Journal of Applied Sciences Research, 7(10): 1402-1410, 2011
ISSN ISSN 1819-544X
This is a refereed journal and all articles are professionally screened and reviewed

ORIGINAL ARTICLES

Estimation of Reserve – Overburden Ratio of A Proposed Quarry Site Using Resistivity Survey: A Case Study of Ajebo, Near Abeokuta, Southwestern Nigeria.

[1]Bale, R.B., [2]Bayewu, O.O., [1]Folorunso, I.O. and [3]Oloruntola, M. O.

[1]*Dept. of Geology and Mineral Sciences, University of Ilorin, Kwara State, Nigeria.*
[2]*Dept. of Earth Sciences, Olabisi Onabanjo University, Ago Iwoye, Nigeria.*
[3]*Dept. of Geosciences, University of Lagos, Lagos, Nigeria.*

ABSTRACT

The geophysical and geotechnical assessment of the granite deposit at Idi-Osan Ofagada village near Abeokuta, southwestern Nigeria, have been undertaken and the exploitation suitability of the deposit established. The area is underlain by the granite gneiss rocks of the Precambrian Basement complex of southwestern Nigeria. Fourteen Vertical Electrical Soundings (VES) of Schlumberger array were carried out on the areas covered with overburden to determine their resistivity characteristics, overburden thickness and the reserve tonnage of the basement rock. The compressive strength and the specific gravity of the rock were measured to determine its competency and density respectively. The area is gridded into 5 by 6 blocks for more accurate calculations of the parameter for the estimation of the reserve. The reserve is estimated for elevation datum of 150m, 160m and 170m. Taking into account the economic implication for the removal of overburden, a minimum ratio of overburden to basement thickness of 1:1 and a limiting 10m overburden is considered to be the economically exploitable area. The VES results showed a two to three geoelectric layers; the sandy weathered layer, clayey layer and the basement. The isopach and geoelectric sections revealed that the overburden thickness varies from 1.5m to 23.6m with the thickest overburden of 10m and above occurring in the north-western and south-eastern parts. Geotechnically, the deposit has an average compressive strength of 47.68N/mm^2 Young Modulus of 633N/mm^2 and specific Gravity of 1.615. The reserve estimates obtained for 170m, 160m and 150m elevation datum are 4.42 x 10^5, 17.17 x 10^5 and 37.09 x 10^5 tons respectively. The results showed that the exploitation of rock in the area is economically viable most especially at 160 and 150m datum.

Key words: VES, Reserve Estimation, Specific Gravity, Overburden Thickness

Introduction

The recent growth in populations in Abeokuta town and its environs 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 granite 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.

Different authors have established the economical importance of the southwestern basement complex of Nigeria (Oyawoye, M.O. 1972; Rahaman, M.A. 1976; Elueze, 1981; Ajibade and Wright, 1989; and Dada, S.S. 2006) and this complex has been found out to serve as good hosts to different mineral deposits and most importantly as a good material for civil constructions. Apart from the geochemical studies of this complex (Rahaman, M. A. 1978; Olarewaju, V. O. 1987), they have also been explored using geophysical methods (Bayewu *et al*., 2008; Okurumeh and Olayinka, 1998; Olayinka, 1996 and Olorunfemi and Okhue, 1992), while some authors had used these geophysical methods in the estimation of these complex reserves (Bayewu and 2002; Ehinola *et al*., 2009 and Joshua *et al*., 2004).

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)

The aims of this work are to carry out the geophysical and geotechnical assessment of the rock deposit at Idi-Osan, Ofagada village near Abeokuta and to evaluate the geological parameters that will influence the

Corresponding Author: Dept. of Geology and Mineral Sciences, University of Ilorin, Kwara State, Nigeria.

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

economic viability of the 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. This is complemented by the determination of the specific gravity and uniaxial compressive strength and eventually, reserve tonnage is estimated.

The Location And Geology Of The Study Area:

The study area can be assessed by the tarred Abeokuta – Ajebo road and the site is located about 2km off the tarred road. The site lies between co-ordinates 07.1555^{0}N - 07.157889^{0}N and 003.479389^{0}E – 003.48275^{0}E (Fig. 1). The location of the rock mass is far from human settlements and highways and the 3D of its topography is shown in fig. 2. The climatic condition of the area is tropical rain belt as typical of southwestern Nigerian and expressed a contrast between the dry and wet seasons. It is characterized by very high rainfall, low pressure, high precipitation, high evaporation and relatively high humidity. The dry season is between November-March, and we season is between March-November. Annual rainfall is about 1500mm (Duze and Ojo, 1982). A relatively low amount of rainfall is recorded in August due to little dry season other wise called August break, which is a form of climate anomaly through Nigeria. (Akanni, C.O. 1992). Temperature ranges from a mean maximum of 32^{0}C in February to a mean minimum of about 21^{0}C in August. This high temperature, coupled with high rainfall, is likely to enhance or promote weathering (Adeyemi G.O. 1985). The topography is generally undulating; the highest elevation is about 192m, which was recorded almost at the centre of the lease while the lowest elevation is about 160m in the southeast. The area lies within the Precambrian Basement of South-Western Nigeria. The study area is exclusively underlain by granite gneiss and this rock has been crosscut by the quartz and pegmatite veins. There is also evidence of fractures observed.

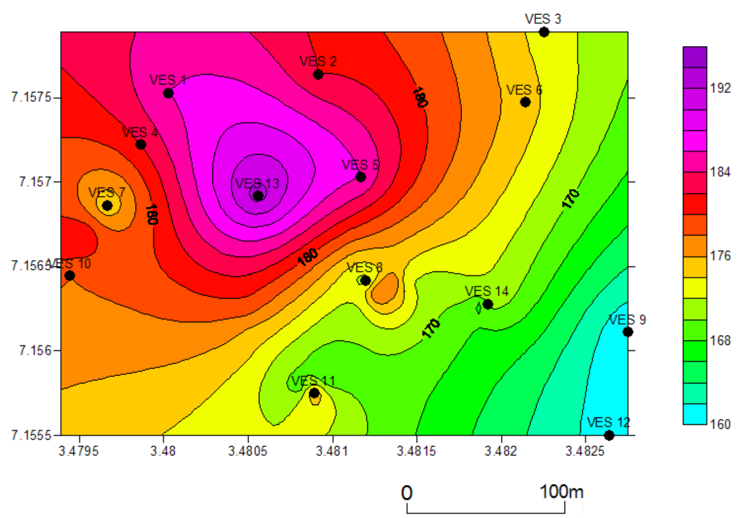

Fig. 1: The Location Map showing the Elevation and VES survey of the study area.

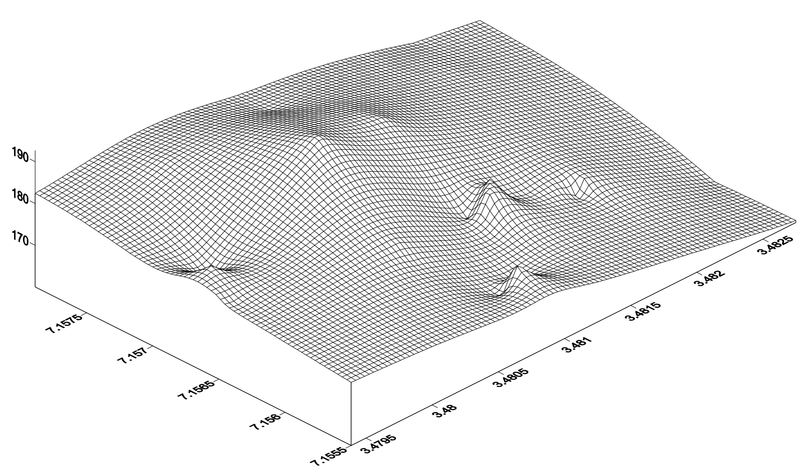

Fig. 2: The 3D of the topography of the study area

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

Methodology:

The elevation measurements of the area were made using the Garmin 76 Global Positioning System (GPS), with a view to determine 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.

Geophysical Investigations:

The geophysical investigation was carried out using the ABEM SAS 300C 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.

Schlumberger array method 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 15m to 80m was used throughout the study based on the nearness of the basement in each location with potential electrode spacing of between 0.25m and 2.5m while equally maintaining the potential electrode and current electrode geometric relationship at MN $\leq$1/5 AB (20). 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. 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, O.,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 WINRESIST Program for the interpretation (Vander Velpen, 1988) until it finds a final geoelectric model that is satisfactorily best of fits for the data.

Fourteen VES surveys were conducted around the study area as shown in fig. 1 to determine the overburden thickness and these were carried out and spread across to areas where the overburden is covering the basement.

Geotechnical Investigations:

Block samples of the Idi-Osan Ofagada granite were investigated for the suitability of the rock as a building and construction material. The uniaxial compressive strength of the rock blocks was determined using the Universal Testing Machine (UTM) model AXM500-50KN. The specific gravity of the rock was also measured to calculate its tonnage in the laboratory of Department of Civil Engineering, University of Ilorin, Nigeria.

Reserve Estimation:

The tonnage estimate is derived from elevation, the rock density and the overburden thickness of the area. Gridding method was adopted in this exercise, the area was divided into 5 by 6 grids and average elevation was calculated for each grid. The length and breath of each grid were measured to be 62m and 52.3m respectively.

Results And Discussion

Geotechnical Interpretation:

The calculated uniaxial compressive strength of the rock blocks gave an average value of 16.67N/mm^2, this falls within the class of moderately strong as classified by (Anon, 1979). The foliation in the rock may be responsible for the significant loss in strength compared to granite; however, the strength is still adequate for materials to be used as construction aggregate. The engineering performance of gneiss is usually similar to that of granite; the presence of foliation does not significantly affect it engineering behavior (Bell, F.G., 2008).

Geophysical Interpretations:

The VES resistivity results for the 14 locations were plotted and interpreted. A typical VES curve in this area is shown in fig. 3. The geoelectric sections along Traverses 1, 2 and 3 are shown in fig. 4a-c. The sections showed that the area is predominantly made of 2 geoelectric layers, i.e. the weathered layer and the basement rock, the weathered layers are mainly sandy, and there is also occurrence of clay especially in Traverse 1. The resistivity range of the weathered layer varies between 53 Ωm to 3950 Ωm and has thickness range of 1.5 to 17.4m while the basement resistivity ranges from 380 Ωm to 16252 Ωm. The interpreted depths to the bedrock obtained in the different VES stations were plotted and contoured to produce the isopach map of the area (fig. 5) and the average overburden thickness was calculated for each grid of the area and is presented in fig.6. These

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

showed that the thickness varies from 1.5m to 23.6m. The thickest overburden is observed at the north-western and south-eastern parts while relatively thin (under 7m) overburden were observed at the central-north, western and eastern parts.

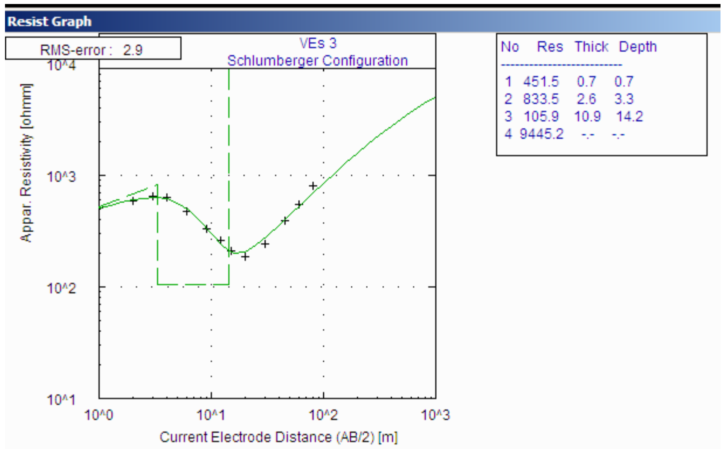

Fig. 3: A typical Iterated VES curve in the study area.

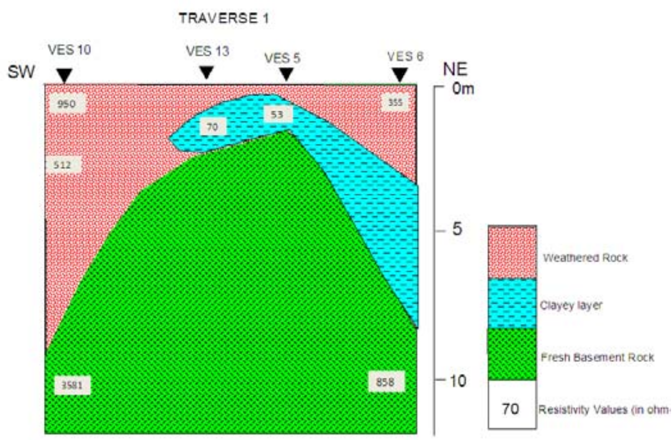

Fig. 3a: The Geoelectric section across Traverse 1 in the study area.

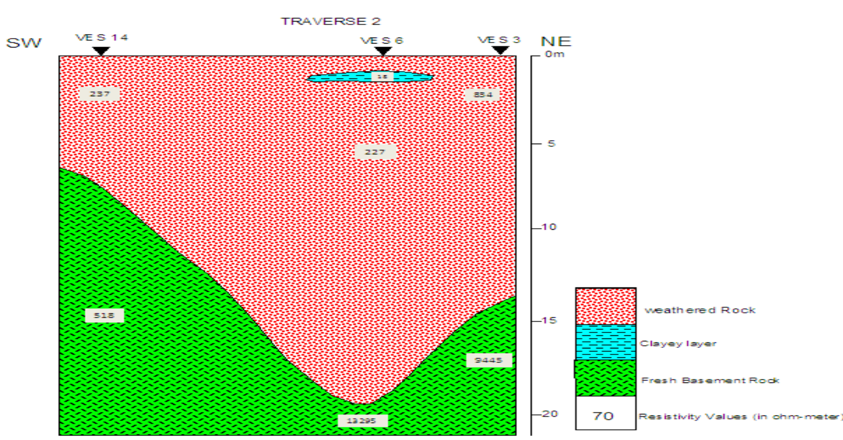

Fig. 4b: The Geoelectric section across Traverse 2

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

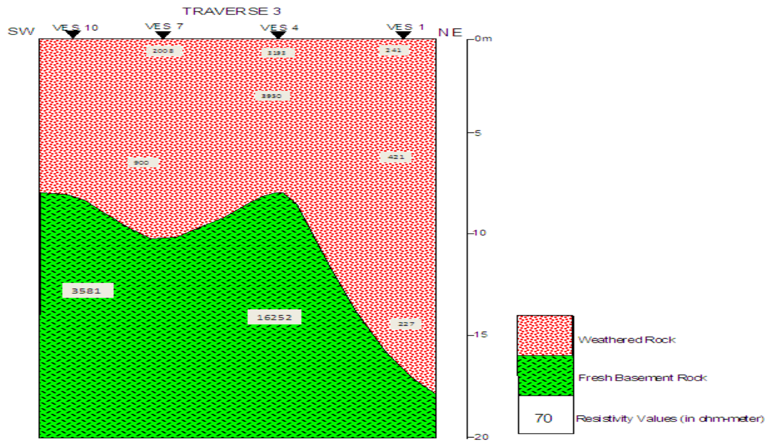

Fig. 4c: The Geoelectric section across Traverse 3

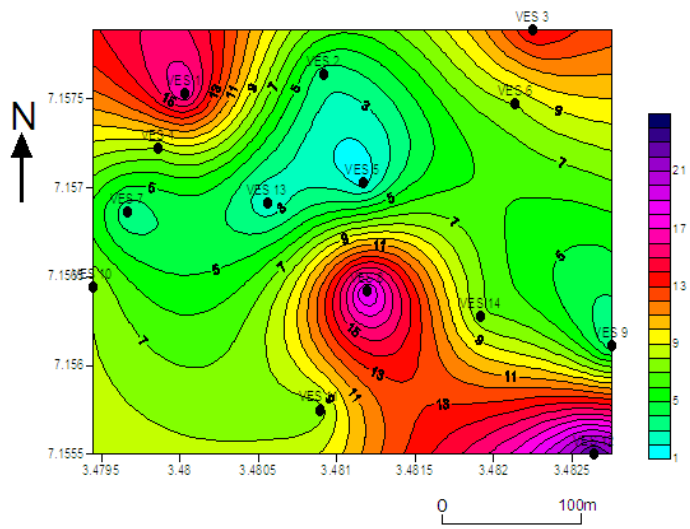

Fig. 5: The isopach map of the overburden thickness in the study area

3.479389 E — 7.157889 N

N ↑

14	11.5	5.5	6.5	10	11
10	9	3.8	4.4	6.7	8
5.5	5	10.5	11	7.5	5.5
7	7	13	14	9	7
8	8	10	12.6	14	16.5

7.1555 N — 0 — 100m — 3.48275 E

Fig. 6: The average overburden thickness for each grid in the study area.

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

Calculation of Reserve:

The average overburden thickness in each grid was subtracted from the corresponding average elevation grid and the result was shown in fig. 7. The result represents the top surface elevation (Ordinance Datum) of the underlying fresh bedrock in the area.

i.e. $OD = \Sigma(\overline{EG} - \overline{OT})$ where OD is the ordinance datum, $\overline{EG}$ is the average Elevation Grid and $\overline{OT}$ is the average overburden thickness

The lowest ordinance datum observed in the grid is 138m while the highest is 184.2m. The average thickness of the overburden over the whole lease area is 9m; this is of course rather high overburden thickness especially when the cost of removing it is put into consideration for profitable quarrying. Therefore, there is the need for selection and consideration of parts of the study area that are economically viable for exploitation. The criterion employed for area selection for the reserve estimation is such that the minimum ratio of overburden thickness to rock thickness is ratio 1:1. Three levels of reserve estimate could be made taking the rock base to be at successively lower ordinance datum of 170m, 160m and 150m. Figures 8, 9 and 10 show average thicknesses of the overburden and the thicknesses of the fresh rock body at the specified ordinance datum in the area which has been split into thirty (30) grids and were labeled 1A to 5F (i.e. at OD of 170, 160 and 150m respectively). The average thickness of the overburden is in parenthesis while the thickness of the rock is in square bracket. Each grid is 62m by 52.3m or 3,242.6m^2 area extents. The grids that meet the above criterion were shaded, and the volume of the reserve was calculated using the formula:

Reserve Volume (m^3) = Σ (area grid (m^2) x average thickness of grid (m))

The reserve tonnage is therefore calculated by:

Reserve Tonnage (tons) = Σ (volume grid (m^3) x specific gravity of the rock).

The reserve estimate calculations for these three ordinance datum were recorded in Table 2 and showed that the reserve estimate for economically viable grids for 170m, 160m and 150m are 4.42 x 10^5, 17.17 x 10^5 and 37.08 x 10^5 tons respectively. Although high volumes of overburden need to be removed to get to the fresh basement at the different elevation levels, the prospective granite tonnage is significantly very high to ensure satisfactory profitability following the criteria stated above.

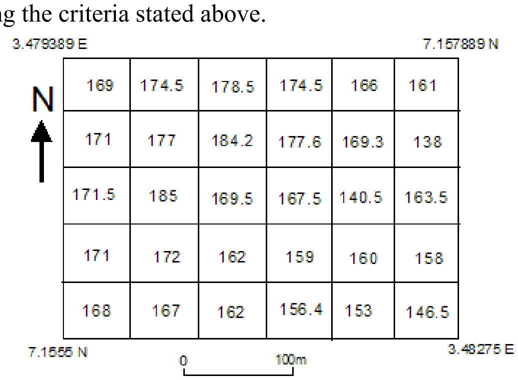

Fig. 7: The average residual elevation after the removal of the overburden thickness.

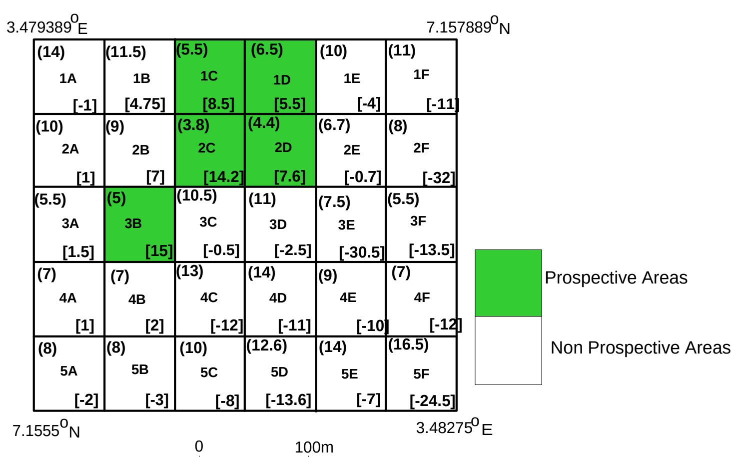

Fig. 8: The average thickness of overburden (in bracket) and granite body [in square bracket] at 170m datum.

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

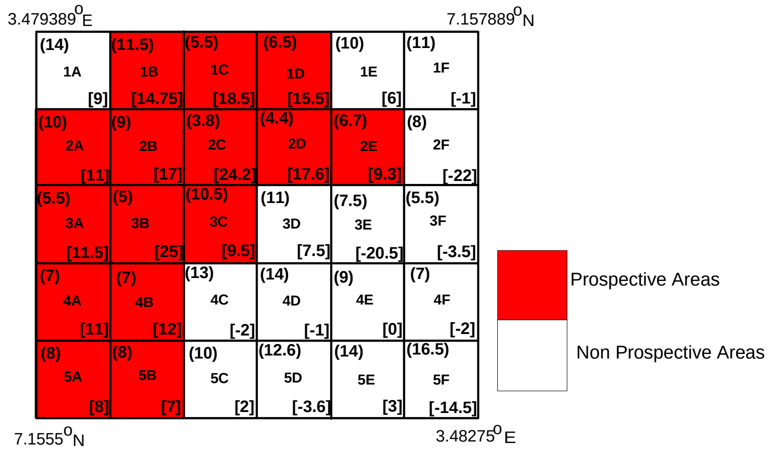

Fig. 9: The average thickness of overburden (in bracket) and granite body [in square bracket] at 160m datum.

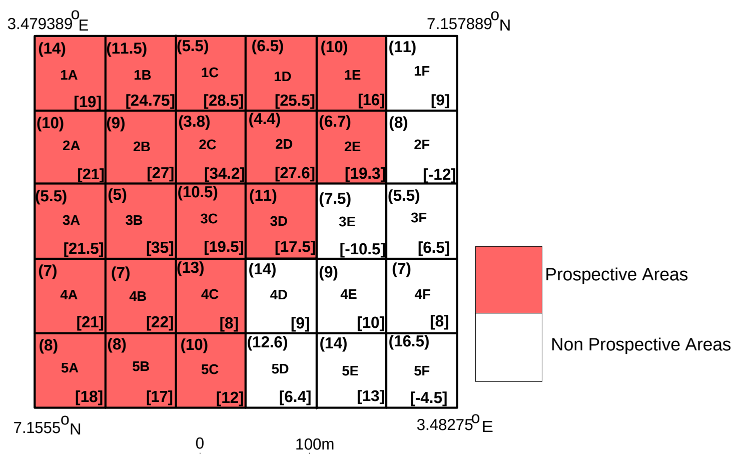

Fig. 10: The average thickness of overburden (in bracket) and granite body [in square bracket] at 150m .

The rock mass to overburden thickness ratio and duration:

The cost of removing the overburden thickness should be considered in mining of rocks. It is important to take into cognizant the economic viability of the mining. The rock: overburden thickness ratios of 1 to 1 very much satisfy the universal profitability factor of thickness ratio of 0.5 for mineral deposits. Though the overburden materials are not waste as they could be excavated and marketed as 'bulk-fill materials', where their thickness is more than the rock thickness are not considered in order to minimize the cost of removing the overburden, environmental implication and profitability. This will very much assist to mitigate the cost of accessing the fresh granite gneiss in areas with thickness lower than the rock thickness. The quarrying of the rock could thus be undertaken in stages to target the above considered 170m, 160m and 150m ordinance datum. Table 2 also shows calculation of the rock mass : overburden thickness ratios in these three data and revealed a ratio of 2 to 2.6, which very much satisfy the universal profitability factor of thickness ratio of 0.5 for mineral deposits. (Yavuz *et al*., 2005; Bell, 2008). Apart from considering the rock mass to overburden thickness ratio, the life span of the reserve is also very important. For a reserve to be considered to be economically viable, the volume must sustain not less than 20 years of quarrying (Bell, 2008). However, in this area, if an exploitation rate of 250 tons per day is adopted, the duration for exhausting the reserve estimates will successively be 6.7years, 26years and 56years for the adopted ordinance data of 170, 160 and 150m respectively. This however makes the ordinance datum of 150 and 160m to be good and suitable for mining when their economic viability is considered.

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

Table 2: Summary Of Overburden And Granite Reserve Estimates

Elevation Datum (m)	Granite Thickness (m)	Granite Reserve Estimate (tons)	Overburden Thickness (m)	Overburden Volume (m^3)	Rock Mass Reserve/Overburden Volume Ratio	Granite Thickness/Overburden Thickness Ratio	Duration of Reserve at 250 tons per day (yr)
170	51.1	442,410.62	25.2	81,713.52	5:1	2:1	6.7
160	198.35	1,717,263.13	108.4	351,606.24	5:1	2:1	26
150	428.34	3,708,543.79	166.4	539,568.68	7:1	2.6:1	56

Conclusion:

The Idi Osan Ofagada granite gneiss has been evaluated with careful consideration for rock mass: overburden ratio using three different ordinance data of 170m, 160m and 150m to estimate the tonnage with careful consideration of economic viability. The rock mass possess geotechnical properties comparable to competent rocks commonly exploited as aggregate materials.

The closeness of the location to Lagos (one of the world top 10 most populous city) is an advantage on cost of transportation. The rock as is largely fresh, though its fractured nature will limits its used in the production of dimension stone. Nevertheless it's moderately strong strength suggests that it can be used as aggregates for construction works. Areas with minimum ratio of granite gneiss to overburden thickness of 1:1 are assessed to be suitable for exploration.

Furthermore, the volume of reserve that can be quarried from the area is to 26 to 56 years at ordinance datum of 160 and 150 respectively when quarrying of 250tonnes is done per day, hence the rock mass is economically viable for quarrying as construction aggregates.

References

Adeyemi, G.O., 1985. Groundwater Exploration in parts of Oyo and Ogun State using remote sensing techniques (Unpublished M.Sc. Thesis) University of Ife, pp: 20-25.

Ajibade, A.C. and J.B. Wright, 1989. The Togo-Benin Shield: evidence of crustal aggregation in the Pan African Belt. Tectonophysics, 165: 125-129.

Akanni, C.O., 1992. Relief, Drainage, Soil and Climate of Ogun State in Map. (Eds) Onakomaya, S.O., Oyesiku, O.O. and Jegede, F. J. Rex Charles Publication., pp: 6-20.

Anon, 1979. Classification of rocks and soils for Engineering Geological Mapping, part 1-Rock and Soil Materials. Report of the Commission of Engineering Geological Mapping, Bulletin International Association of Engineering Geology, 19: 364-371.

Bayewu, O.O., 2002. Resistivity Survey for Reserve Estimation of Clay Deposit at Omi-Adio, Near Ibadan, SW Nigeria. Unpublished M. Sc. Project, University of Ibadan., pp: 82.

Bayewu, O.O., M.O. Oloruntola, G.O. Mosuro and O. Olagunju, 2008. Determination of Groundwater Potential Of An Area Using Electrical Resistivity Method: A Case Study of Olabisi Onabanjo University Mini Campus. Afri. Jour. of Pure and Applied Sc., 2(1): 17-23.

Bell, F.G., 2008. Engineering Geology,2nd Edition,Elsivier, pp: 581.

Dada, S.S., 2006. Proterozoic Evolution of Nigeria. In: O. Oshin (Ed). The Basement Complex of Nigeria and its Mineral Resources. M.A.O. Rahaman symposium., pp: 29-44.

Duze, M. and A. Ojo, 1982. Senior School Atlas. Macmillan, pp: 113.

Ehinola, O.A., M.A. Oladunjoye and T.O. Gbadamosi, 2009. Chemical composition, geophysical mapping and reserve estimation of clay deposit from parts of Southwestern Nigeria. J. Geol. Min. Res., 1(3): 57-66.

Elueze, A.A., 1981. Petrography and Geochemistry of Metasediments rock of Schist Belt of Ilesha area, SW Nigeria, Journal of Wmas, 18(1): 5-7.

Joshua, E.O., M.A. Oladunjoye and O.O. Bayewu, 2004. Mapping Structure Using Combined Seismic Refraction and Electrical Resistivity methods: A case study of Omi-Adio Overburden and its Environs, South Western Nigeria. Africa Geosciences Review, 11(4): 281-291.

Keller, G.V. and F.C. Frischknecht, 1966. Electrical Methods in Geophysical Prospecting. Pergamon Press. London., pp: 519.

Koefoed, O., 1979. Geosounding Principle-1, Elsevier, Amsterda, pp: 276.

Okurumeh, O.K. and A.I. Olayinka, 1998. Electrical Anisotropy of crystalline Basement Rocks around Okeho, southwestern Nigeria: Implications in Geologic Mapping and Groundwater Investigation. Water resources, Journal of NAH, 9: 41-50.

J. Appl. Sci. Res., 7(10): 1402-1410, 2011

Olarewaju, V.O., 1987. Charnockite-Granite Association in SW. Nigeria: Rapakivi granite type and charnockitic plutonism in Nigeria. J. Afri. Earth Sci., 6(1): 67-77.

Olayinka, A.I., 1996. Non Uniqueness in the Interpretation of Bedrock Resistivity from Sounding Curves and its Hydrological Implications. Water Resources, Journal of NAH., 7(1&2): 55-60.

Olorunfemi, M.O and E.T. Okhue, 1992. Hydrogeologic and Geologic significant of a Geoelectric survey at Ile-Ife, Nigeria. Journal of Mining and Geology, 28(2): 221-229.

Orellana, E. and H.M. Mooney, 1966. Tables and Master Curves for Vertical Electrical Sounding. Interciencia, Madrid, pp: 160.

Oyawoye, M.O., 1972. The Basement complex of Nigeria in Dessauvagie, T.F.J., Whiteman, A.J. (Eds). African Geology. Ibadan University Press, Ibadan, Nigeria, pp: 41-56.

Rahaman, M.A., 1976. Review of the basement geology of southwestern Nigeria. In Kogbe,C.A (ed) Geology of Nigeria. Elizabethan Pub. Co. Lagos, pp: 45-58.

Rahaman, M.A., 1978. Geochemistry of some Gneiss from parts of southwestern Nigeria. Jour. Min. and Geol., 15(1): 38-48.

Vander Velpen, B.P.A., 1988. "Resist Version 1.0". M.Sc. Research Project, ITC: Delft, Netherlands.

Yavuz, A.B, N. Turk and M.Y. Koca, 2005. Geological parameters affecting the Marble production in the quarries along the southern the Flank of Menderes Massif, in SW Turkey. Engineering Geology, 80: 214-241.

Zohdy, A.A., 1965. The Auxillary Point Method of Electrical Sounding Interpretation and its relationship to the Dar Zarrouk parameters. Geophysics., 30: 644-660.

Zohdy, A.A., 1974. Application of Surface Geophysics to Groundwater Investigation. Techniques of water resources investigations of the US Geological Survey, Book2, pp: 5-66.