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Research article

The Use of Geographic Information System in Wenner Offset Electrical Resistivity Appraisal of Oyo-Iwah Marble Deposit, Lokoja Local Government Area, Kogi State, Nigeria

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Abstract

Geographic Information System (GIS) was applied to geophysical Wenner offset appraisal of Oyo-Iwah marble deposit in the Basement Complex of south-western Nigeria. The offset Wenner sounding electrical resistivity method with a multi-core cable was adopted to determine the surface lateral extent, trend including overburden thickness/bedrock topography and thickness of Oyo-Iwah marble deposit. The response curves obtained were processed and interpreted using IXID and IPI2WIN, a combination of applicable software. The data obtained were fed into various GIS software (TIN, grid surface modeling and 3-D analyst). The study area was grouped into three units of relatively high resistivity values: greater than 1000 Ωm found in the north and southern parts, attributed to the effect of the host rocks (gneisses, schist, quartz/quartzite) separated by low resistivity contour (less than 300Ωm) with narrow closure trending NE-SW, and another narrow closure of 500Ωm. These were inferred to indicate faulting or some form of structural disturbances and may be influenced by differential weathering due to contact zone effect. The marble deposit occurrences are exposed in some areas, while in some places it starts from 3-4m as overburden and thickness of occurrence goes between 20-30m conservatively in some places, while in other places it goes beyond 30m. The marble deposit occurrence appears massive in nature and structurally controlled.

Keywords: Geographic Information System (GIS), Wenner offset, Appraisal, Basement Complex, differential weathering, contact zone effect, lateral extent, trend, thicknesses and bedrock topography.

1.0 Introduction

In Wenner offset sounding, resistances are often measured with the spacing series 1, 1.5, 2, 3, 4 … 128m. This system requires a total of 48 electrodes to produce a 16-point Wenner apparent resistivity curve. The total number of electrode positions can be reduced by increasing the spacing according to the series 1.44, 2.08, 3, h/3 - - 117m (Barker,1981; Barker,1989). After the first two spacings the potential electrodes will fall on positions previously occupied by current electrodes. A total of 34 electrode positions will now produce a 14-point Wenner curve. This is still a large number of electrode positions. Schlumberger sounding suffers from the same problems. If AB/2 is increased according to the series 1, 1.5, 2, 3, 4, --- 128m and potential electrodes fall on positions previously occupied by current electrodes a total of 32 or 34 electrodes are needed to produce a 15-point apparent resistivity curve.

A method by which a number of electrodes in a sounding may be greatly reduced became apparent through the development of the “OFFSET” sounding method for reducing the effects of lateral resistivity variations (White & Scott, 1998; Barker,1992 & Barker, 1996). Lateral changes in the surface resistivity will cause changes in the subsurface resistivity values, which might be and frequently are misinterpreted as changes with depth. In many engineering and environmental studies, the subsurface geology is very complex where the resistivity can change rapidly over short distances. The resistivity sounding method (I-D) may not be sufficiently accurate for such situation (Loke, 1997, 1999). Offset Wenner sounding is conveniently conducted using a five electrode array (Fig. 1). In practice, this is not different from the normal sounding, although additional electrodes are used to change from one adjacent set of 4 electrodes to the other. Two resistance values are obtained which are averaged to provide the offset Wenner resistance, RD. RD is equivalent to high quality Wenner resistance, RW. If the spacing is increased according to the series 0.5, 1, 2, 4, 8, 16, 32, 64 and 128m, so that the potential electrodes always fall on positions previously occupied by current electrodes high quality resistance measurements are obtained. Additional points on the apparent resistivity curve are obtained by measuring resistance with various arrangements of the five electrodes. The electrode arrangements that allow the measurements of RA, RB, and RC are shown in Figs. 2 and 3. There are various ways in which intermediate Wenner points may be computed by the relationship

$$Rw(3a) = ½RD(2a) + RB(2a) – RB(a) + ½RD(4a) \quad \text{… (1)}$$

RB(2a) is the resistance measured with arrangement B and spacing 2a. Using this equation Wenner resistance is computed for spacing 1.5, 3, 6, 12, 24, 48, 96 and 192. A further resistance on the Wenner apparent resistivity curve may be obtained from the relationship

$$RW(2a) – 2[(RC(a) – RD(a)] \quad \text{-- (2)}$$

This enables a Wenner resistance at 256m to be computed from resistance measured at a spacing 128m. However, the latter calculated will amplify errors of observation and the computed value of RW(2a) is likely to be unreliable [1]. It is then possible by occupying only spacing 0.5, 1, 2, 4, 8, 16, 32, 64 and 128m, to measure sufficient resistance to enable the construction of an 18-point Wenner apparent resistivity curve.

	Δ2	Δ3	Δ4	Δ5	
ΔC	ΔP	ΔP	ΔC		RD_1 }
	ΔC	ΔP	ΔP	ΔC	RD_2}RD

Figure 1: Offset Wenner sounding basic array.

2. Geology of the Study Area

The study area is bounded by latitudes 6^0 26’E and 6^0 30’E and longitudes 7^0 54’N and 7^0 59’N with a total area of $8km^2$ (Figs. 5, 6 and 7). It falls within the Precambrian Basement Complex of south-western Nigeria consisting predominantly of migmatite, biotite granite gneiss, porphyroblastic gneiss, schists, with minor pegmatites and quartz veins (Elueze & Bolarinwa, 2001). Mica-schist is the most common rock type. Interbanded with the mica schist is Banded Iron Formation (BIF), talcose schists of Komatitic affinity and psammitic rocks (Olobaniyi, 1997; Olobanyi,

Adekeye Annor, 2001). The local geology is underlain by the Basement Complex rocks of western Nigeria consisting of quartz/quartzite, pebbles and ferrugenized quartzite boulders, migmatite, schist and pegmatite exposures. The lithological units are magmatic and intrusion of older granite series, folded metasediments of the Igarra, Kabba Jakura Formation, which comprises gneiss (Jatau & Oyinloye,2003; Jatau, Oyinloye & Ogah, 2005).
The major mineral in the area that is geophysically mapped is marble. Some pockets of iron ore are located as iron capping on top of some ridges quartz in form of pure lenticular quartzites is another mineral of economic importance which are white and milky in colour, good for industrial use. This is located predominantly in the western part of the study area. There are few pegmatite dykes occurring within and outside the marble. The main minerals of pegmatite are quartz and feldspar. The marble appears to have roughly NE-SW trend, thinning out in the south-westward direction. In grab samples, the marbles are the massive crystalline white and grayish types most probable a product of intense metamorphism of the Precambrian rock suites. The evenly distributed residual calcite in the pegmatites and absence of contamination of the rocks in the marble suggest a metasomatic origin (Jatau, Oyinloye & Ogah, 2005). The major rock types encountered in the area understudy are migmatite, schist, quartzite and quartz schist, ferrugenized sandstone, pegmatite, marble, clay/laterite and sand (Fig. 6).

3.0 Materials and Methods

Multicore cable provides offset Wenner resistance at 0.5, 1, 2, 4, 8, 16, 32, 64 and 128m. Spacing is therefore increased by doubling, which was adopted for this study.

	Δ1	Δ2	Δ3	Δ4	Δ5
Δ1	Δ2		Δ3	Δ4	Δ5

Figure 2: The principle of offset sounding as employed in the BGS multi-core cable.

Δ1	Δ2	Δ3	Δ4	Δ5	
C	P	-	P	C	RA
C	C	-	P	P	RB
	P	-	C	P	RC
C	P	-	P	C	RD_1}RD
	C	P	P	C	RD_2}

Figure 3: Various resistances measured with the five electrode array.

The check on the reliability of the results is given by the relationship RA = RB + RC … (3). The "tripotential" field check for most conditions the observed resistances magnitude will be varying in the following way RA > RC > RD, = RD_2 >> RB … (4).
The Wenner resistance at spacing 256m is obtained from the following relation Rw(256) = 2Rc(128) – RD(128) … (5). The errors involved in this calculation are relatively high and especially in curves in which the last segment is dropping; this point can be unreliable [1, 2]. All the Wenner resistances however derived may be converted to apparent resistivity, PW using the relationship PW = 2aRw (6). The basic electrode arrangement comprises five equally spaced electrodes, the third electrode being at the center of the array. The spacing between electrodes is determined by the spacing switch as follows: spacing switch position 1, 2, 3, 4, 5, 6, 7, 8, 9; electrodes spacing (a) metres 0.5, 1, 2, 4, 8, 16, 32, 64, 128. The configuration switch determines the arrangement of the four electrodes used in any one measurement is as follows (Fig. 4)

Configuration Switch	Electrodes	Measured Resistance	
	1 2 3 4 5		
A	C P – P C	RA	
C	C P – C P		RC
D_1	C P – P C	RD_1	

D_2 - C P P C RD_2
B C C – P P RB

Figure 4: The configuration switch.

The potential reverse (PC) switch enables the poles of the potential electrodes to be reversed, if this is necessary for the correct functioning of the resistance-measuring apparatus.
This method of electrical resistivity gives both vertical electrical sounding (VES) and horizontal electrical profiling inference simultaneously. This was preferred to other geophysical method because of the sharp contrasts between the ore body and overburden/host rocks.
This study was aimed at ascertaining the general subsurface lateral extent trend including overburden thickness/topography and probable thicknesses of the deposit. Probable geologic structure (fault, fractures and weak zones) within the deposits are also identified. This may influence mining consideration strategies and ground-water conditions.

4.0 Result and Discussion

A total of 492 sounding points were used. The results were interpreted using a combination of applicable software, AT0, Vesmond, IXID and IPWIN to determine the resistivity values, of the various layers, depth probe and their corresponding thicknesses. The isometric contour maps for the study area were also prepared using the apparent values obtained for AB/2 = 8, 10, 16, and 32 (Figs. 6, 7, & 8). The geophysical map of the area is shown in Fig.9. The marble inferred area is considered less than 1000Ωm with depth occurrences between 20-30m conservatively. While greater values are non marble occurrences. The iso-resistivity contour map gave the lateral variation (overview) in the resistivity values. The area is grouped into 3 units of relatively high resistivity values greater than 1000Ωm in the north and south parts of the study area separated by low resistivity contour less than 300Ωm with narrow closure value trending roughly NE-SW in the southern part of the surveyed area. In the north, there is an observed narrow closure of 500Ωm contour lines being inferred to indicate faulting or some form of structural disturbances that might have been influenced by differential weathering due to contact zone effect (Elueze & Bolarinwa, 2001). The pseudo-sections plot gave vertical sectional view of the variation in apparent resistivity values with depth of penetration of the input current along each profile were quantitatively deduced into geo-electrical sections as shown (Figs. 9, 10 and 11), also showing depths of marble occurrences and depicts a good degree of correlation with the geological sections obtained. The main sources of water are surface and groundwater. The water table in the area varies between 12m during raining season and up to maximum of 30m during dry-season as observed in the boreholes. The marble is monolithic and impervious in nature, with few geological disturbances; therefore make the ground water seepage expectation minimal. A suitable size sump may be provided for any increase in seepage of water during raining season. This can be provided with a suitable size bound and garland drainage at the entire periphery of the mine and the sides of the streams and River Mimi (Fig. 5). The rain seepage water should then be collected to mine sumps for settlement of suspended solids. Therein the water should be pumped to the settling tanks which should be provided on a high elevation top of the mine for desiltation and discharged to natural water course.

5.0 Conclusion

Wenner offset electrical resistivity appraisal of Oyo-Iwah marble deposit, Lokoja Local Government Area of Kogi State, Nigeria was carried out with a total of four hundred and ninety-two (492) sounding points. The study area was grouped into three units of relatively high resistivity values greater than 1000Ωm attributed to the effect of host rocks (gneisses, schist, quartz/quartzite) separated by low resistivity contour less than 300Ωm with Narrow closure trending NE-SW and also other narrow closure of 500Ωm indicating some form of structural disturbances, attributed to differential weathering due to contact zone effect. The isometric maps of the study area were produced at AB/2 = 8, 16, and 32 metres showing lateral variation of the marble deposit. The pseudo-section were qualitatively deduced into geoelectric sections of the traversed profiles, depicting depth of the marble occurrences ranging from 20 – 30m mostly and in some places ranging beyond 30m and therefore massive in nature. Comparing the geoelectric sections with existing geology showed a good degree of correlation. The study area main sources of water are surface and ground water. The water table varies between 12m during raining season and up to a maximum of 36m during dry season as reduced from the sounding results and observed in the boreholes. The need to provide suitable size sump for seepage collection during drilling and blasting operation to avoid drainage problems is vital. It is also recommended that well-planned exploration holes may be desired for future quantification of the marble deposit.

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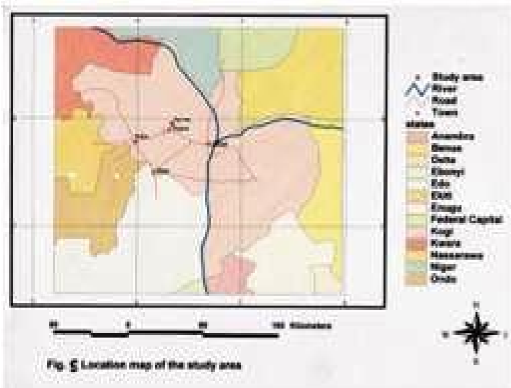
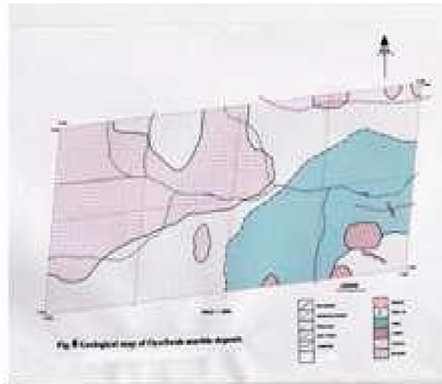
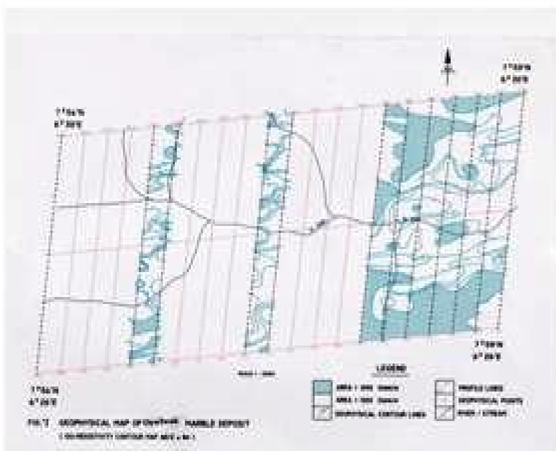
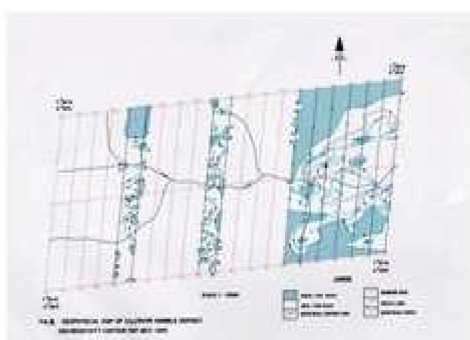
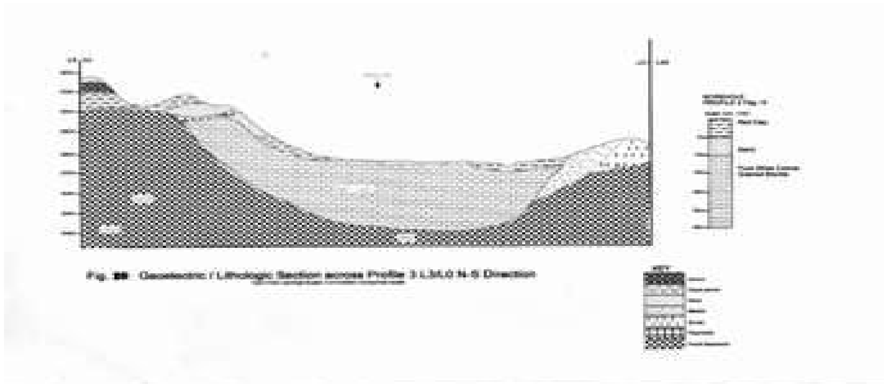


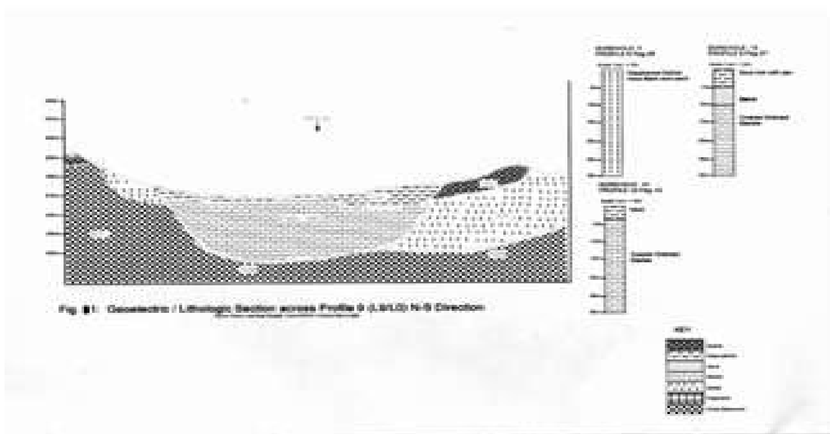
Fig. 5 Location map of the study area








Geoelectric / Lithologic Section across Profile 3 L3/L0 N-S Direction


Geoelectric / Lithologic Section across Profile 9 (L9/L0) N-S Direction