GEOLOGICAL AND GEOELECTRICAL CHARACTERIZATION OF THE UKOMI DIORITE DEPOSIT LOKPAUKWU, UMUCHIEZE AREA, SOUTH EASTERN NIGERIA: IMPLICATIONS FOR ESTABLISHING A QUARRY SITE

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***Abstract*- Geological and Geoelectrical studies have been carried out at a potential quarry site in UkomiLokpaukwu, Umuchieze area of Southeastern Nigeria. The surveys aimed at evaluating the geological parameters and establishing the surface and downward trends of a suspected quarry rock material, through resistivity variation characteristics, prior to the location of a rock quarry as well as estimating the overburden thickness. Geological study revealed that the diorite has a mean density of 2.85 x10^3 kgm^{-3}. Petrographically, laths of plagiosclase / Labradorite were set in a groundmass of smaller laths, iron oxide, olivine and pyrite. This texture is seen to be ophitic, similar to that of dolerite (diabase).The symmetrical Schlumberger configuration was used for the VES data acquisition with a maximum half current electrode spacing (AB/2) of 95m ensuring down to 63m of depth probe and potential electrode spacing of 28m. A total of twenty Six (26) VES points were established in the study area. Six (6) geoelectric sections (AA^1, BB^1, CC^1, DD^1, EE^1, and FF^1) were taken along NW-SE profiles (across main strike of rock mass). The diorite along profile AA^1 is buried below 6 to 9m at VES 3 and 4 respectively. This indicates that the event at VES 25 and 26 continues at VES 4 and 3 deeply buried at these two locations. Along profiles BB^1 and CC^1, the event in B^1 end is the same as the event in C end, pinching out toward BB^1. The diorite continued to VES 17 and 9 points. Wherever the shale occurs, resistivity values are low (1.9 – 120 Ohm-m). Along these profiles the diorite is buried between 1.0 to 3m. Along profiles DD^1 and EE^1, the diorite is buried at between 2.5 and 4m at VES 20, 21, 22 and 23, having a conical structure and shown in EE^1 profile with enhanced resistivity of 25-570 Ohm-m. Along profile FF^1 the diorite is deeply buried at VES 18 and 19 and not encountered at VES 16 and 15. Depths of burial range from 13m in VES 18 to 12m in VES 19, with resistivity value range of 44-4413 Ohm-m. This implies that deeper burial enhances quality due to less weathering. Again the conical shape is portrayed as the rock is not encountered at VES 16 and 15 locations. The central and southern parts of the mapped area do not have near surface rock exposure but buried to depth of about 12m. This is a lot of overburden and is made up of fractured shale and silty top soil which may introduce quite a lot of underground water into any quarry site thereby increasing working cost or production expenses. Core drilling in a NW-SE trend at 2 points per profile be carried out to estimate the reserve since the establishment of any quarry site is predicated on the correct estimation of reserves. Adequate dewatering system must be put in place when the quarry is established due to the presence of the existing dam within the vicinity of the quarry. This study not only confirmed the presence of an igneous intrusion (Diorite), but proceeded to estimate the downward distribution thereby prompting further investigations aimed at determining projected reserves.**

***IndexTerms*—Diorite, Geolectric, Lokpaukwu, Mineralogy, Quarry, Schlumberger configuration.**

I. INTRODUCTION

Diorite is an intrusive rock intermediate in composition between gabbro and granite. It is produced in volcanic arcs, and in mountain building where it can occur in large volumes as batholiths in the roots of mountains. Because it is commonly speckled black and white, it is often referred to as "salt and pepper" rock. Diorite is the plutonic equivalent of andesite. Texturally, diorite is phaneritic (medium to coarse grained), contain mostly plagioclase, amphibole (hornblende) and / or pyroxene (augite). It is known to contain 52%-63% silica. Quarrying is a very old technology, used since the time of the ancient Egyptians for the limestone used in their immense pyramids, temples and monuments (Loupasakis and Kafakis 2008). Evidence at a quarry might also show available technology in the form of tools left behind and cut marks in the walls of the excavation pits. According to Bloxam (2011), the historical value of quarry site is listed as four data elements: the resource itself (that is, the raw material); the production remains (tools, and discarded products); the logistics (what it takes to get the raw material out of the quarry); and the social infrastructure (the organization of people required to use the quarry, make the objects and transport them away). She argues that quarries should be seen as complexes, fitting into a dynamic landscape where tradition, ancestry, memory, symbolism and information about territorial ownership coexist. A quarry is a type of open-pit mine from which rock or minerals are extracted (Lameed and Ayodele 2010). Quarries are generally used for extracting building materials, such as dimension stone, construction aggregate, riprap, sand, and gravel. They are often collocated with concrete and asphalt plants due to the requirement for large amounts of aggregate in those materials (Webmaster 2012). The recent growth in populations in the southeastern part of Nigeria has imposed significant stress on the existing inadequate building materials for construction. Consequently, it became very expedient to expand the existing quarry sites in the area as a result of the daily increase in the demand of crushed rock for building construction. This has caused the need for the exploration for more competent rocks to serve as quarry sites so as to meet this ever increasing demand. A number of factors determine whether a rock can be quarried for construction. These include the volume of material that can be quarried, the ease with which it can be quarried; the wastage consequent upon quarrying; and the cost of transportation as well as its appearance and physical properties (Yavuz et al, 2005). Furthermore, the volume must sustain not less than 20 years of quarrying (Bell, 2008).

II. AIMS AND OBJECTIVES

The aims of this work are to carry out the geological and geoelectrical assessment of the Ukomi diorite deposit in Lokpaukwu, umuchieze area and to evaluate the geological parameters that will influence the economic viability of quarrying the rock mass. This is done by the study of the resistivity variation characteristics of the subsurface in the area, to determine the overburden thickness.

III. LOCATION AND ACCESSIBILITY

Ukomi Lokpaukwu is located at bout 2.5km south of the Leru-Awgu Highway or at about 3km southeast of Lokpanta junction (figure 1). The Ukomi area presents gently undulating terrain with ridges that trend east to northeast. Valley areas are characterized by ponds or rock outcrops. Vegetable farms also occur at such valley areas. Ukomi Lokpaukwu is accessible through an East-West untarred road and through the Ishiagu highway at the SETRACO by-pass.

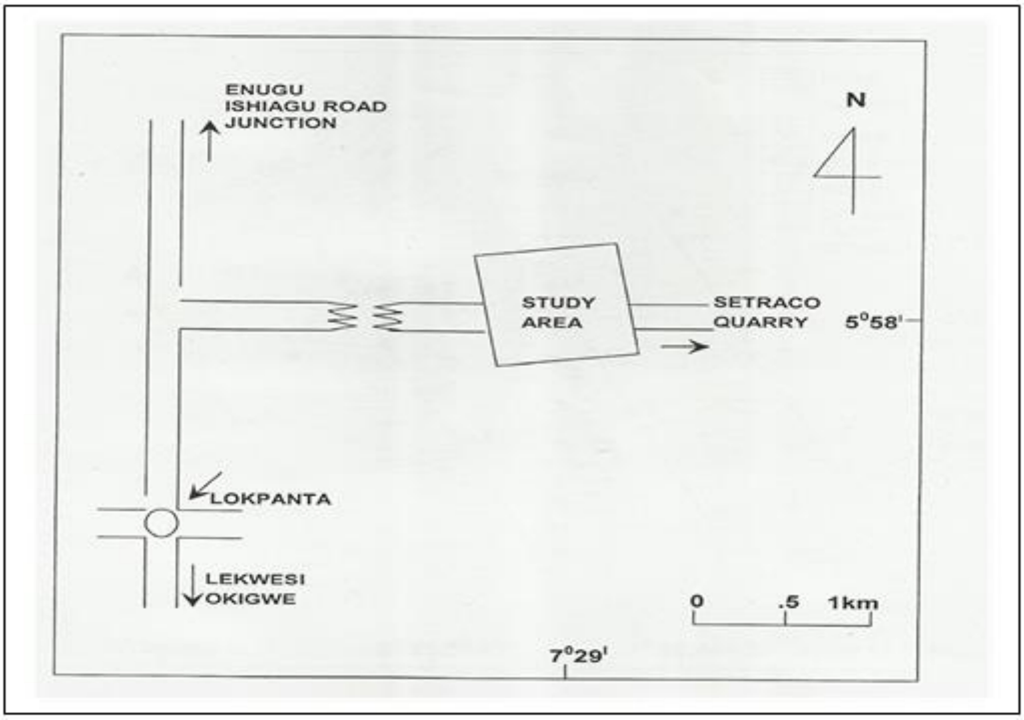

Fig 1: Location Map of the study area (UkomiLokpaukwu)

IV. GEOLOGICAL SETTING

Lokpaukwu is located within the Lower Benue Trough of Nigeria (figure 2), and it accommodates discontinuous exposures of eroded volcanic and hyperbyssal features (Adighije 2009). Lodged in the bowels of Lokpaukwu,Umunneochi local government area are vintage accumulation of lead, zinc and copper (John-Onwualu and Ukegbu 2009). Lead is used for the manufacture of car batteries and X-ray equipments, as it protects doctors and nurses working the machines from the rays. Still at Lokpaukwu is found gypsum – a raw material which is utilized in the production of cement, pharmaceuticals, Plaster of Paris (POP). The Benue Trough formed as a result of series of tectonism, accompanied by magmatism and repetitive sedimentation in the Cretaceous during the separation of South America from Africa. This separation left the Benue Trough as an aulacogen, a failed arm of an RRR Triple Junction (Burke, 1972; Olade, 1975). The Benue Trough is itself a part of the very expansive west and central African rift system in which it opened as an extensive sinistral wrench complex (Emery *et al*., 1975; Whiteman, 1982; Genik, 1993). A reconstruction by Murat (1972) shows the southern part of the Benue Trough as longitudinally faulted, with its eastern half subsiding preferentially to become the Abakiliki depression. During the filling of the Abakiliki-Benue sector of the Benue Trough in the Albian-Santonian times, the proto-Anambra Basin was a platform that became only thinly sediment-draped (Etuk et al., 2008). Basin subsidence in the southern Benue Trough was spasmodic. It was at a high rate in pre Albian time, low in lower Cenomanian, and very high in Turonian; the latter was an important phase of platform subsidence (Ojoh, 1990). This is thought to be the actual time of initiation of the Anambra Basin; a process that gained momentum in the Coniacian and climaxed during the Santonianthermotectonic event (Nwajide, 1990). Careful synthesis of the works of several authors (Murat, 1972; Nwachukwu, 1972; Olade, 1979; Benkhelil, 1982; Nwajide and Reijers, 1996; Mode and Onuoha, 2001; Ukegbu 2008) reveals that the Santonian movement or tectonic pulses (or compressional uplift) dating back to 84 Ma, was accompanied by widespread magmatism, folding and faulting that caused the Abakiliki area to become flexurally inverted to form the Abakiliki Anticlinorium. These forces displaced the depocentres to the west and southeastwards, forming the Anambra Basin and Afikpo syncline, respectively (Murat, 1972; Burke, 1972).

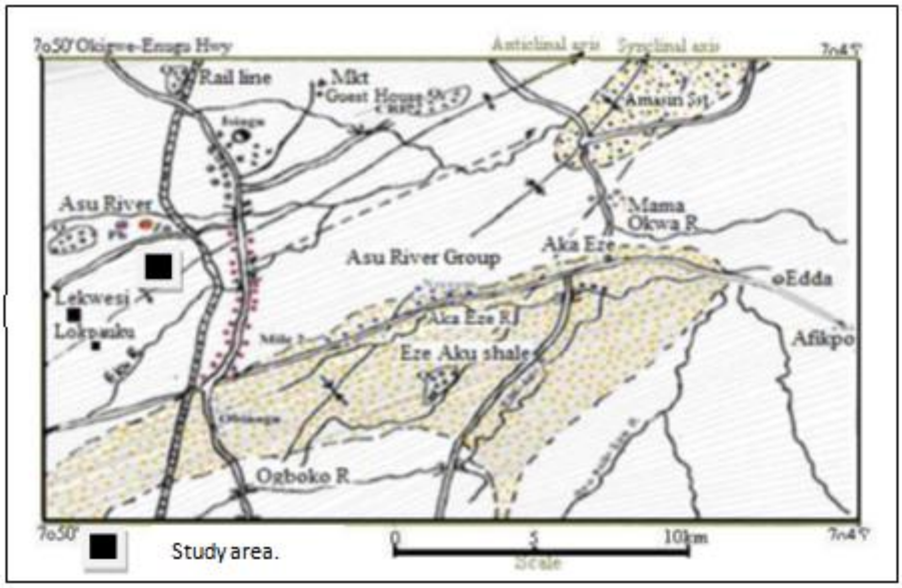

Fig 2: Generalised Geologic map of the study area within the lower Benue Trough (After Nwachukwu et al. 2010)

V. MATERIALS AND METHODS

The elevation measurements of the area were made using the Garmin 76CSx Global Positioning System (GPS), with a view to determining the spatial distribution of the rock mass. The GPS was also used in the location of the VES and sample points and this helped in the production of maps and other interpretations.

GEOLOGICAL STUDY

Geological mapping was carried out on a scale of 1:250, allowing for greater details and leading both physical and textural studies on the rock matter. Samples were collected for laboratory studies so as to comment on the quality. Result of the geological mapping (figure 3) informed the general trend of the outcrop hence the trend of the geoelectrical profiles shown in figure 3.

Samples of Diorite obtained from the field were first weighed in air and subsequently reweighed in water of density 1.00 x 10^3 kgm^{-3}. The samples were then soaked in water for 48 hours and the wet density determined. The average of the dry and wet values was taken as the mean density.

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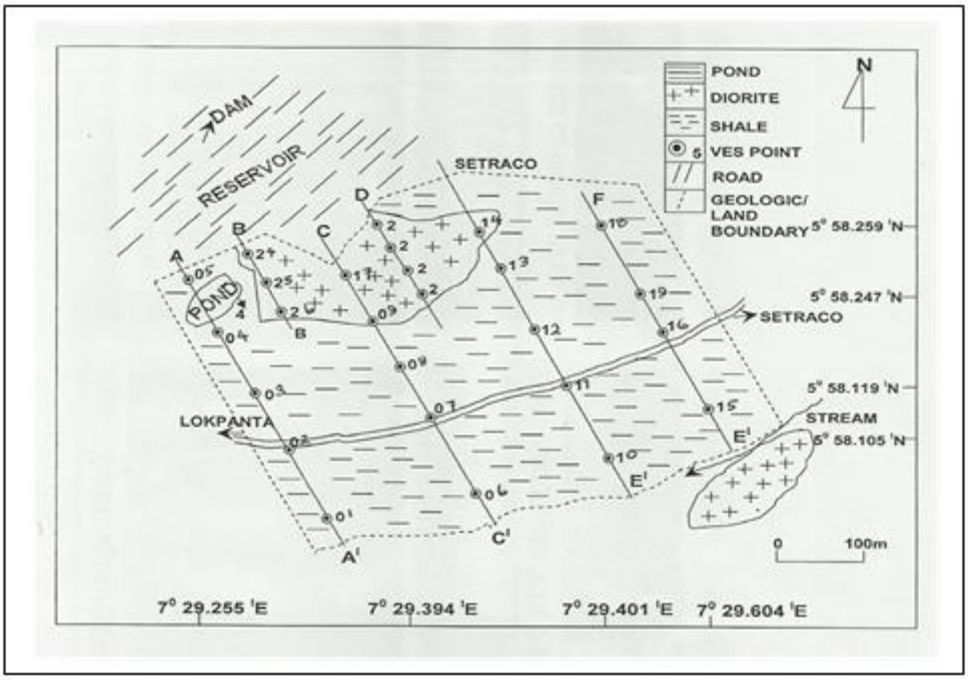

Fig 3: Geological map of Ukomi Lokpaukwu showing Rock distribution and Electrical Sounding profiles.

GEOELECTRICAL STUDY

The geophysical investigation was carried out using the ABEM SAS 4000 Terrameter. This equipment is equipped with an in-built digital display and recording system. Rechargeable 12-volt batteries coupled to the equipment provide the energy for the equipment operation. The symmetrical Schlumberger configuration was used for the VES data acquisition and is capable of isolating successive geoelectric layers beneath the surface and a maximum current electrode spacing (AB/2) of 1.5 to 95m ensuring down to 63m of depth probe was used throughout the study with potential electrode spacing of 1 to 28m while equally maintaining the potential electrode and current electrode geometric relationship at MN ≤1/5 AB (Zohdy 1974). The configuration used is shown in figure 4.

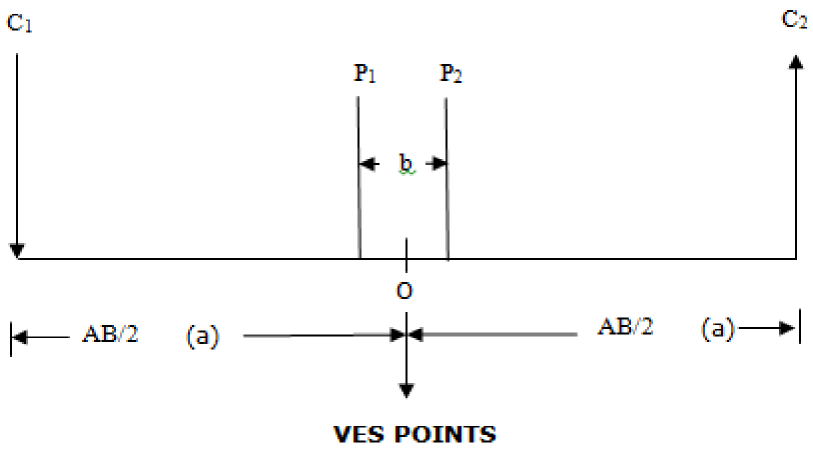

Fig 4: Schlumberger Electrode Configuration

The instrument displays the resistance of the area and the result was multiplied by its Geometric Factor to calculate the apparent resistivity of each point using the relation:

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ℓa = $\pi(a^2/b - b/4)$ R where
ℓa = apparent resistivity in Ohm-m
a = AB/2, the Half Current Electrode Separation in metres
b = Potential electrode separation in metres
R = Meter Reading in Ohms

The values obtained were then plotted on a log-log paper as points with the apparent resistivity values being on the vertical axis and the electrode spacing (AB/2) on the horizontal axis. The field curves were manually interpreted (Koefoed,1979),using master curves (Orellana, and Mooney,1966) and auxiliary point charts (Zohdy, 1965 and Keller and Frischknecht, 1966). Geoelectric parameters obtained from manual interpretation were then used as an in-put model for computer aided iteration of Zohdy Program for the interpretation (Vander Velpen, 1988; Ehirola et al., 2009) until it finds a final geoelectric model that is satisfactorily best of fits for the data. Twenty Six (26) VES surveys were conducted around the study area as shown in figure 3.

VI. RESULTS AND INTERPRETATION

GEOLOGIC INTERPRETATION

Samples of the fired shale were observed at VES 4 and VES 5 locations near a pond. The shale was highly fractured, hard and probably was so due to contact metamorphism from the hot diorite matter. Mineralogically only phyllo-aluminosilicate are expected. Very fine grained without any visible minerals characterize the shale. Elsewhere, fissile shale matter was observed from borings of crustaceans which indicates indirectly the rock/soil matter below the surface. Outcrops of the diorite were noted at stations VES 24, 25, 26, 27, 17, 9, 20, 22, 23, 14.

In the field, the diorite occurs as huge boulder with oval to spherical structure, weathering spheroidally. Fresh samples are dark grey in colour with visible plagioclase, olivine and dark minerals (Plates 1 and 2).

Plate 1: Occurrence of Diorite near VES 21

Plate 2: Diorite with Dolerite tint at VES 22

Under the petrographic microscope, laths of plagiosclase / Labradorite were set in a groundmass of smaller laths, iron oxide, olivine and pyrite. This texture is seen to be ophitic, similar to that of dolerite (diabase) . The views under the microscope are shown in plate 3.

Table 1: Modal Analysis of Diorite

Plagioclase	Quartz	Olivine	Dark Minerals	TOTAL
60%	<10%	<5%	20-25%	100%

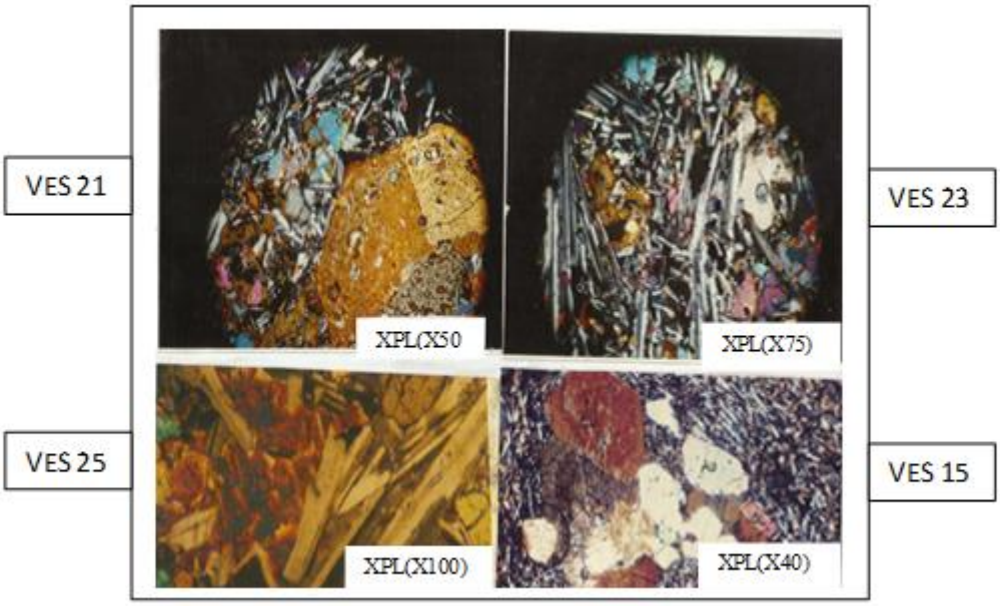

Plate 3: Photomicrograph of UkomiLokpaukwu Diorite.

Five (5) samples from VES 25, VES 17, VES 21, VES 14 and VES 23 were chosen for the density studies. Table 2 shows the results of the density analysis carried out on diorite samples.

Table 2: Result of Density of Diorites in the Study area

VES POINT	25	17	21	14	23	MEAN DENSITY
DENSITY	2.81	2.80	2.85	2.91	2.91	2.85×10^3 kgm^{-3}

From the map presented in figure 3, it is clear that a NE-SW trend in rock mass is the case. The outcrop noted at the SE comes in another lot and confirms the NE-SW trend. It is along a stream channel that trends 210^o SW. Dip values near VES 5 point of 45^o indicates higher angle possibly due to faulting or folding associated with the Santonian event in Eastern Nigeria. Shale occupies over two-third (2/3) of the map area surfacially. From the data presented in Table 2, it is clear that the density of $2.85 \times 10^3 kgm^{-3}$ is consistent with the average value of 2.8×10^3 kgm^{-3} in literature. Thus weathering is minimal.

GEOELECTRICAL INTERPRETATION

QUALITATIVE TREATMENT

Curve shapes and not really the resistivity values are employed in resistivity sounding data interpretation. This is because the values of resistivity may vary due to wetness or dryness occasioned by rainy or dry season or the presence of conductive materials such as shale or brine. However the true thicknesses of rock masses and the geoelectric boundaries/layers remain the same. Thus curve shapes were used to propose the number of layers for each VES data before running the data on software. In nearly all the VES points, 3-layer cases were proposed. These are: overburden of silty dry soil, weathered or fresh shale and the diorite. Where the diorite was not encountered, silt/weathered shale and fresh shale were modeled as in VES 07, 12 and 19.

QUANTITATIVE TREATMENT

Data from qualitative treatment above for all the VES points were fed into a Zohdy software to generate true resistivities and depths to geoelectric boundaries. Figures 5 to 8 show typical VES curves of the study area. The results emanated there from were used for interpretation.

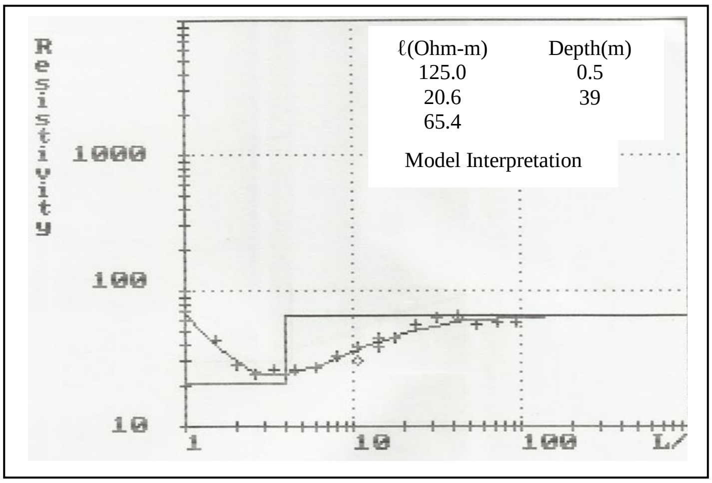

Fig 5: Modeled Curve for VES 13

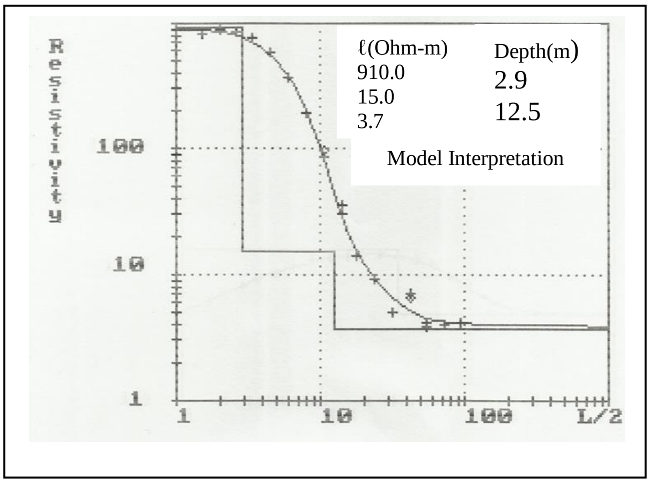

Fig 6: Modeled Curve for VES 16

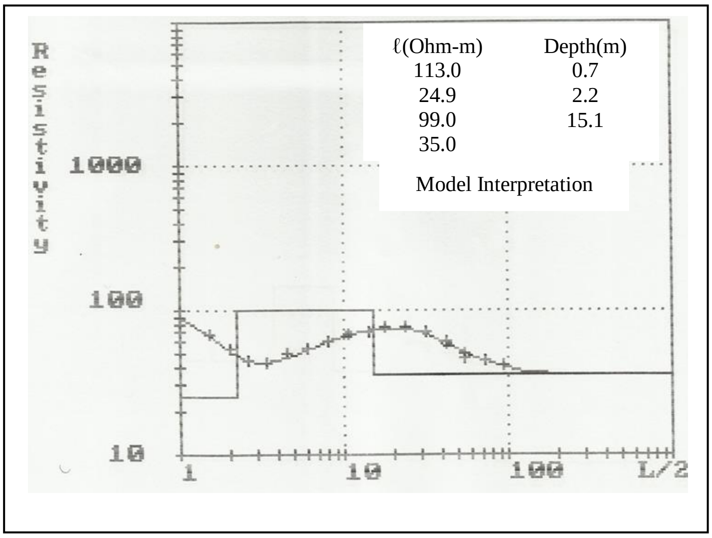

Fig 7: Modeled Curve for VES 23

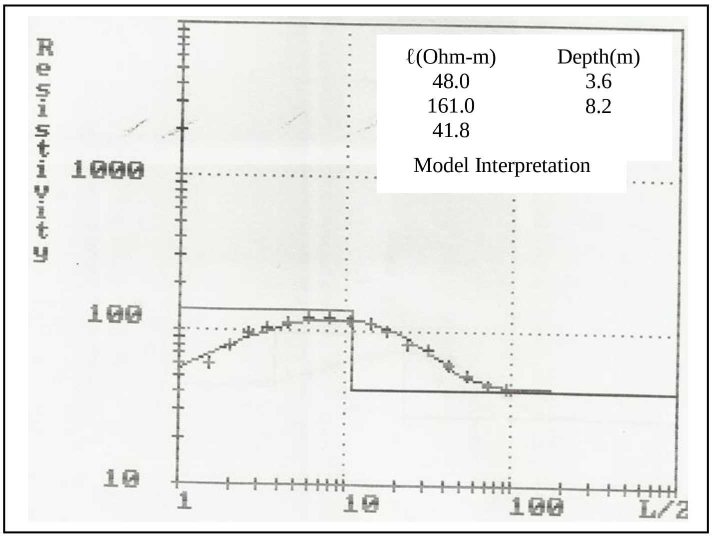

Fig 8: Modeled Curve for VES 25

Six (6) geoelectric sections in NW-SE profiles (across main strike of rock mass) were taken (figure 2). These are AA^1, BB^1, CC^1, DD^1, EE^1, and FF^1 shown in figures 9 to 12.

MODEL ALONG AA^1 PROFILE

The diorite here is buried below 6 to 9m at VES 3 and 4 respectively. This indicates that the event at VES 25 and 26 continues at VES 04 and 03 deeply buried at these two locations (figure 9).

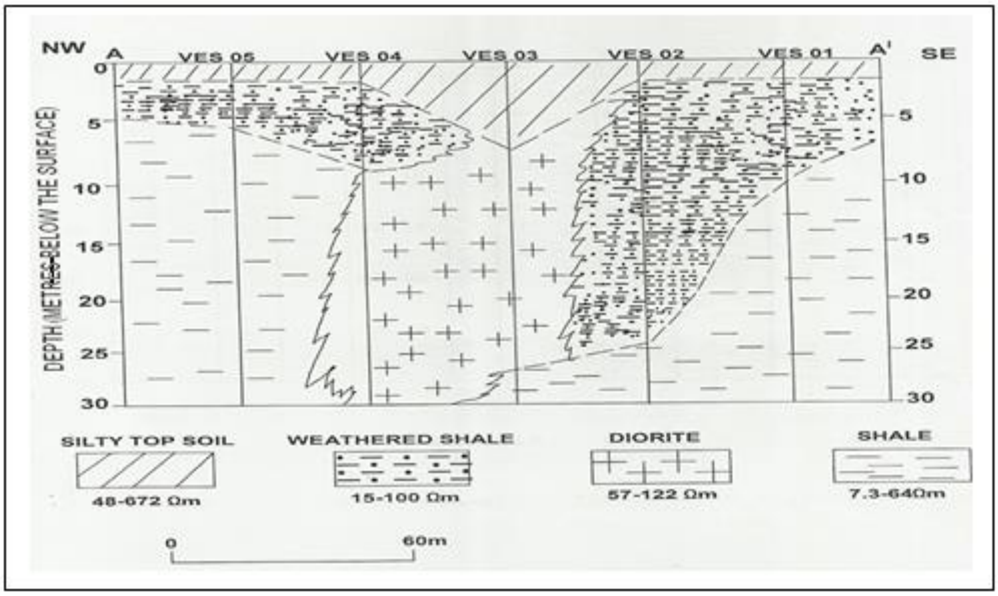

Fig 9: Geoelectric section along profile AA[1]

MODEL ALONG BB[1] AND CC[1] PROFILES

Along these two profiles shown in figure 10, the event in B[1] end is the same as the event in C end, pinching out toward BB[1]. The diorite continued to VES 17 and 09 points. Whenever the shale occurs, resistivity values are low (1.9 – 120 Ohm-m). Along these profiles the diorite is buried between 1.0 to 3m.

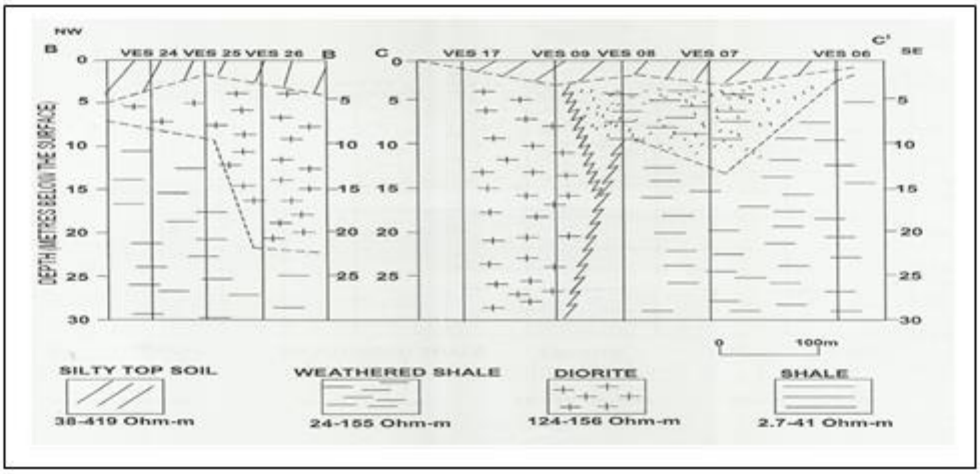

Fig 10: Geoelectric section along profile BB[1] and CC[1]

MODELE ALONG DD[1] AND EE[1] PROFILES

At VES 20, 21, 22 and 23 the diorite is buried at between 2.5 and 4m having a conical structure and shown in EE[1] profile (figure 11). Here the resistivity of the diorite is enhanced. (25-570 Ohm-m).

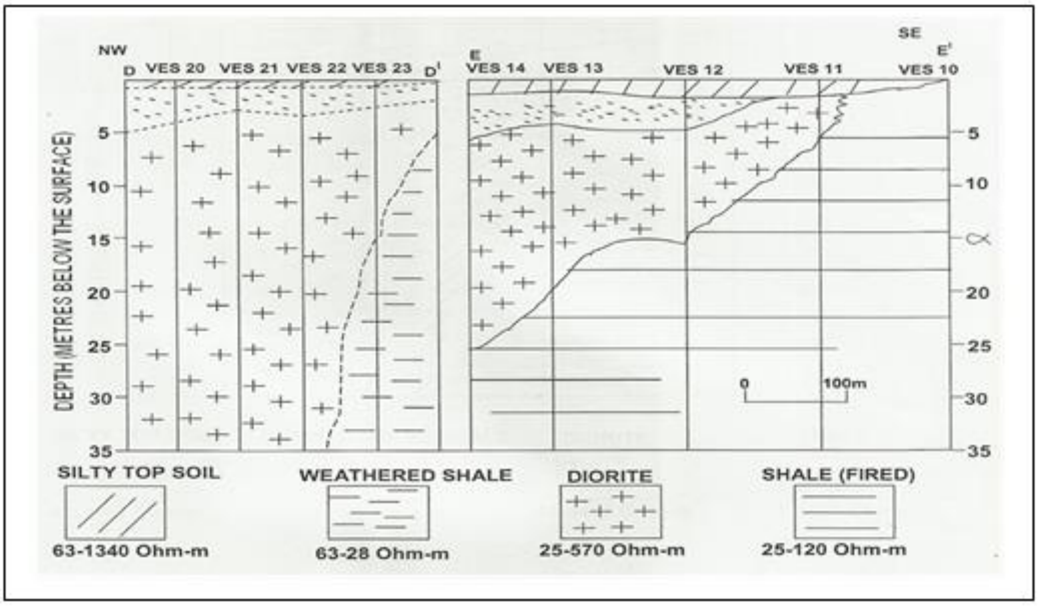

Fig 11: Geoelectric section along profile DD[1] and EE[1]

MODEL ALONG FF[1] PROFILE

Here the diorite is deeply buried at VES 18 and 19 and not encountered at VES 16 and 15. Depths of burial range from 13m in VES 18 to 12m in VES 19, with resistivity value range of 44 – 4413 Ohm-m (figure 12). This implies that deeper burial enhances quality due to less weathering. Again the conical shape is portrayed as the rock is not encountered at VES 16 and 15 locations.

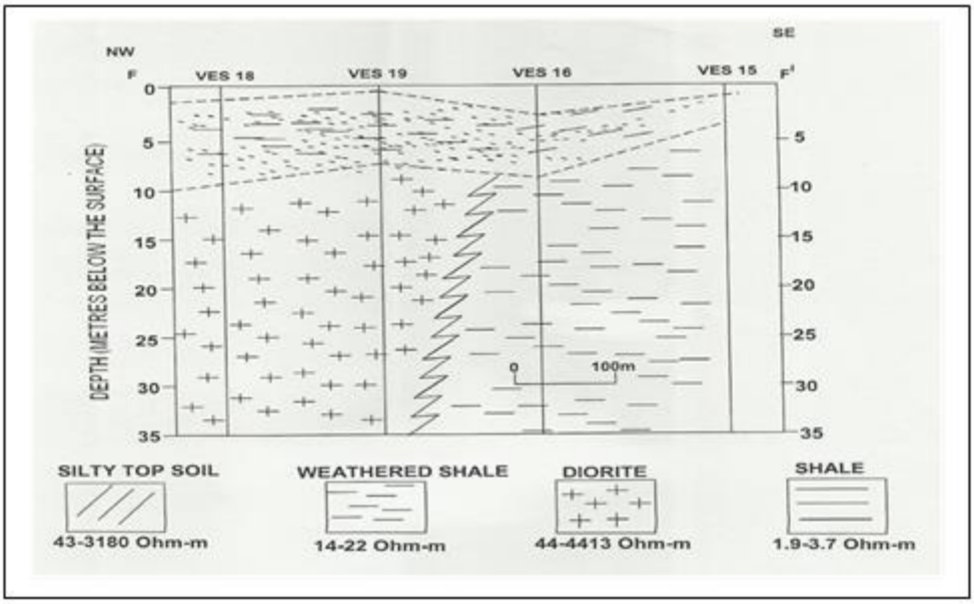

Fig 12: Geoelectric section along profile FF[1]

VII. DISCUSSION

From the geological mapping, surface trend and field relationship among rock units, difference in layering, the quarry material is diorite with strong inclination toward the dolerite suite. The material intruded pre-existing shale in a NE-SW trend, coming out in a normal conical shape rather than the preferred inverted cone shape. The central and southern parts of the mapped area do not have near surface rock exposure but buried to depth of about 12m. This is a lot of overburden. Such overburden made up of fractured shale and silty top soil may introduce quite a lot of underground water into any quarry site thereby increasing working cost or production expenses. From the density and mineralogical data, there is high quality diorite in Ukomi area studied. The density conforms to that in Literature. The colour is dark grey unlike most intrusions that are grey. Using a total outcrop length of 600m, a width of 400m a total projected reserve of 23.94 million metric tons of exploitable rock material of diorite suite is available using a thickness of 35m and a density of 2.85 x 10^3km^{-3}. This is only speculative and requires confirmation through core drilling.

VIII. CONCLUSION

From the data presented in this research work, we conclude that a high quality quarry diorite of about 23.94 million metric tons occurs at the studied land at Ukomi Lokpaukwu Umuchieze area of Southeastern Nigeria. The reserves estimated here is only speculative. It is recommended that core drilling be carried out to be sure of the accurate reserve. The establishment of any quarry site is predicated on the correct estimation of reserves. Coring in a NW-SE trend at 2 points per profile will guide initial reserve estimation. When established, adequate dewatering system must be put in place due to the presence of the existing dam in the area. The shale is hard and fractured. It may release its water once a quarry is opened up. The Dam may be a huge problem in the vicinity of the quarry.

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