

INTRODUCTION

Feldspars ($KAlSi_3O_8$ – $NaAlSi_3O_8$ – $CaAl_2Si_2O_8$) are found widely in abundance because the temperature, pressure, elements within the magma and melts favour their formation. They are thus tectosilicate minerals with structures that allows for inclusion of many elements (Kayode, Oyedele, Oladele & Emakpor, 2016). The occurrence of Feldspar deposits in addition to some other minerals (Clay, Silica, Sand, Copper, Iron, Lead, Kaolin & Limestone) has been reported in different areas of Niger State, North-Central Nigeria, specifically in Mokwa according to the Niger State Statistical year Book (2011) edition. Despite the report, the Feldspar deposits remains largely un-exploited within the State. Feldspars are important in agricultural practices for promoting water and nutrients retention in soil and are always mined for a wide array of some other human uses such as being a common raw material used in glassmaking, ceramics, and to some extent a filler and extender in paint, plastics, toothpastes, rubber and adhesive Industries (Kayode, Oyedele, Oladele & Emakpor, 2016). In glassmaking, alumina from Feldspar improves product hardness, durability, and resistance to chemical corrosion. Feldspars usually are white or nearly white, though they may be clear or light shades of orange or buff. They usually have a glassy lustre. Feldspar, also called a rock-forming mineral, is very common, and usually makes up a large part of the rock. Most of the products we use in our domestic activities every day are made with Feldspar, the most abundant group of minerals in the earth's crust. The increase in domestic and global demand for these clay minerals, most especially, the Feldspars has led to the renewed interest in the search for its economically viable deposits locations in Nigeria (Oluwafemi, 2012). The numerous uses of Feldspar provided a ready market for any available amount because of its high consumption by the Industries. The Feldspar products are sold directly to the various consumer Industries namely ceramic, crockery, and sanitary ware, and foundry, glass, paint and paper industries. A sizeable quantity is believed to have been consumed by small-scale units as well as cottage Industries (Oluwafemi, 2012).

In relation to mineral investigations, the mineral's subsurface characteristics of interest to the researcher include; the location, distribution, depth, deposits economic viability, structure of the Feldspars deposits, grain size, material strength, porosity, permeability, to name a few. The earth's inherent complexity can make it difficult or impossible to infer these characteristics from direct observation. Therefore, they often must be inferred from the distribution of more fundamental physical properties such as density, electrical resistivity, magnetic susceptibility, and acoustic impedance. These basic properties can be measured via geophysical surveys that record the earth's response to various types of natural or artificial signals (Okunlola & Jimba 2006). Thus the geophysical methods have been found to be very useful for Feldspar deposits investigations because of the intrinsic heterogeneity of the medium (Okunlola & Jimba 2006), Okunlola & Ofonime (2006). The high contrast in resistivity values between carbonate rock, clayey and sandy materials favours the use of electrical resistivity method for determining the boundary between these Earth materials (Okunlola & Somorin 2006).

In lieu of the above, electrical geophysical technique was used to discover the Feldspars deposits location, depths and estimated quantity at Mokwa. These methods have been used in the reserve estimation of mineral deposits in Nigeria as captured online (Non-Metallic Mineral and Industrial Materials 2012), (Kayode, Oyedele, Oladele & Emakpor 2016). This research is aimed at determining the Feldspar deposits location, depth and the economic viability of its deposits that can serve as Industrial fillers or induce the development and sustainability of both small and medium scale paint, plastic, rubber and adhesive Industries within and outside the study area.

Geological Settings of the Study Area

The study area is in Mokwa, capital town of Mokwa Local Government of Niger State, North-Central, Nigeria. It is bounded by latitudes 9.16°N to 9.17°N and longitudes 5.03°E to 5.04°E with land mass of 4,338 Km2 and 244,937 population size according to the 2006 census figure. It is geologically located within the Bida Basin which is a NW–SE trending intracratonic sedimentary basin extending from Kontagora in Niger State of Nigeria to areas slightly beyond Lokoja in Kogi State. The Bida Sandstone is the basal sediment of the Middle Niger Basin and it consists mainly of fine to coarse grained sandstone, conglomerates, siltstone and claystone (Yusuf 2016).

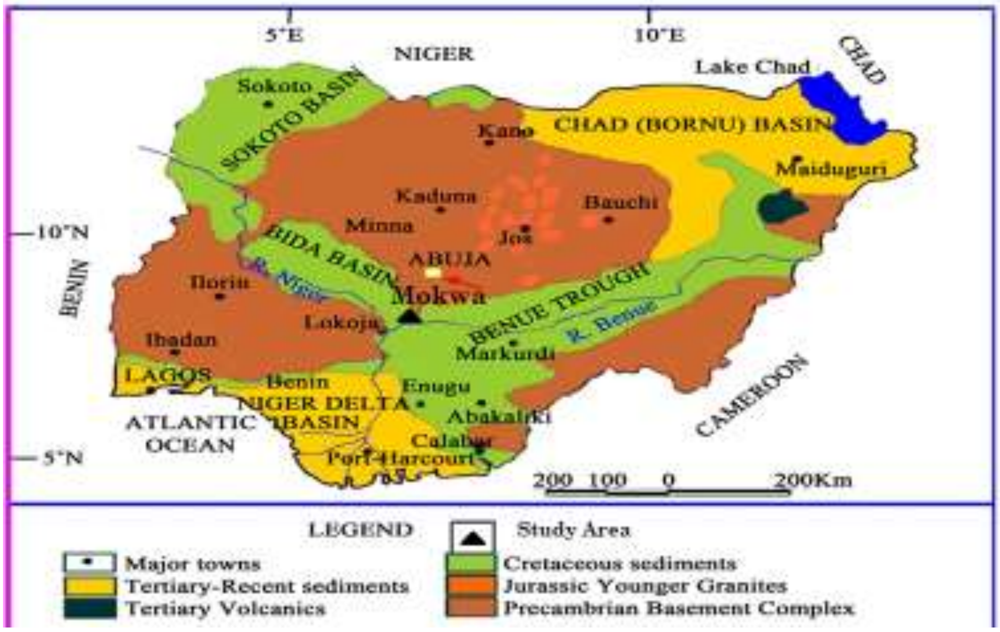


Figure 1: Geologic Map of Nigeria indicating the study area.(Yusuf *et al.,* 2018)

Theory of Electrical Resistivity (ER) Method

ER method allows artificial electric current to be introduced into the land via two current electrodes (A and B) which measures the potential voltage generated along the two other voltage electrodes (M and N) (Figure 2) under the current flowing across (Atonio *et al.,* 2016). The introduction of an electrical current into the land through the electrodes A, B, will produce potential difference (ΔV) across M and N, thus allowing the calculation of the apparent resistivity through the equation (1):

$$\rho_a = K\frac{\Delta V}{I}(ohm.m) \quad (1)$$

This make it possible to identify the different layers of soil minerals, weathered rock, and bedrock through the resistivity values obtained from the field surveys using various possible electrode configurations.

METHODOLOGY

This geophysical electrical investigation is focused on the subsurface geological structure (Feldspar deposits) and would be based on the accurate interpretations of resistivity data collected from field surveys carried out. The vertical and lateral distribution of Feldspar deposits in Mokwa was investigated with ABEM SAS 4000 Terrameter, using the electrical resistivity method of Vertical Electrical Sounding (VES) with Schlumberger electrode array configuration technique covering six profiles with maximum AB/2 spacing of (1 to150) m. The reason for using this method aside its greater depth penetration (Badmus, & Olatinsu, 2009), is to be able to delineate the depths and regions of high and low concentrations of Feldspar deposits within the study area with optimum accuracy as well as economy of time, fund and labour (Yusuf *et al.,* 2018).

Field Procedure

The adopted VES technique in this investigation consists of rock resistivity measurements using the Schlumberger electrode array and increasing separation between the emission and reception electrodes and the centre of the array (allocation point test), and its orientation is kept fixed (Figure 2).

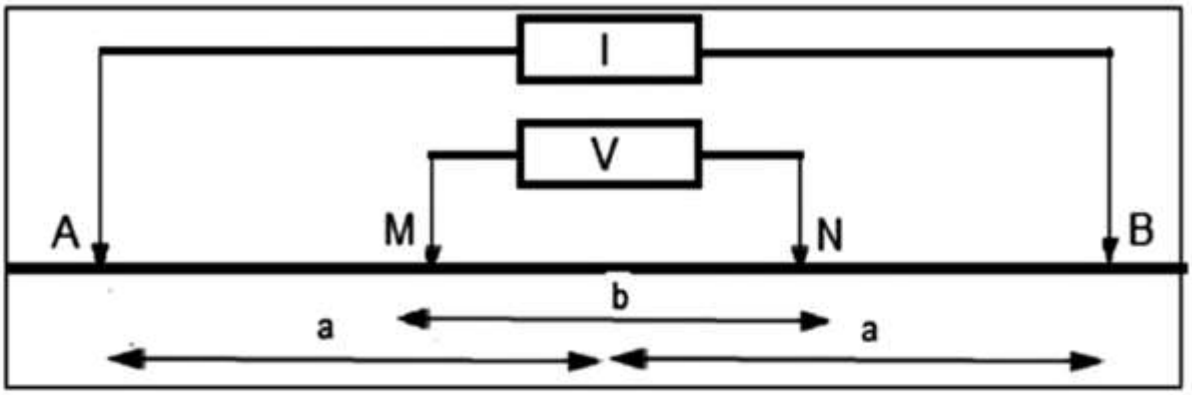


Figure 2: Electrode arrangement in the field - VES Schlumberger electrode array (yusuf *et al., 2018)*

This procedure allows for injecting a steady state electrical current into the ground and observing the resulting distribution of potentials (voltages) at the surface, i.e. the observation of apparent resistivity values at a fixed point, at increasing depths, by increasing the separation between the current electrodes A and B. Several other electrode arrays can also be adopted for this same field surveys; however, the Schlumberger array was chosen because of its superiority in vertical resolution, since the interest is in economy of the thickness and it usually records higher quality data than other arrays. Another important advantage it also possesses over the other alternative arrays (such as Wenner and others) is the possibility of improving the signal to noise ratio by moving only the MN electrodes during data acquisition.

Field Data Analysis

The VES field survey data collected from different locations along the six profile lines were interpreted with the state-of-the-art interpretation technique, called the 2-D smoothed damped least squares inversion algorithm. The results obtained based on 2-D inversion of field data and other geologic information, were interpreted and the lithology of the area, spatial variability in soil electrical properties in relation to the economic viability of Feldspar deposits were determined. In interpreting this Imaging data, Computer software was used due to the large amount of data collected from the field. IPI2WIN.EXE software which performs smoothness constrained inversion (automatic model interpretation) using finite difference forward modelling and quasi-Newton techniques was employed (Yusuf 2016). The VES field data were plotted as pseudo and resistivity cross-sections in order to look at the spatial distribution of the Feldspar deposits within the study area. The results were presented in terms of layer numbers (N), resistivity values (ρ), thicknesses (h) and depths (d) of the geo-electric section for all the VES points from which revealed the achievement of the objectives of this investigation.

Results and Discussion

The electrical resistivity of the mineral rocks in the study area were investigated for the thirty Vertical Electrical Sounding points taken with 50 m interval from each of the reference points. The resulting plots (sounding curves) of some of the profiles obtained are shown in Figures 3 (a) – (c).

Tables 1 (a) and (b) summarizes values of the apparent resistivity, thickness (h) and depth (d) at different layers in each of the sounding curves, while Table 2 gives that of the selected points of interest (possible Feldspar deposits locations) with their possible rocks in each layer of the vertical electrical soundings (VESs).

TABLE 1 (a): Apparent Resistivity, Thickness and Depth Values Across Profiles 1-3 Mokwa

VES	L	PROFILE 1			PROFILE 2			PROFILE 3		
		P	h	D	P	H	d	P	H	D
	1	418	0.12	0.00	314	0.39	0.00	637	2.13	0
1	2	497	14.78	0.12	334	25.32	0.39	857	11.24	2.13
	3	1391	α	14.90	1770	α	25.71	1238	α	13.37
2	1	326	2.11	0.00	22.89	0.48	0.00	276	5.01	0.00
	2	345	3.80	2.11	304.9	15.13	0.48	296	8.36	5.01
	3	420	α	5.91	1071	α	15.61	1320	α	13.37
3	1	146.5	0.499	0.00	169	0.78	0.00	276	4.19	0.00
	2	166.5	7.17	4.99	189	13.23	0.78	322	7.03	4.19
	3	1193	α	12.16	1181	α	14.01	1071	α	11.22
4	1	151	2.10	0.00	174	0.68	0.00	302	2.52	0.00
	2	171	10.30	2.10	194.1	10.52	0.68	304.8	132.97	2.52
	3	1417	α	12.40	1217	α	11.20	1345	α	135.49
5	1	72.60	0.90	0.00	157	0.55	0.00	284.8	4.11	0.00
	2	48.70	13.33	0.90	177	140.45	0.55	278.3	30.88	4.11
	3	1405	α	14.23	1681	α	141	1060	α	34.99

VES = Vertical Electrical Sounding; L = Layer; P = Apparent Resistivity in (Ωm); h = Thickness in (m); d = Depth in (m) and α = Infinity.

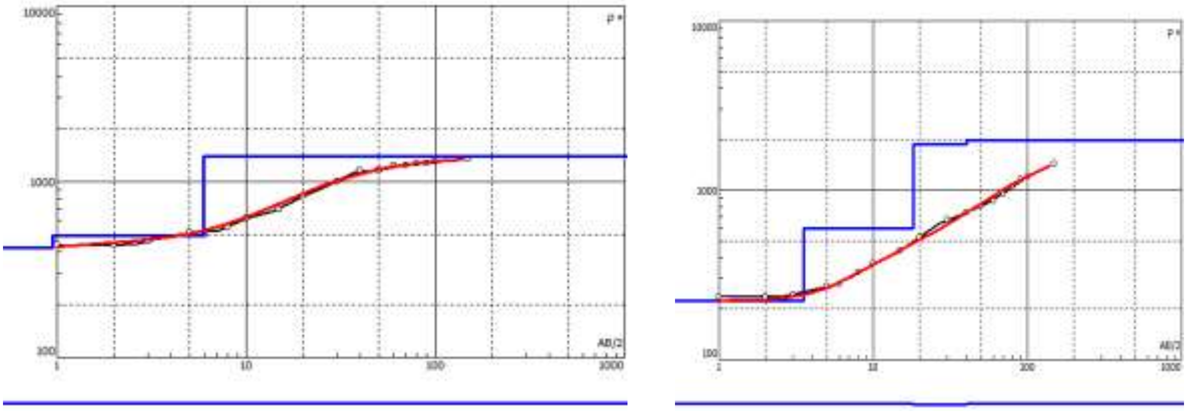
TABLE 1 (b): Apparent Resistivity, Thickness and Depth Values Across Profiles 4-6 Mokwa

VES	L	PROFILE 4			PROFILE 5			PROFILE 6		
		P	h	D	P	H	d	ρ	H	D
1	1	258.3	2.40	0.00	385.6	2.65	0.00	169	1.54	0.00
	2	192	12.13	2.40	294	10.15	2.65	655	6.63	1.54
	3	1270	α	14.53	1096	α	12.80	1305	α	8.17
2	1	436	2.00	0.00	172	2.57	0.00	274	2.81	0.00
	2	167	5.63	2.00	270	3.37	2.57	440	19.19	2.81
	3	970	α	7.63	1620	α	5.94	1162	α	22.00
3	1	436	4.50	0.00	137	2.14	0.00	250	2.46	0.00
	2	113.4	158.49	4.50	290	30.86	2.14	431	30.54	2.46
	3	1329	α	162.99	1511	α	33.00	1304	α	33.00
4	1	432	2.19	0.00	93.4	0.49	0.00	270	2.99	0.00
	2	92.6	167.79	2.19	273	6.62	0.49	432	19.10	2.99
	3	1340	α	169.98	1920	α	7.11	1455	α	22.09
5	1	488.3	2.91	0.00	72.6	0.06	0.00	253	4.11	0.00
	2	189	12.83	2.91	266	19.55	0.06	885	22.99	4.11
	3	2190	α	15.74	1920	α	19.61	1455	α	27.10

VES = Vertical Electrical Sounding; L = Layer; P = Apparent Resistivity in (Ωm); h = Thickness in (m); d = Depth in (m) and α = Infinity.

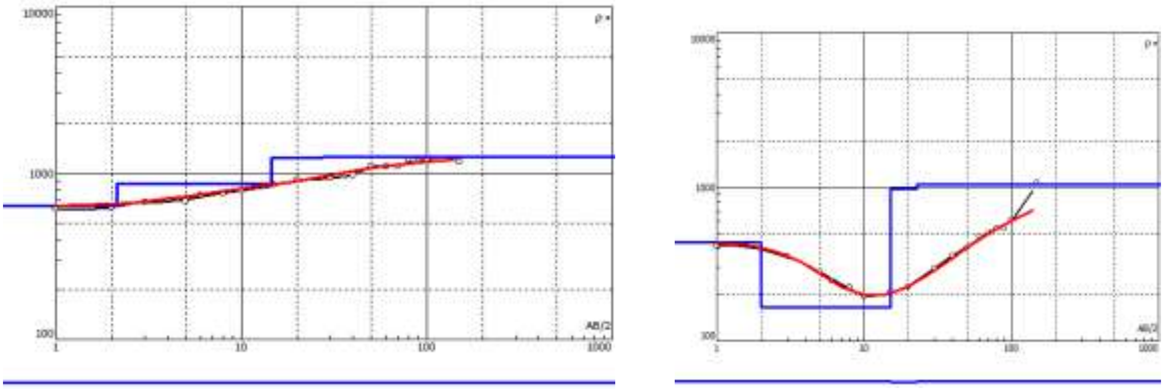
TABLE 2: Apparent Resistivity Ranges with Thickness, Depth Values and possible Feldspar deposits locations Across Profiles 1 - 6 Mokwa

Profiles	Layers	Resistivity range (Ωm)	Depth (m)	Thickness (m)	Possible rocks
1	1	72.60 – 418	0.12 – 4.99	4.87	Clay, Feldspar, Sandstone
	2	48.70 – 497	5.00 – 8.00	3.00	Clay, Feldspar
	3	420 – 1417			
2	1	22.89 – 314	0.48 – 3.5	3.02	Clay, Feldspar
	2	177 – 334			
	3	1071 – 1770			
3	1	276 – 637			
	2	278.30 – 857			
	3	1060 – 1345			
4	1	258.30 – 488.30			
	2	92.60 – 192	2.00 – 4.50	2.50	Clay, Feldspar, Sandstone
	3	970 – 2190			
5	1	72.60 385.60	0.06 – 2.57	2.51	Clay, Feldspar, Sandstone
	2	266 – 294			
	3	1096 – 1920			
6	1	169 – 274			
	2	431 – 885			
	3	1162 – 1455			



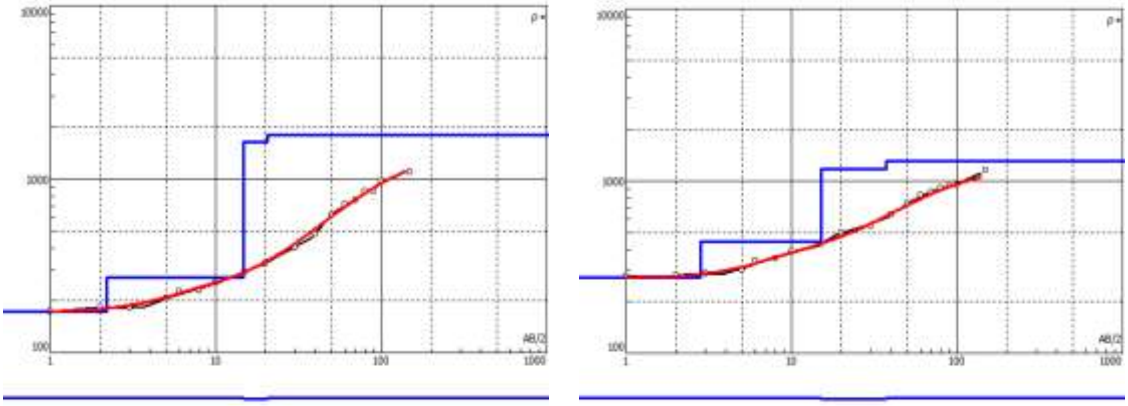
Profile 1 Profile 2

Fig. 3 (a). Computer graphical modelling for VES 1 of Profiles 1 & 2 at the sounded stations.



Profile 3 Profile 4

Fig. 3 (b). Computer graphical modelling for VES 1 of Profiles 3 & 4 at the sounded stations.



Profile 5 Profile 6

Fig. 3 (c). Computer graphical modelling for VES 1 of Profiles 5 & 6 at the sounded stations.

Feldspar Deposits Reserve Estimate

Feldspar Deposit Reserve Estimation (FDRE) for the study area has been determined using equation (2) as also used in estimating Kaolin deposits by (Kearey, Brooks, & Ian, 2002). The study area has the following physical parameters:

Study Area: (300 x 300) m, i.e. 90,000 m^2;

Average thickness of Feldspar Deposits: 4.87 m

Feldspar Density: 2.56 g/m^3.

FDRE=Area x Thickness x Density (2)

Therefore: Applying Equation (2);

FDRE=90,000 m^2 x 4.87 m x 2.56 g/m^3 ≈ **1.0 × 10^6 t.**

GENERAL DISCUSSION

Profile 1 revealed the presence of Feldspar deposits of 2 different litho-facies mainly in the first and second geoelectric layers at VES point 5. The resistivity ranged from (72.60 to 418) Ωm with thickness of between (0.12 and 8.00) m as shown in Table 2. Profile 2 revealed the presence of little Feldspar deposits at a single litho-face in the first geoelectric layer at VES point 2 (Table 2). The resistivity of the profile 2 ranged from (22.89 to 314) Ωm with thickness of between (0.48 and 3.50) m (Table 2). Profile 4 also revealed the presence of little Feldspar deposits at a single litho-face in the second geoelectric layer at VES point 4 (Adekoya, Kehinde-Phillips, & Odukoya 2003). The profile 4 resistivity distributions ranged from (92.60 to 192) Ωm with thickness of between (2.00 and 4.50) m (Table 2). Profile 5 also exhibited the traces of little Feldspar deposits at a single litho-face in the first geoelectric layer at VES point 5. In this profile, resistivity ranged from (72.60 to 385.60) Ωm with thickness of between (0.06 and 2.57) m (Table 2). However, the whole of profiles 3 and 6 in addition to other VES points along the prospecting profiles are underlined with rock features of relatively high resistivity which ranges from weathered sandstones to conglomerates and limestones Loke (1999) and (Ishola, Adeoti, & Obianeri 2010). This is similar to the observations on the Mineral Rocks at Olode Village in Ibadan, Oyo State, Nigeria by (Akintayo, Ojo, Toyin, Omotoso & Olorunyomi 2014). Summarily, profile 1 exhibited the highest Feldspar Deposits with average thickness of 7.87 m, while profile 4 exhibited the lowest with thickness of 2.50 m.

CONCLUSION

Geophysical techniques of geomagnetic and geoelectric methods had been used to investigate the depth and location of some mineral rocks such as mica, feldspar, beryl, tantalite, tourmaline, and other gemstones in other several study areas with optimum successes. The results from this current investigation correlated well with some of the similar results from other areas where same geophysical techniques were applied and thus gave birth to the following conclusions made.

There are minerals rocks with low electrical resistivity values northern edge and away from the center to the southern regions of the study area. However, the central and southern regions exhibited mineral rocks with high electrical resistivity values. The possible rocks in the region of Low electrical resistivity are Feldspar clays and sandstones deposits, while rocks in the region with high electrical resistivity are sandstone, Conglomerates and Limestone. Also, this conclusion affirms the earlier publications on the existence of Feldspar deposits within the study area by State Bureau of Statistics, 2011. On the average, the depths of these mineral rocks from the surface fall in the interval of 0.06 m to 8.00 m. The Feldspar Deposits Reserve for the study area in Mokwa was approximately estimated at **1.0×10^6 t** with overburden thickness that ranged from 0.06 m to 8.00 m. This study has established that the investigated location in Mokwa with average thickness of 7.87 m is not much of economic value as also observed earlier in the south-western Nigeria.

More emphasis should therefore be placed on domestic based researches through provision of domestic research funds to the Researchers, this could enable the expansion of this investigation to cover more prospecting areas within Mokwa for possible discovery of economically viable feldspar deposits locations and many more other economic clay minerals. More investments on the development of local research technologies and techniques by the related Industries that utilizes such local raw materials to enable more coverage of this research and the discoveries of some other economic minerals of their interest. The mining, geological and research Industries should be revitalized to rise up to the challenges of assisting towards maximum utilization of these raw materials. Research and developmental Institutes should be properly equipped for effective utilization by the researchers. Finally, integrated geological, geophysical studies and drill holes should be done for better understanding of the mineral prospect of the study area.

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