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GEOLOGICAL AND GEOELECTRICAL INVESTIGATION OF DIRIOTE DEPOSITS IN OBIAGU, AMAUBURI, AND UMUNEOCHI AREA, SOUTH-EASTERN NIGERIA – SUGGESTIONS FOR QUARRY SITE

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ABSTRACT
The study employs geological and geo-electrical investigation of diorite deposits in south-eastern Nigeria. It involves geological analysis of outcrops and by measuring the electrical values properties of different subsurface materials. The locations were explored to assess the overburden thickness, downward trend, total diorite mineral resource, and rock grade. The results of the geological investigation showed that the rock is a diorite with a mean density of 2.88 x 103 kg-3, 2.71 x 103 kg-3, 2.82 x 103 kg-3 in Obiagu, Umuneochi, and Amaubiri respectively. The rock found in the area showed visible calcite (CaCO3) veins loaded with olivine and pyrite minerals. From the acquired data using the Schlumberger setup, three to five geo-electric layers were deduced from resistivity software in Amaubiri, Obiagu, and Umuneochi. The volume of the diorite materials in the study locations was estimated using the outcrop length, width, thickness, and density to about 365,850metric tons in Umuneochi, 442,656 metric tons in Obiagu, and 2,745,396metric tons in Amaubiri. The trend of outcrops in these areas is in the NE-SW direction. It is suggested to use the core drilling approach to carefully analyze the subsurface to estimate the precise reserve in these places.

Keywords: Diorite, Geoelectric, Quarry, Schlumberger Array, Obiagu, Amaubiri, Umuneochi Lokpaukwu

INTRODUCTION
Recent expansion and development in the construction industry, especially in Nigeria and the other part of West Africa, have increased the need for building materials. One of such material is rock aggregates. Rocks need to be the right quality of material in addition to being readily available and in a large quantity for the production and construction of structures, roads, ballast, airports, and seaports. Although certain sedimentary rocks, such as marl and pure limestone, are now being mined for rock aggregates. Igneous rock has higher impact strength than metamorphic rock, intermediate and extrusive igneous rocks are more suitable in terms of density and impact strength. Quarrying is the process of removing rock materials such as stone, gravel, and construction aggregate from the subsurface using some machines to excavate them. Concrete and asphalt production facilities are similar with one another due to the high rock requirements of those products (Webmaster, 2012). The diorite rock in these locations was analyzed to estimate the quantity and quality of the rock material. Ibe (2003) conducted a geological and geophysical survey in the Uru region in south-eastern Nigeria, and he made correlation with his result with the known geological and geo-electric study of the area. The study area's geological environment, which is part of Nigeria's lower Benue Trough, supports discontinuous exposures of eroded volcanic and hypabyssal structures (Adighije 2009). When South America and Africa split apart from one another in the Cretaceous, a series of tectonic movements—accompanied by magmatism and recurrent sedimentation—led to the formation of the Benue Trough. The Benue Trough was left as an aulacogen—a failed arm of an RRR Triple Junction—as a result of this separation (Burke, 1972; Olade, 1975).

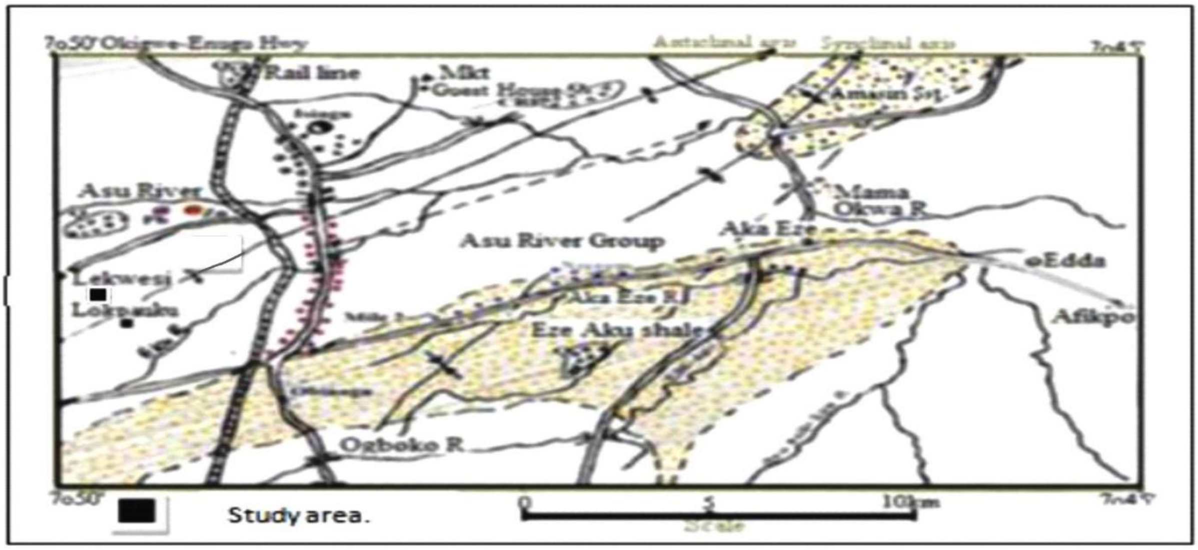


Figure 1: Map showing the Generalized Geologic of the study area within the lower Benue Trough (After Nwachukwu et al. 2011)

Amaubiri area is bounded by latitudes $5^0 54.800^1$N to $5^0 55.100^1$N and by longitudes $7^0 26.900^1$E to $7^0 27.180^1$E. It measures about 464-1050m^2 or 7 hectares and is located about 1.3km southeast of the Amaubiri Lokpaukwu community. It is located on an uninhabited land that is used mostly for Agriculture. With a major ridge trending 3100, the northernmost region of the terrain is heavily undulating. Obiagu Lekwesi community is located about 2km east of the Lekwesi-Achara road junction. However, the land investigated is located about 15km east of the Okigwe – Enugu road at Achara junction. Lokpaukwu area is located about 1km east of the N – S trending Okigwe – Enugu highway. An area of 11.46 acres or 4.4-hectare land which is about 18 hectares was investigated.

Umuneochi Lokpaukwu area is bounded by latitudes $5^0 56.36^1$N and $5^0 56.78^1$N and between longitudes $7^0 25.36^1$E and $7^0 26.16^1$E. Height above sea level ranges from 377ft (115m) to 456ft (139m) in the area that is underlined by suspected igneous rock.

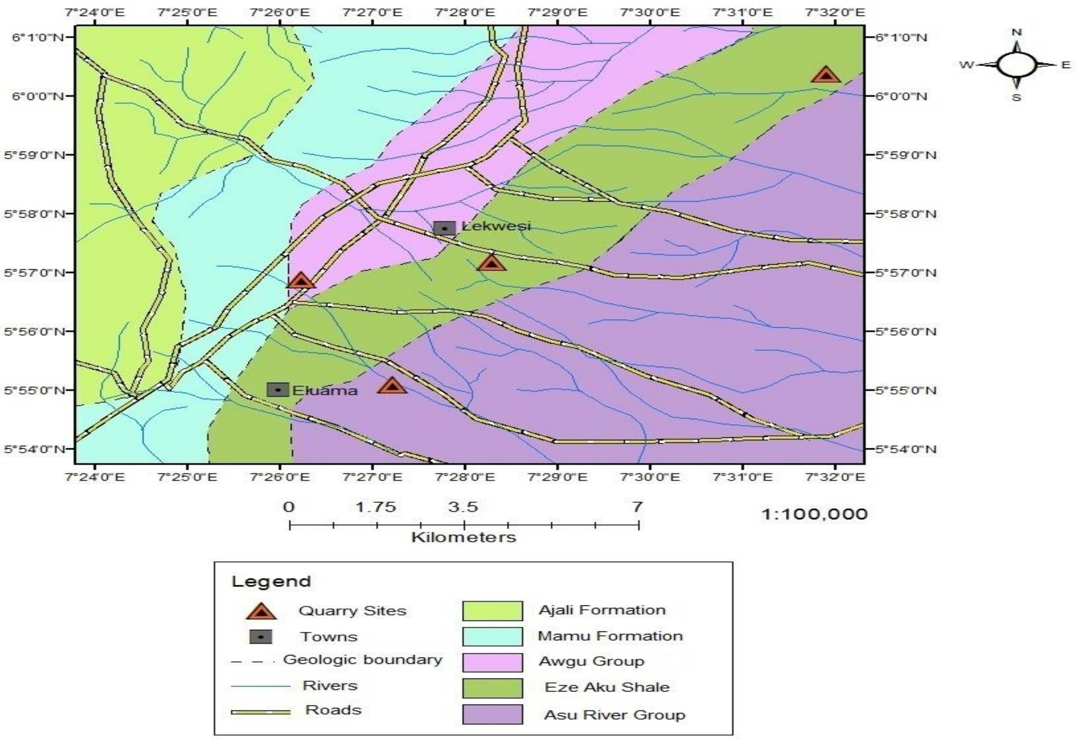


Figure 2: Location map of the study area.

Obiagu Lekwesi area is bounded by latitudes $5^0 56.999^1$N - $5^0 57.290^1$N and longitudes $7^0 28.113^1$E - $7^0 28.290^1$E, covering an area of about 12, 2071.7 hectares. Heights above sea level range from 254ft (77.4m) to 368ft (112.2m), the lowest areas being to the northern fringes.

In this work, the purpose of investigating these areas is to evaluate the economic viability and parameters that might affect mining of diorite rock using geological and geo-electrical methods. Geo-electrical analysis will be used to determine downward trend and overburden thickness while geological analysis will determine the quality of rocks to get the total reserve in the study areas.

MATERIALS AND METHODS

The investigation started with a very detailed geologic field mapping to identify rocks, outcrops, the topology of the area, and geographic settings. This involves mapping the outcrop, obtaining the dip and strike, and elevation. The Garmin 76CSx Global Positioning System (GPS) was used to capture elevation measurements of the locations in order to map the spatial distribution of rock. The GPS positions were gotten at each VES locations, which aided in the creation of maps and other interpretations. The planning of the geophysical and geological transverses was from the geologic trend in the area. Along lines for rock outcrops, geological transversal was done. The mapping of rock outcrops, rock units, and the gathering of rock samples from the research region are also important for examining the minerals in the rock unit.

Samples were analyzed to determine the rock quality and to establish the rock density. Samples were weighed in both air and water to measure their dry density before being soaked for 48 hours in clean water. The procedure was then repeated to determine their wet density. The mean density was determined to be (d+w/2) where (d=dry density and (w=wet density). The study employed five samples, one from each of the five sampling sites.

Geoelectric Study

The ABEM TERRAMETER SAS 300C was the device utilized for the survey. The fundamental ABEM TERRAMETER SAS 300C instrument may be used for resistivity and potential surveys. The Laboratory used Archimedes' principles to determine density and performed petrographical analysis to examine physical and textural features. AB/2 values for the vertical electrical sounding (VES) with Schlumberger configuration varied from 1.5 to 55m, ensuring up to 37m of penetration depth, which indicated the overburden and intrusion thickness in the research region. Through the Schlumberger equation, apparent resistivity values were converted from field data in ohms.

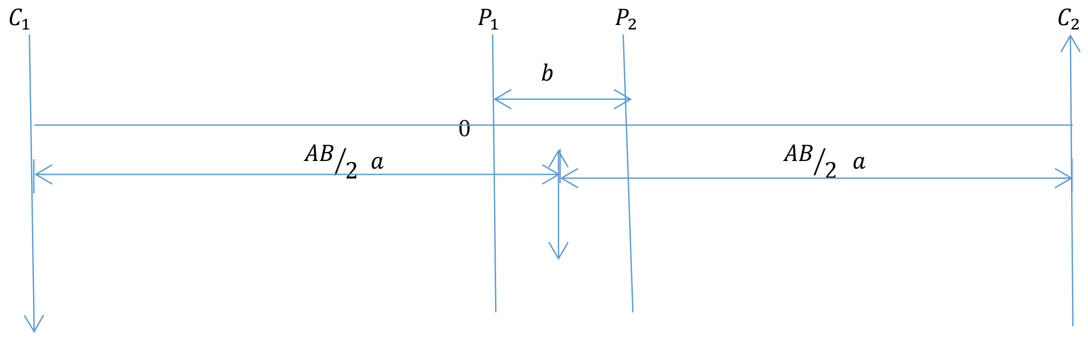


Figure 3: Configuration of Schlumberger Electrode

From Figure 3, the VES points are defined as;

$$C_1 0 = {}^{AB}/_2 = a \quad (1)$$

$$C_1P_1 = {}^{a-b}/_2,\ \ C_2P_2 = {}^{a-b}/_2 \quad (2)$$

$$\ell a(s) = \left({}^{a2}/_b - {}^{b}/_4\right)R \quad (3)$$

The device indicates the area's resistance, and its Geometric Factor was used to multiply the result to get the apparent resistivity of each point.

$$\ell a(s) = \left({}^{a2}/_b - {}^{b}/_4\right)R \quad (4)$$

Where ℓa the apparent resistivity in Ohm-m is, $a = {}^{AB}/_2$ is the Half Current Electrode Separation in meters, b is the Potential electrode separation in meters, and R is the meter reading in Ohms. Equation (4) is called the expanding array/Schlumberger array.

The field curves were produced by plotting ℓa values against ${}^{AB}/_2$ values on log-log graphs.

With the use of equation (4), the resistance value shown by the measuring device (terremeter) and the Schlumberger geometric factor are used to determine the apparent resistivity value for each electrode separately.

$$K = \left({}^{a2}/_b - {}^{b}/_4\right)\pi \quad (5)$$

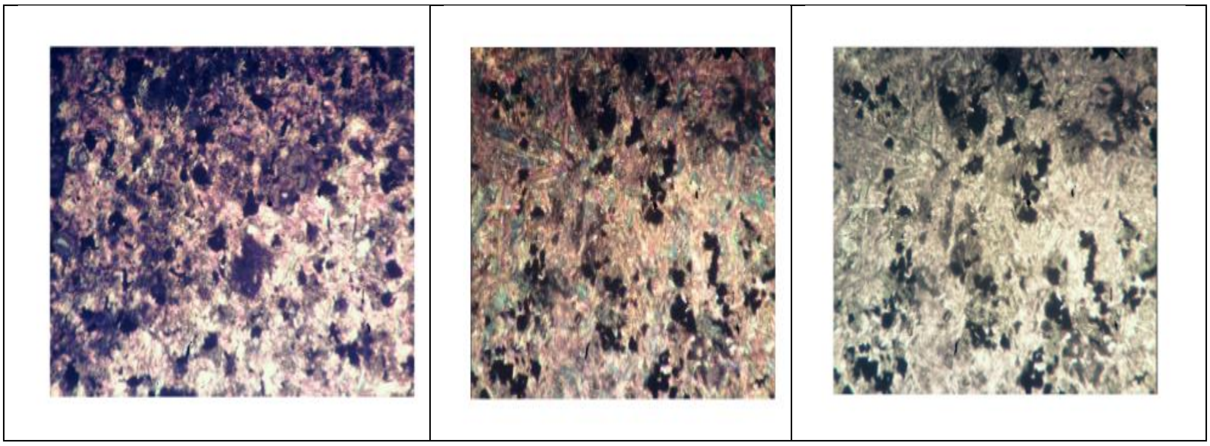
The interstitial fluid (or water), which usually exists in the rock and invariably contains some dissolved salt, is responsible for conducting electricity in the ground. The chemistry of the fluid in a rock's pores has an impact on whether or not the rock conducts electricity. Due to the high activities transferred in clay minerals, the rock's pore spaces would behave as though a highly conductive fluid were present. According to (Onifade, Y. S et al., 2021), non-metric mineral was discovered in Edo state using 2D electrical resistivity tomography in some part study area. The acquired data were represented as dots on a log-log paper with apparent resistivity values on the vertical axis and electrode separation (AB2) on the horizontal axis. Using master curves (Orellana and Mooney, 1966) and auxiliary point charts (Zohdy, 1965; Keller and Frischknecht, 1966), the field curves were manually interpreted (Koefoed, 1979). The Zohdy Program for the interpretation (Vander Velpen, 1988; Ehirola et al., 2009) employed geoelectric characteristics derived via manual interpretation as an input model until it found a final geoelectric model that was satisfactory and the ideal match for the data.

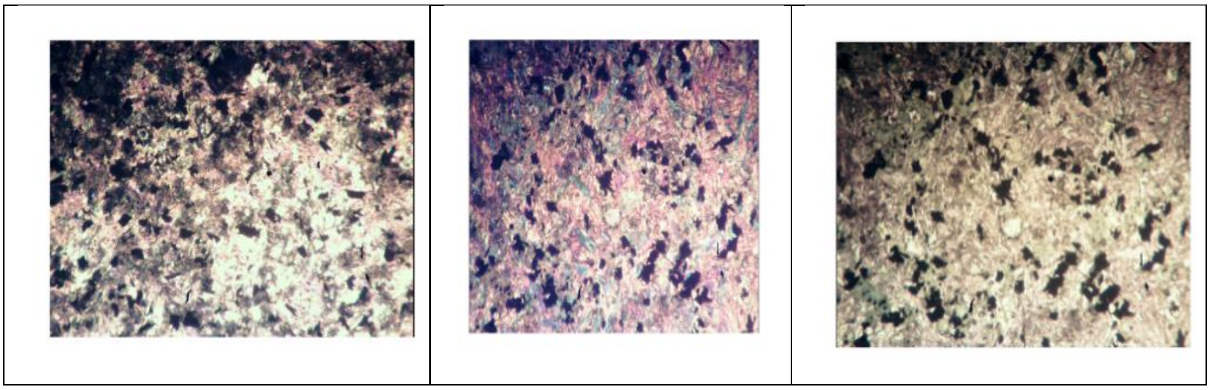
RESULT AND INTERPRETATION

GEOLOGIC INTERPRETATION

Plagioclase/Labradorite laths were found to be embedded in a groundmass of smaller laths, iron oxide, olivine, and pyrite according to petrographic study. It appears that this texture is ophitic and resembles dolerite (diabase).

They are variations in the diorite, some portions have been faulted and calcite ($CaCo3$) veins are common. This has been confirmed by the microscopic study. This section of the hand specimen exhibits geodes created by recrystallized calcite along fault-generated fissures and microcracks. The medium-grained calcite veins contain pyrite and olivine minerals. Under a microscope, the diorite appears to have a dark grey coloration. It is composed of tiny amounts of plagioclase, iron oxide, and pyroxene, as well as laths and strands of labradorite. The texture conforms to the intermediate igneous rocks as seen in Fig (4).





(a)Obiagu Lekwesi (b) Amaubiri Lokpaukwu (c) Umuneochi Lokpukwu

Figure 4: Pictures showing the Photomicrograph of outcrop in the study areas

The geologic mapping result from the Obiagu Lekwesi area reveals an E-W trend with the Ajaka stream being at the NE-W boundary of the surface area. The highest point in the area is underlain by very coarse to conglomerate sandstones. These sandstones stand out and are blended with the highly weathered diorite rock masses. A NE- SW trending diorite mass occurs at some VES points in Amaubiri but is highly weathered. Freshly collected sample exposed near point P24 is medium-grained, grey in color, and has numerous iron-filled cracks and joints. Most outcrops seen at Umunoeochi are mostly confined to the Northern portion of the study area.

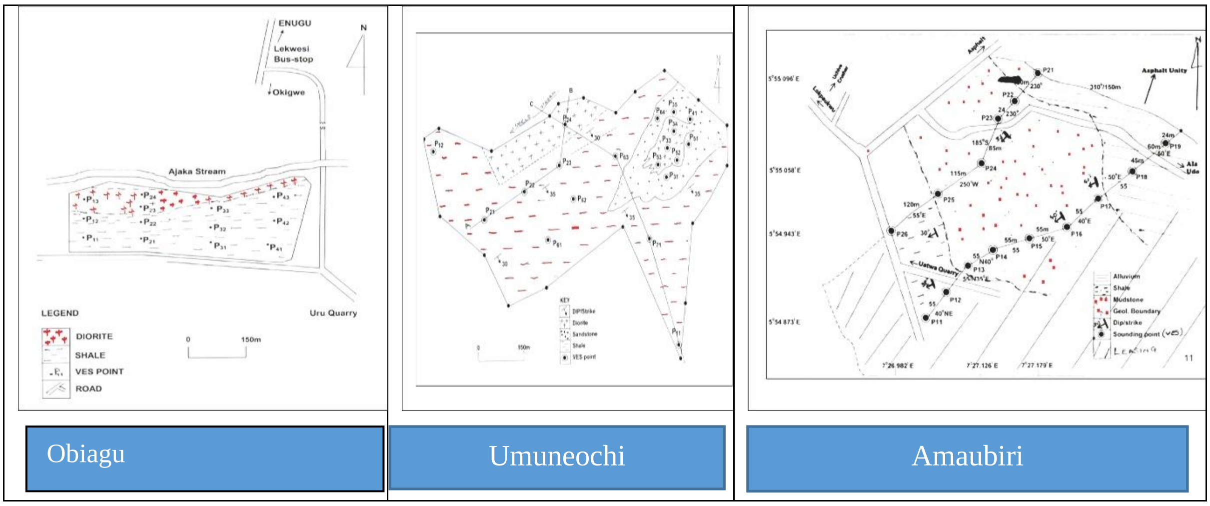


Figure 5: Geological map of the area showing vertical electrical sounding points.

Table 1: Density Interpretation of Obiagu, Outcrop

Samples	1	2	3	4	5
Dry Density	2.85	2.77	2.96	2.84	3.10
Wet Density	2.80	2.72	2.93	2.80	3.06
Sample Density	2.82	2.75	2.94	2.82	3.08
Obiagu Mean Density = 2.88 x 10^3 Kgm^{-3}					

Table 2: Density Interpretation of Umuneochi, Outcrop

Samples	1	2	3	4	5
Dry density	2.74	2.69	2.73	2.82	2.75
Wet density	2.69	2.62	2.68	2.75	2.70
Sample density	2.71	2.65	2.70	2.78	2.72
Umuneochi Mean Density = 2.71 x 10^3 Kgm^{-3}					

Table 3: Density Interpretation of Amaubiri, Outcrop

Samples	1	2	3	4	5
Dry Density	2.84	2.78	2.89	2.81	2.86
Wet Density	2.81	2.75	2.86	2.79	2.82
Sample Density	2.83	2.77	2.88	2.80	2.84
Amaubiri Mean Density = 2.82 x 10^3 Kgm^{-3}					

The above table shows the result of outcrop analysis from samples in different locations of the study. The value density ranges from 2.65 *10kgm-3 to 2.91*10 3kgm-3 and the mean density values range from 2.71*10 3Kgm-3 to 2.88 * 10 3Kgm-3 and this conforms to the value for diorite with stands at 2.60 to 2.95*10 3Kgm-3.

Table 4: Total Reserve Estimation

Parameters	Amaubiri	Umuneochi	Obiagu
Surface Width	140	75	50
Outcrop Length	330	120	530
Thickness	19	15	5.8
Mean Density	2.82 x 10^3 Kgm^{-3}	2.71 x 10^3 Kgm^{-3}	2.88 x 10^3 Kgm^{-3}
Total Estimated Reserve	2,475,396000 **~2,745,396metric Tons**	365,850,000 **~365,850metric Tons**	442,656,000 **~442,656 metric Tons**

Geophysical Interpretation of Data

Field curves were plotted and presented manually on log-log graphs to enable the structures of curves to be shown, the field data were fed into the Schlumberger software program to produce a computer printout of the curves. The curves gave different shapes of resistivity curves named, K, A, Q, and H curves respectively.

To calculate the layer parameter, the curve-matching results were carefully examined. The properties of the bed or strata between the surface and the greatest depth of penetration were revealed by the form of each sounding curve. This is due to the fact that the thickness, number of layers, subsurface, and resistivity ratio of these locations all affect how a VES curve looks. In Figures 5-8, some of the interpreted curves from the VES data are displayed.

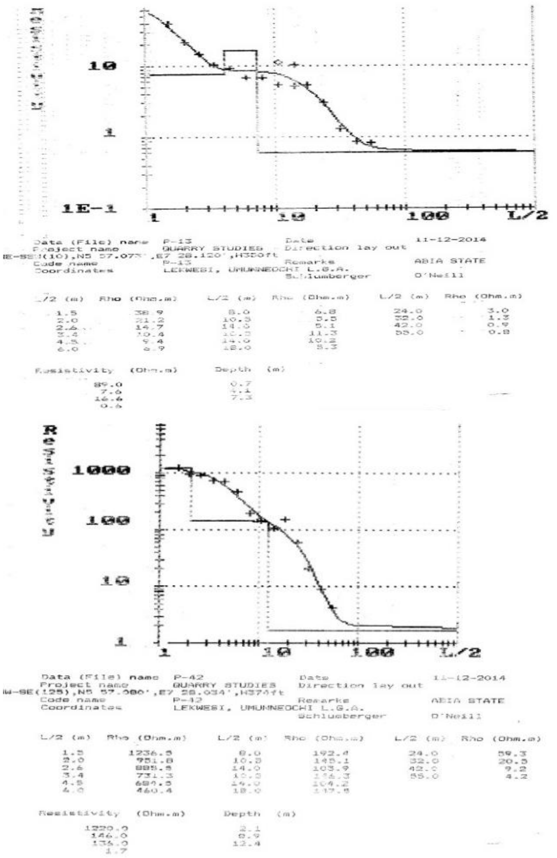


Figure 5: Modeled VES Curve (P-42)

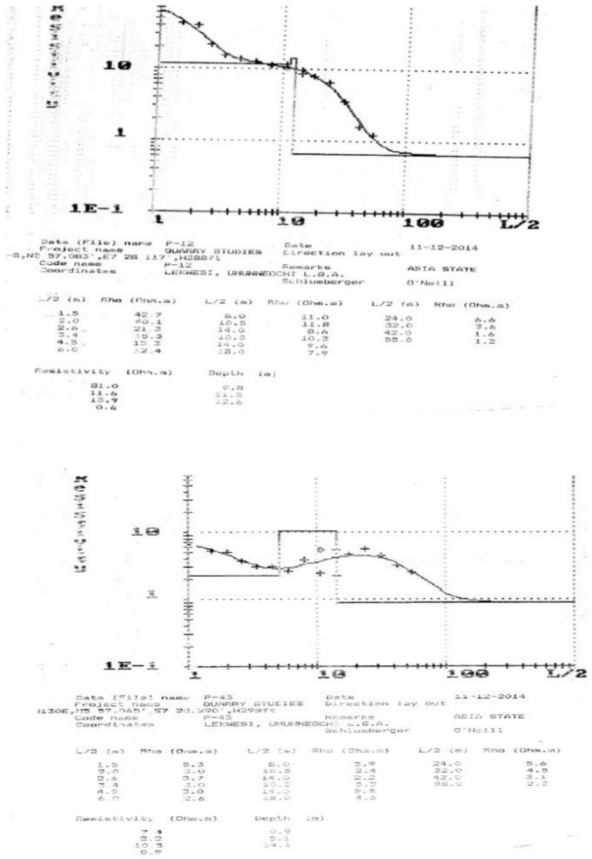


Figure 6: Modeled VES Curve (P – 45)

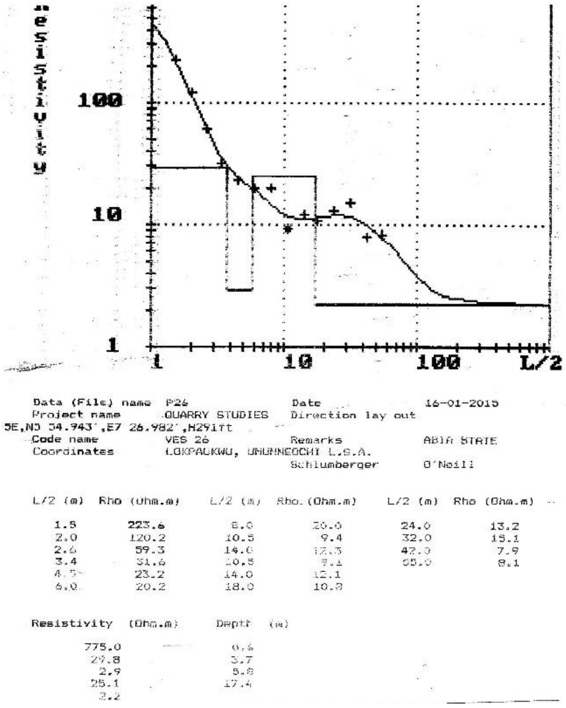


Figure 7: Modeled VES Curve (P – 24)

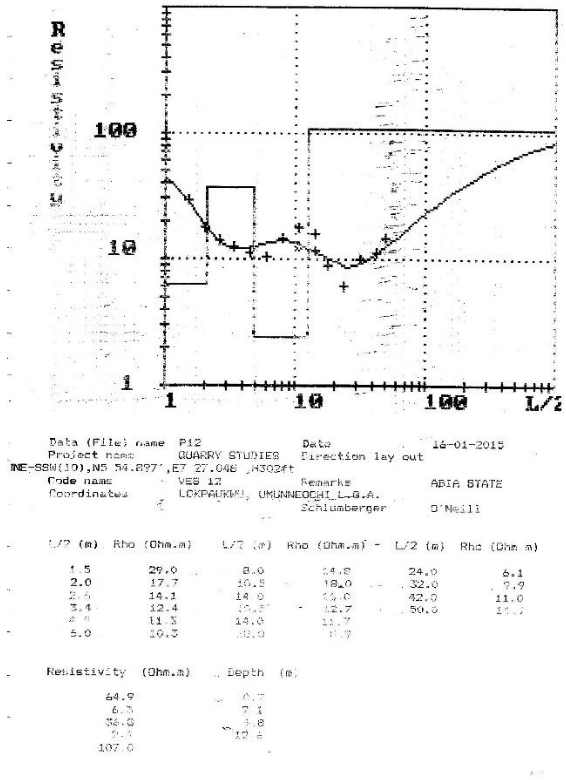


Figure 8: Modeled VES Curve (P – 12)

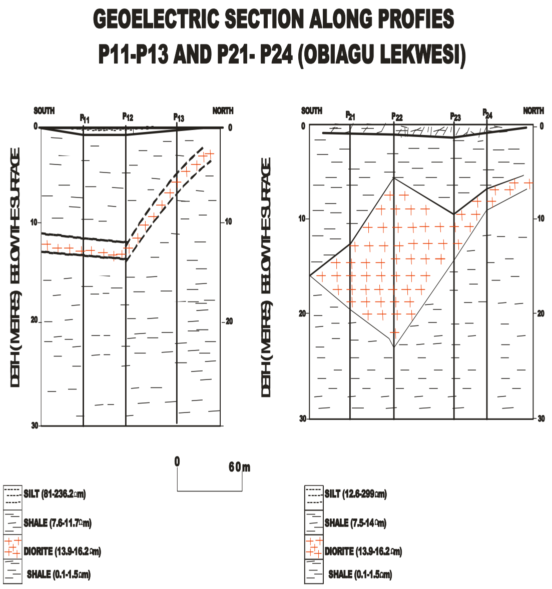


Figure 9: Geo-electric Section along profiles

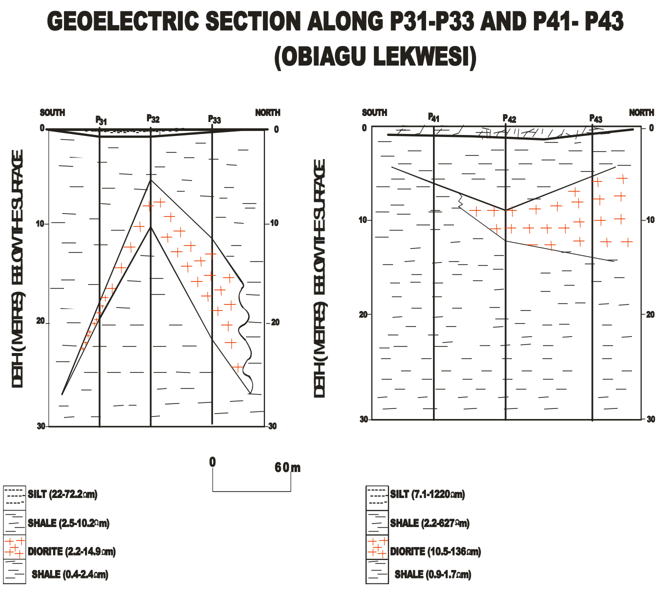


Figure 10: Geo-electric Section along profiles

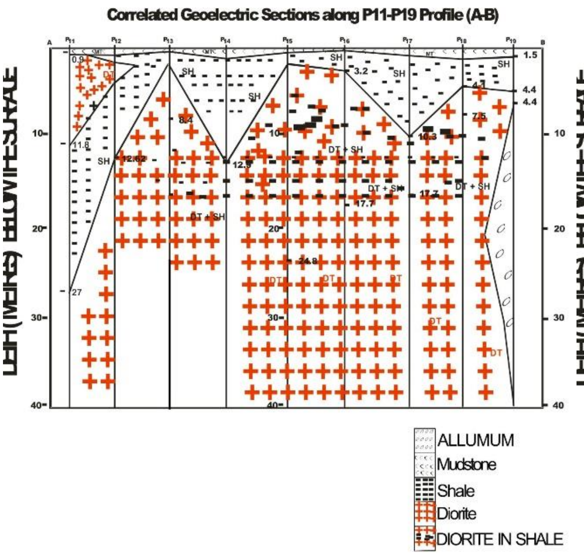


Figure 11: Geo-electric Section along profiles

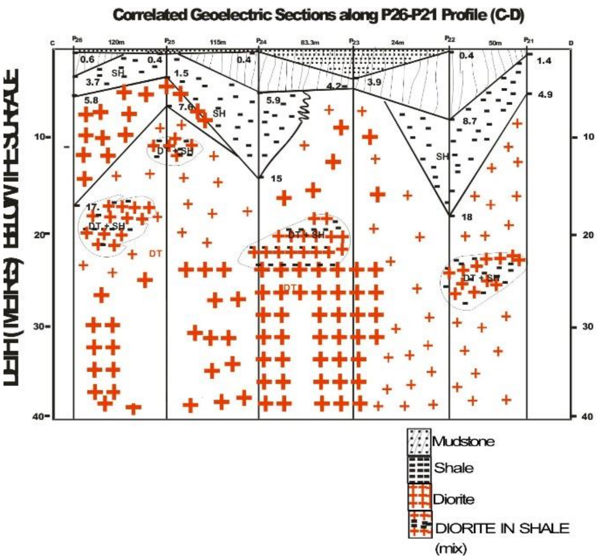


Figure 12: Geo-electric Section along profiles

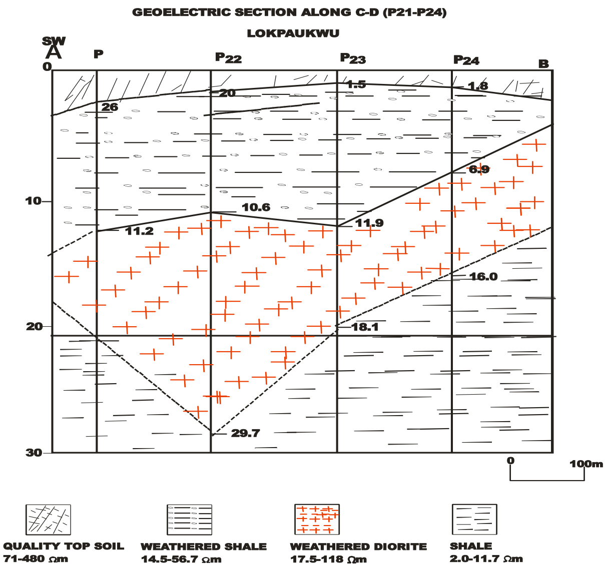


Figure 13: Modeled Vertical Electrical Sounding Curve

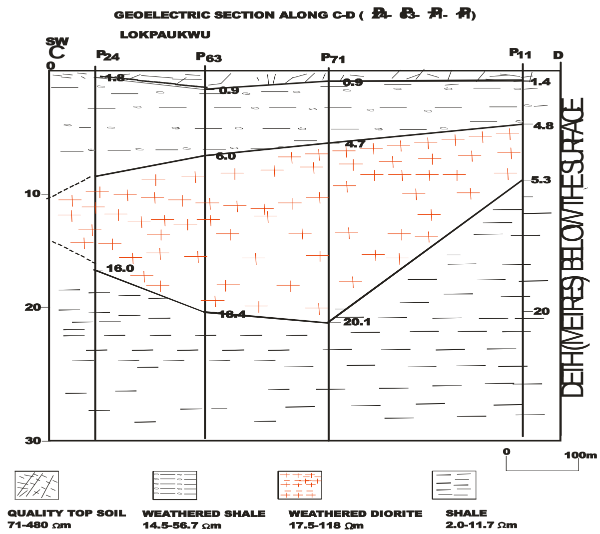


Figure 14: Modeled Vertical Electrical Sounding Curve

DISCUSSION

In this study, we employed geologic reconnaissance survey in the locations and the area was found to have different rock units such as shale, siltstone, diorite, sandstone and iron stone. According to (Kogbe, C. A**.**, 1972) the area is predominantly part of the oldest sedimentary formation made of the Asu-River and Eze – Aku group. Some rock samples found was viewed under microscope that shows calcite veins. These calcite veins contains pyrite and olivine minerals. According to petrographic studies in fig 4, the diorite is seen to be dark-grey in colour with small amount of plagioclase, iron-oxide, pyroxene and laths of labradorite. The texture of the samples collected fits the description of an intermediate igneous rock according to literature. Fig 5 shows geologic map of the area with locations of the electrical resistivity points across features. Geophysical analysis was carried out with the use of Abem Terameter SAS 300 to determine subsurface formations on Zohdy software. Resistivity values and curves shapes were used in the interpretation but resistivity was not necessarily the deciding factor, this is because of the dryness and wetness of each sounding point. Therefore, we used curved shapes to infer geo-electric sections for proper interpretations of geologic layers in each area. Approximately three to five layers was deduced from geophysical analysis in the three study locations as shown in fig 9 - 14. We also confirmed quality of rock in these areas using Archmedies principle by calculating the wet density and dry density of rock to get the true density of rock from each location with 5 samples.

From the geo-electric section analyzed in Obiagu (fig 9 and 10), diorite is buried in highly weathered shale and in small quantity with an irregular shape. Overburden thickness that will be removed to reach diorite rock deduced from modelled geo-electric sections are approximately 10.49m in Obiagu, 18.4m in Amaubiri and 4.1m in Umuneochi area.

Reserve Estimation in each area was done using the length, width, thickness of outcrop respectively and its estimated density of rock as shown in Table 4. The values obtained from each location was used as an idea for further studies and decision for siting quarry in these area.

CONCLUSION

The data acquired and analyzed in this work shows that Umuneochi, Lokpaukwu, has a high quality diorite of about 0.365 million metric tons with a very thick overburden and thin rock mass despite the 0.365 million metric tons reserve, the deposit is not economical. So much might be spent on removing overburden. Obiagu Lekwesi has about 0.442 million metric tons. It is concluded that the diorite rock in Obiagu Lekwesi is not economical for medium to large scale quarry. Based on the interpretation of Amaubiri area, there is high weathering depth with about 2.74 million metric tons, a quarry could be established but extra care should be taken to prevent any pond development. This study has established depth and lateral extent of diorite in the areas investigated. Reserve estimation of the investigated diorite rock was determined from the processed data gotten from the field. According to the estimations from this work, core drilling should be done to ensure an exact reserve.

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