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GEOPHYSICAL INVESTIGATION OF OLI RIVER LODGE DAM AXIS, KAINJI LAKE NATIONAL PARK, NIGERIA

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ABSTRACT

The Kainji Lake National Park is composed of the Borgu and Zurguma sectors. The main objectives of the parks are the conservation of gene resources of indigenous wild life plants and animals and management for educational and tourist purposes. The need to complement the above objectives with a lake for recreation (boating, fishing etc) at the Oli river lodge resulted in proposing a weir across the Oli River at the camp site. Investigations using geophysical (Vertical electrical sounding, resistivity profiling and electromagnetic) methods were carried out, along geophysical traverses TS1, TS2 and Ts3 at the proposed weir across the river. The geoelectrical section along the major Weir axis varies from two to four layers. The western bank depth to basement varies from 3 to 6m. Granite exposures occur along the river channel with highly jointed features (width 80m). The eastern bank shows a more variable and compact topsoil than that of the western bank. The underlying layer is a zone of varying resistivity values, which suggest fracturing/faulting, or jointing. The geophysical result of the marked complexity at the eastern bank, show that it is underlain by conductive materials which probably are due to the presence of water saturated fracture/fault zones within the area. Depth to the fresh bedrock will however be ascertained by the drilling of two additional boreholes that will allow a seepage-free foundation to be laid.

Key words: Weir axis, resistivity, fracture/faulting and geoelectric section

INTRODUCTION

The Kainji Lake National Park is composed of the Borgu and Zurguma Sectors. The Borgu Sector is situated in Borgu Local Government area of Kwara State. The Oli river lodge is located within the Borgu Sector of the parks (Fig. 1). The main objectives of the parks are the conservation of gene resources of indigenous wild life plants and animals, and management for educational and tourist purposes. The need to complement the above objectives with a lake for recreation (boating, fishing etc) at the Oli lodge resulted in proposing a weir across the Oli River at the campsite. The study involves investigation at the site using geophysical methods.

The information is required for the design and construction of the dam axis foundation, the assessment of the ease of evacuation and identification of possible seepage zones. All earth and rock-fill dams are subject to seepage through embankment, foundation, and abutments. Seepage control is necessary to prevent excessive uplift pressures, sloughing of downstream slope, piping through the foundation and abutments. As a result, preliminary investigations were carried out along the dam axis to ascertain the suitability of the axis, and to recommend for detailed investigations at specific portions along the axis. This is necessitated due to the fact that in Nigeria there is the likelihood of weathering beneath the stream channel and it may be possible to suggest that the weir become "superposed" upon the irregular basal surface of weathering (Thomas, 1966, 1994).

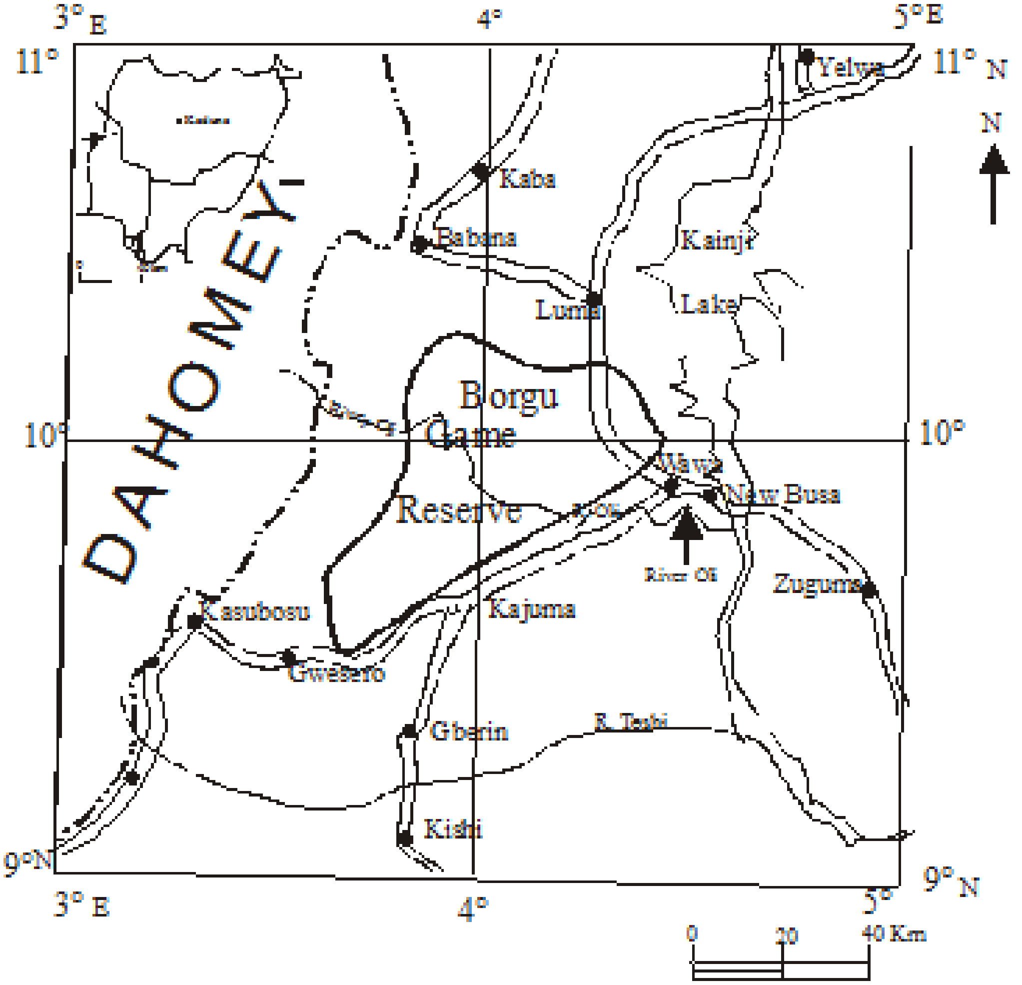


Figure 1: Location of River Oli, Nigeria (After Nigerian Mapping Company, 1974)

Geophysical methods have been used extensively in dam site investigations (Artsybashev, 1973; Ako, 1976; Artsybashev and Azeez, 1977; Kilty et al., 1986; Annor et al., 1989; Ojo and Olorunfemi, 1995; Olasehinde and Adelana, 1999). For cost-effectiveness the electrical resistivity sounding (VES), resistivity profiling and VLF electromagnetic surveys were employed in this study to throw more light on the subsurface geology along the dam axis site.

SITE DESCRIPTION AND GEOLOGICAL SETTING

Kainji lies in the Savannah belt of Northern Nigeria on latitude 9^0 08'N and longitude 4^0 49'E. The climate of the area is divided into wet season from April to November and a dry season from November to April. Rainfall is about 1000mm, whereas evapotranspiration is estimated at about 1500-2000mm (Iloeje, 1982). The vegetation of the park is typical of the Sudan-Guinea Savanna, although in some areas it appears more Sahelian. Riparian forests occur on the banks of the larger watercourses (Iloeje 1982).

The temperature of the air ranges from a minimum of about 15^oC in January – February to a maximum of around 40^oC in March – April, when the humidity is very high.

GEOLOGY OF THE STUDY AREA

Geologically Kainji is situated on the Basement Complex rocks of Africa (Rahaman, 1976). Several rock types, such as granitic, dioritic and hornblende-biotite gneiss, diorite, mica quartzite and pegmatite and dolerite (the last two as intrusives) were found at Kainji. The quartzite is highly jointed, though investigations revealed the joints to be shallow seated (Sarkar, 1985). The massive outcrops of granite gneiss cover nearly 50% of the area, whereas diorite and quartzite each occupy another 10%. The dioritic and hornblende-biotite gneiss constitute the remaining 30% of the area. Both concordant and discordant pegmatite veins, 3-25 cm wide are present in the gneiss (Sarkar, 1985). The other intrusive rock, dolerite, also occurs mainly as veins. A major unconformity separates these crystalline rocks from sandstones, conglomerates and gravels found overlying them in certain areas upstream of Shagunu (FAO, 1973).

Geological survey carried out by the authors show that Oli river lodge site is underlain mainly by porphyritic granites intruded by basic dykes with sharp chilled contacts indicative of fracturing. The granites exposure is extensive at the campsite. They are highly jointed with major joint directions of between 0^0 to 20^0 and plunges of between 62^0E to 68^0E. These major joints have virtually the same direction as the regional strike; and are cut by another set of joints having directions of between 102^o to 128^0 with plunges of between 74^oS to 88^oS.

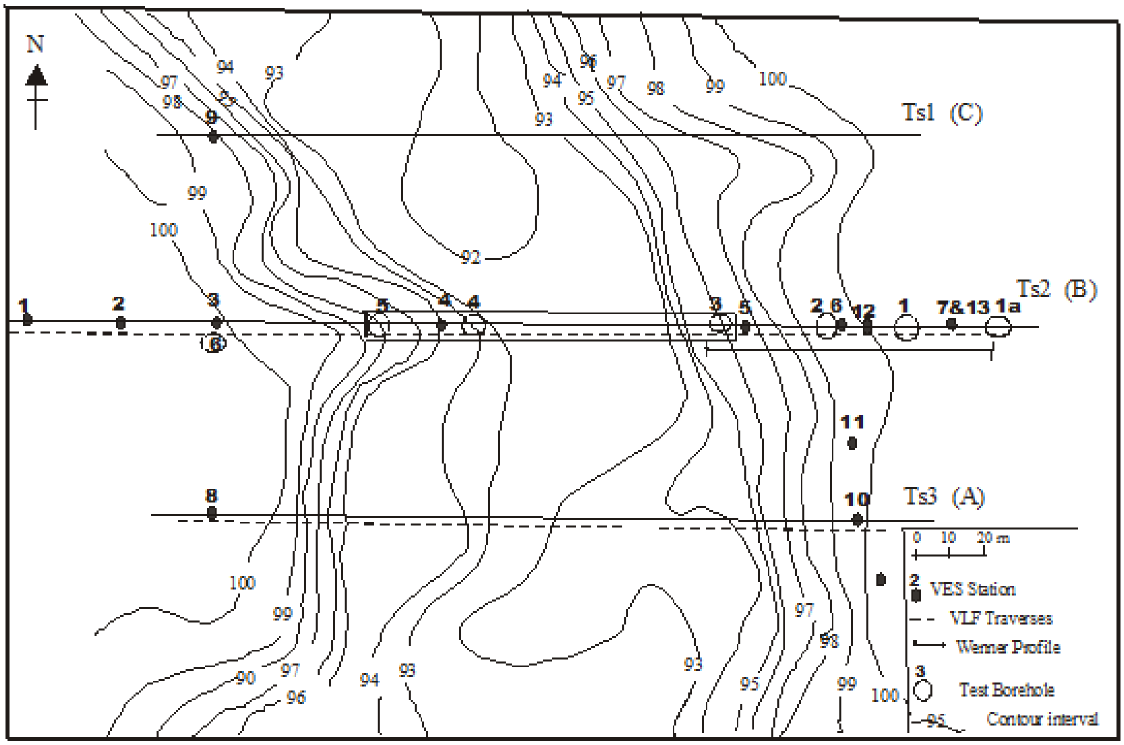
Rocks of this type may be hazardous as foundation for structures such as Dams and Weirs. Consequently, a detailed study of the site must be carried out. Such studies include geological mapping, geophysical investigation, test drilling/coring and geotechnical studies. This paper deals with only the geological and the geophysical investigation of the study area.

METHOD OF STUDY

Geophysical site investigation at Oli lodge involved the use of vertical electrical resistivity sounding (VES), resistivity profiling and Very Low Frequency (VLF) electromagnetic method. The VLF method, which provides a quick and powerful tool for the study of conductive near surface lineament features (Telford et al., 1977), is based on the measurement of the secondary magnetic field induced in the local conductors by the primary EM fields generated by radio transmitters in the very low frequency range (15 – 25kHz). The measured in-phase/Real (R) and the out-of-phase/Imaginary (I) field components of the induced vertical field H_v as a percentage of the horizontal primary field H_y are interpreted to quickly and effectively locate fracture and fault zones in the basement environment with the aid of an operating manual (GEONIC 1979). Figure 2, shows the geophysical traverses and VES stations, TS 1, TS 2 and Ts 3. The VLF electromagnetic survey was carried out with the Geonics EM – 16 (VLF-EM), along TS 2 and TS 3 respectively, using a station separation of 10m. The measured data are presented as profiles and interpreted qualitatively. The real component of the vertical magnetic field of the VLF-EM data were linearly filtered using the data processing program developed by KIGAM (Chung et al., 1990; EM2Dmodel, 2002). The program is based on the discrete linear filtering methodology proposed by Karous and Hjelt (1983). The Karous and Hjelt linear filter is given as:

$$I_a(0)=\frac{2\pi\left(-0.102\cdot H_{-3}+0.059\cdot H_{-2}-0.561\cdot H_{-1}+0.561\cdot H_1-0.059\cdot H_2+0.102\cdot H_3\right)}{z}$$

Where I_a (filtered result) is the equivalent current at a specific horizontal position and depth z is based on a symmetrical filter of the measured current; H_{-3} through H_3 are the original measured VLF data.



Ts1 – Traverse (line) 1, Ts2 - Traverse 2, Ts3 – Traverse 3

Figure 2: Site showing geophysical traverses and test borehole locations.

Vertical Electrical Sounding (VES) was carried out in the study area using Schlumberger array. Thirteen VES stations were undertaken, using the ABEM SAS 300 Terrameter along the three profiles (Fig. 2), with half- current electrode separation (AB/2 m) of 2 m to 150 m. The obtained data were plotted as VES curves and interpreted using partial curve matching (Orellana and Mooney, 1966; Keller and Frischkneckt 1966) and computer iteration software programme RESIXP (Interpex, 1992). From the interpreted VES curves a number of geoelectrical sections were drawn and interpreted in terms of the subsurface geology.

Based on the initial interpretation of the VES data along TS 2, a Wenner electrical resistivity profiling was carried out on TS 2 a distance of 80m (Fig 2). The electrode separation was 10m whilst station separation was 5m.

RESULTS AND DISCUSSIONS

Table 1 shows the results of the interpreted curves. Figure 3 to 6 are the geoelectrical sections. The Wenner profiling data are presented as profile (Figs 7) and VLF electromagnetic profiling data are shown in Figs. 8 to 11.

Figure 3 shows the geoelectrical section along the major Weir axis (TS 2). The geoelectrical layers vary from two to four layers. VES 1 to 4 are located on the western bank of the Oli River while VES 5, 6, 12, 7 and 13 are on the eastern bank. Granite occurred along the river channel valley.

TABLE 1: Results of Interpreted Curves

VES	RESISTIVITY(Ωm) $\rho_1/\rho_2/\ldots/\rho_n$	THICKNESS (m) $h_1/h_2/\ldots h_n$	NO OF LAYERS
1	200/108/	0.5/6.5	3
2	90/41/	1.0/6.0	3
3	50/1950	6.7/	2
4	115/280/9600	2.0/10.0	3
5	550/400/1900	0.5/6.5	3
6	170/850/80/1600	2.2/4.0/6.0	4
7	32/112	1.5/--	--
8	340/34	1.6/--	--
9	130/87/240	2.2/6.6	3
10	680/367/3600	1.3/2.6	3
11	1000/667/4725	1.5/6.5	3
12	600/200/872		

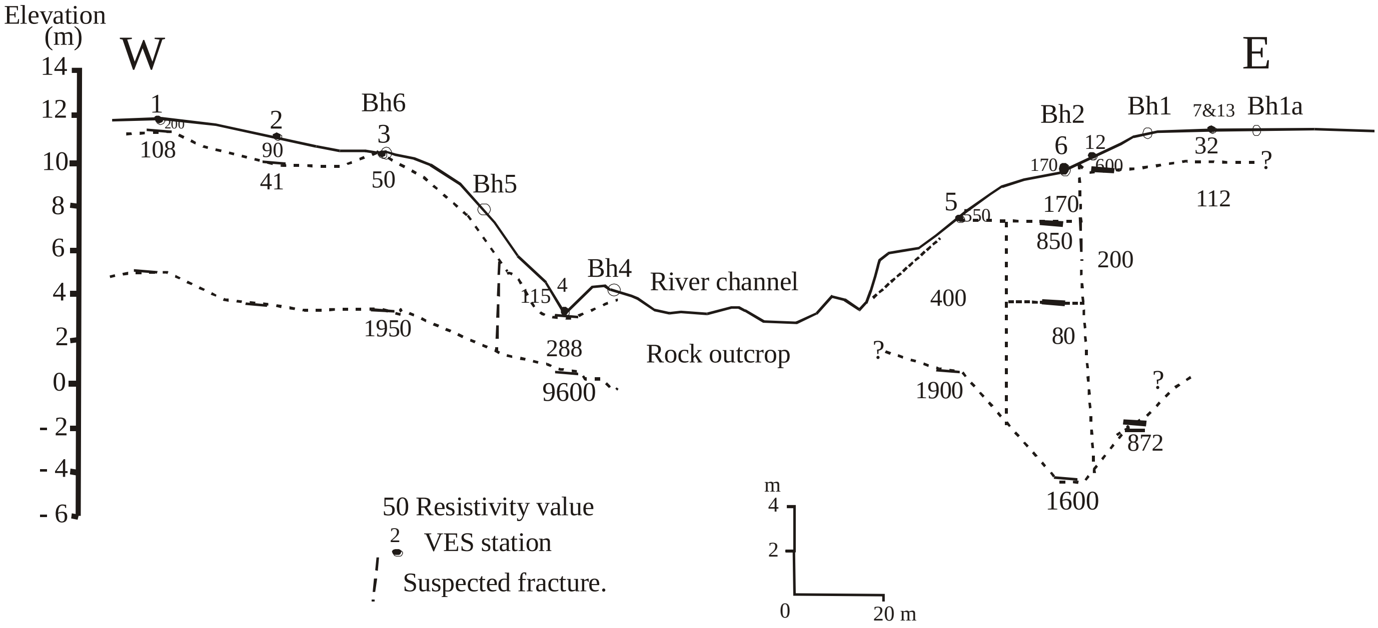


Figure 3: Geoelectric section along Ts 2 (main axis)

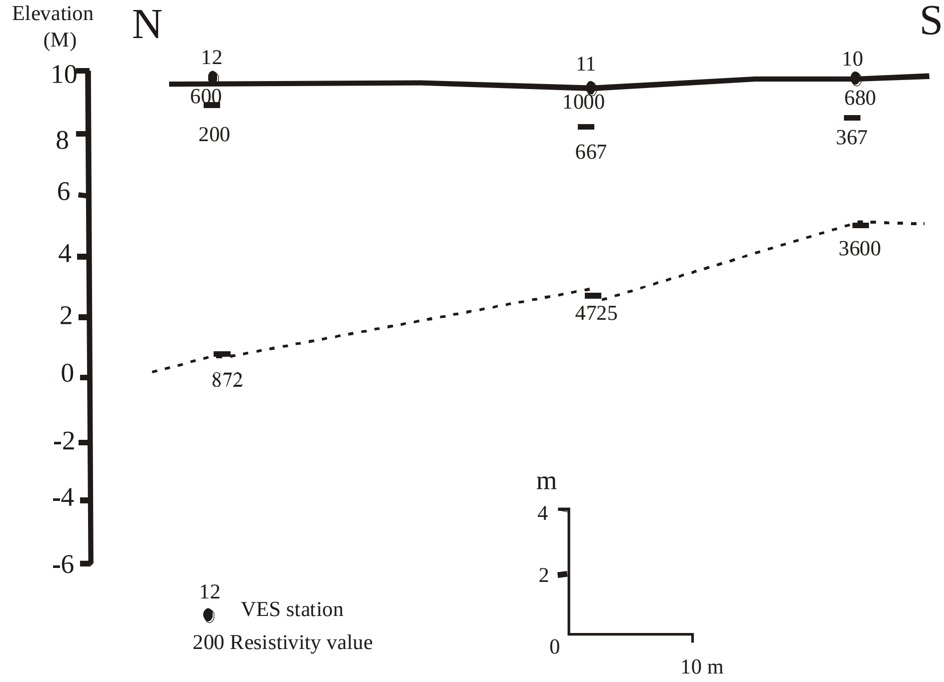


Figure 4: Geoelectric section along eastern section (1)

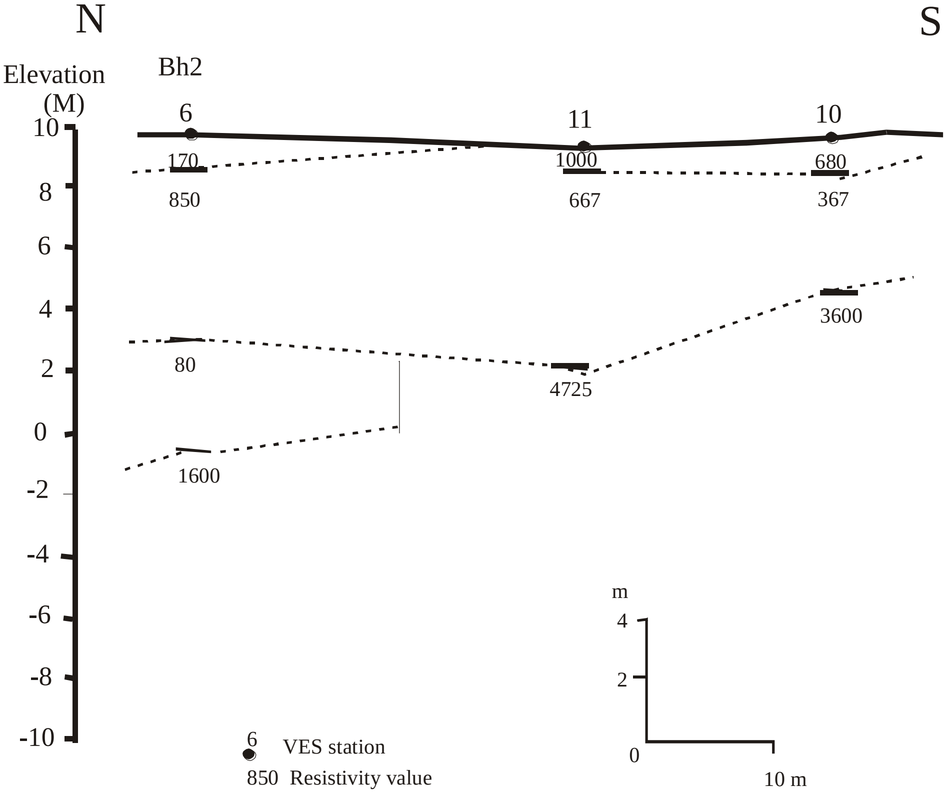


Figure 5: Geoelectric section along eastern section (2)

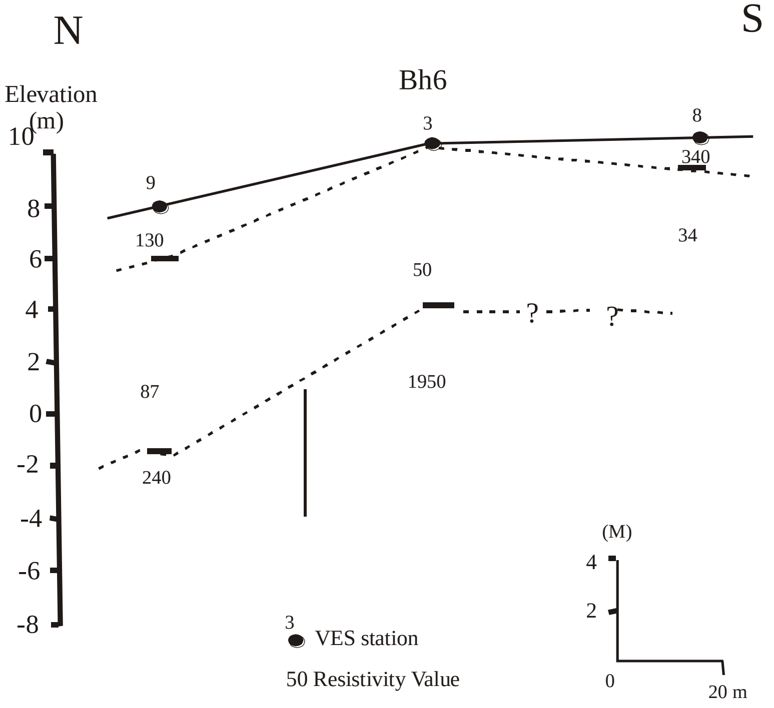


Figure 6: Geoelectric along western section

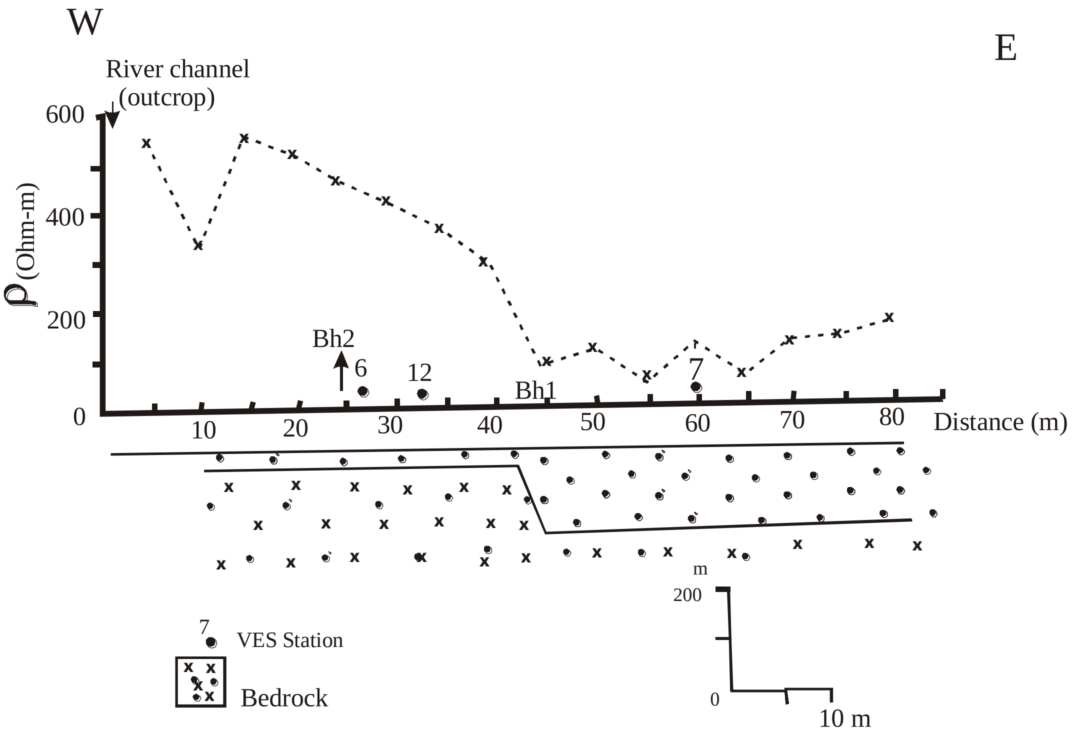


Figure 7: Resistivity profile along TS 2 (main axis).

There are three geoelectric layers underlying the western bank. The first layer has resistivity values ranging from 90 to 200 Ohm–m, representing variable topsoil. It has an average thickness of 0.5m. It is underlain by clay/sand layer (ρ = 41 to 288 Ohm-m). The clay (ρ = 41 – 50 Ohm-m) is between VES 2 and 4 and an average thickness of 5m. The basement is at a depth of 6m with resistivity greater than 1950 Ohm-m. Immediately to the east of VES 4 is the river channel, which is about 80m wide with outcrops of highly jointed granite.

The geoelectric layering on the eastern bank is rather complex. The surface resistivity values of 32, 170, 550 and 600 Ohm–m respectively show that the top soil although variable is more compact than that of the western bank. In the underlying second layer, zones of varying resistivity values are juxtaposed suggesting fracturing/faulting and/or jointing. The geoelectric section between two closely spaced VES stations (6 and 12) confirms the presence of fractures/faults (Fig 3). The second layer thickness is about 9m. At VES 7 and 13 the thickness of the second layer could not be accurately determined because of scatter in the VES plot.

The geoelectric Basement resistivity (ρ = 1600 to 2000 Ohm-m) correlates fresh granite rock. The depth to the top of the partially weathered granite is 7m at VES 5, 10m at VES 6, and about 9m at VES 12. The value was not mapped at VES 7 and 13 as it could not be accurately determined. Figures 4, 5 and 6 which are geoelectric sections along N – S direction confirm the increase in depth to the fresh rock north-wards that is from TS 3 to TS 1. It also shows the clay/sand second layer dipping towards the north.

As a result of the complexity at the eastern bank, a Wenner profiling was carried out. Figure 7 shows the profile. It is likely that apart from the depth to the fresh rock increasing to the east, a fracture/fault exists very close to BH 1, making the depth to basement west of BH 1 shallower than to the east.

Figure 8 shows the linearly filtered real component of the vertical magnetic field of the VLF data along traverse 2 and Figure 9 is the modeled data. Figure 8 shows conductors at 48m, 100m 160m 210m and 248m. The conductor at 48m, appears at shallow depth while the conductor 210m is deepest (Karous and Hjelt, 1983). Figure 9, the modeled data, shows the depth of the conductors. The interpretation shows a network of fractures, thus the VES confirms results from the VLF interpretations. Figure 10 and 11 show the filtered data for traverse 3. It shows very shallow conductors at about 55m, 75m and 110 to 240m. The conductor at 55m, appears at very shallow depth while it is deepest at 110m and gradually decrease in conductivity from 110m to 210m.

From the surface geological mapping, the occurrence of intruding dolerite dykes and accompanying mylonitisation on the eastern bank confirm the presence of fracture/fault zones. Occurrence of intruding dolerite dykes and accompanying mylonitisation is clear evidence fracture and fauling.

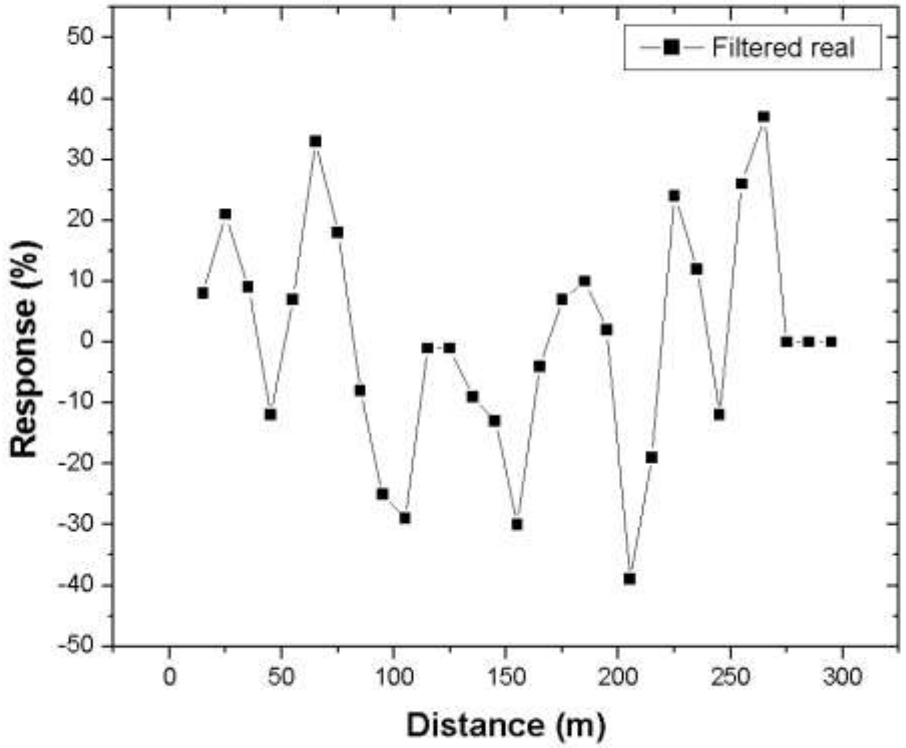


Fig. 8: VLF filtered (Real Component)

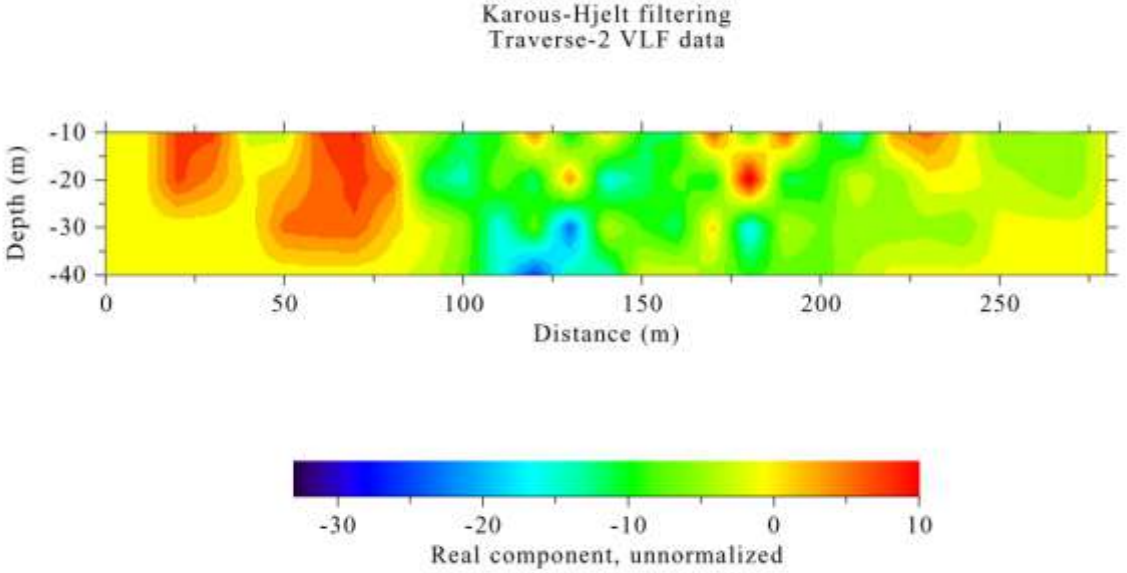


Fig. 9: VLF filtered date (Modeled) along Ts 2.

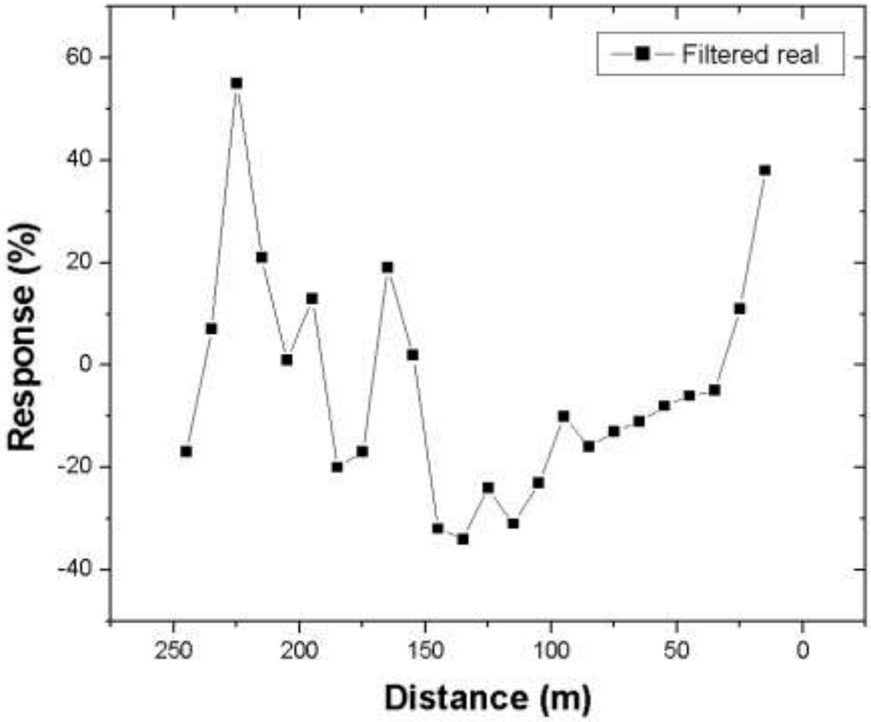


Fig. 10 : VLF filtered (Real Component) along Ts 3

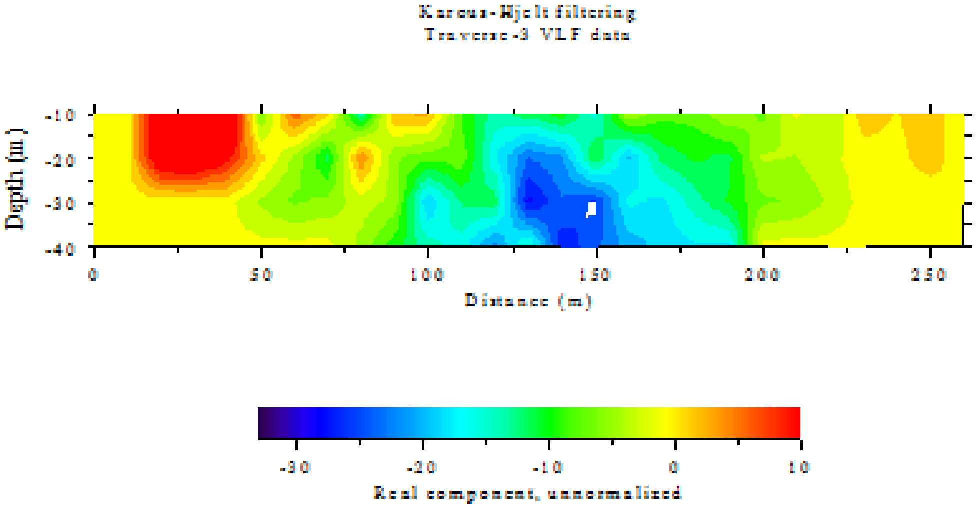


Fig. 11:VLF filtered data (Modeled) along Ts 3.

From geological and geophysical mapping of the Oli river weir site, the subsurface geology can be subdivided into three via:

- The western bank – which is fairly simple with depth to fresh rock varying from 3 m to 6 m. The depth obtained at VES 4 which is very close to the exposure of granite could suggest jointing, fracturing or faulting.
- The river channel with highly jointed coarse-grained weathered granites outcrops in the river channel.
- The eastern bank has a series of fracture/fault zones. The depth to partially weathered granite increases towards VES 12 (7m to 10m). However, outcrops of granite occur beyond about 60m east of VES 12.

Based on this study, depth to the fresh bedrock will however be determine by the drilling of two additional boreholes viz. BH 2 and 1A (Fig. 2).

CONCLUSION

Foundation investigation using geophysical methods has been carried out at the proposed weir across the Oli River located within the Kainji lake national parks. The geoelectric layers along the major Weir axis (TS 2) vary from two to four layers. VES 1 to 4 were located on the western bank of Oli River while VES 5, 6, 12, 7 and 13 were on the eastern bank. Exposures of highly jointed granite rocks (width 80m) occurred along the river channel or valley.

There are three geoelectric layers underlying the western bank. The first layer has an average thickness of 0.5 m and resistivity values of 90 to 200 Ohm–m, representing variable top soil. The geoelectric basement (resistivity > 1950 Ohm-m) is at a depth of 6 m. The surface layer on the eastern bank has variable resistivity values. This shows a variable and more compact top soil than what we have on the western bank. The underlying second layer with thickness of about 9 m, is also a zone of varying resistivity values which suggest fracturing/faulting or jointing. Depth to the bedrock could not be accurately determined from the VES curves at VES 7 and 13. This is because of scattering of points in the VES plot. The geoelectric basement (ρ_a = 880 to 2000 Ohm-m) correlates with fresh granite rocks. The depth to the top of the partially weathered granite is between 7 and 10 m

The geoelectric sections along N – S direction indicate increase in depth to the fresh rock north-wards from (TS 3 to TS 1). A Wenner profiling carried out as a result of the complexity at the eastern bank shows that a fracture/fault exists very close to BH 1, making the depth to basement at BH 1 shallower than the surrounding points. The results of the VLF electromagnetic data show conclusively that the eastern bank of river Oli is underlain by conductive materials, which probably is due to the presence of water saturated fracture/fault zones within the area. This is confirmed by the occurrence of intruding dolerite dykes and accompanying mylonitisation on the eastern bank from surface geological mapping.

Depth to the fresh bedrock will however be ascertained by the drilling of two additional boreholes that will allow a seepage-free foundation to be laid.

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REFERENCES

Ako, B. D. 1976: An integration of Geophysical and Geological data in Dam site Investigation. The Case of Opa Dam. Jour. Min. Geol., Vol. 13 No. 1 Pp 1-6.

Annor, E. A., Olasehinde, P. L. and Pal,, P. C. 1989: A geological evaluation of a Prospective site for a Weir in the River Oyin, Ilorin, Nigeria. Zangew: Geowiss, heft 8, S. 83 – 90.

Artsybashev, V. A. 1973: Geophysical Investigation of Oyimo dam site, Ikare, Western Nigeria. (Unpublished report) Department of Geology. University of Ife.

Artsybashev, V. A. and Azeeze, L. O. 1977: Geophysical Investigation of Oyile dam site, Ilesha. Journ. Of Min and Geol., Vol 14, No 2, Pp 44 – 46

Chung, S. H., LEE, S. H and KIM, J. H., (1990). Depth presentation of VLF-EM data using digital filtering. Geophysical exploration method development series KR-89-2D-2 of Korea institute of energy and resources, 97-115.

EM2DMODEL, 2002. EM2DMODEL™ VERSION 1.0, Processing and interpretation software for electrical resistivity data. KIGAM, Daejeon, South Korea.

FAO, 1973. Kainji Lake Research Project. Nigeria. Pelagic primary production in Kainji Lake. Report prepared for the Government of Nigeria by the Food and Agriculture Organization of the United Nations acting as executing agency for the United Nations Development Programme. Technical Report 3. 59 pages http://www.fao.org/docrep/field/009/e2108e/E2108E01.htm#ch1.5

Feininger, T. 1971: Chemical weathering and Glacial erosion of Crystaline rocks and the Origin of till. U. S Geological Survey, Professional paper 750C, pp 65-81.

Geonics, 1979 Operating manual for EM 16 VLF – EM data Geonics Ltd Ontario Canada.

Iloeje, N.P.; A new geography of Nigeria, New Revised Edition. Longmas Nigeria Ltd.

Interpex, 1992, Resix^{plus} Resistivity data Interpretation Software. Interpex Ltd., Colorado U.S.A.

Joint Consultants 1961: (Nedeco and Balfour, Beatty and Company, Ltd) Niger Dam Project, Vols 2,5.

Karous, M., AND HJELT, S. E., 1983. Linear filtering of VLF dip-angle measurements. Geophysical Prospecting, 31, 782-794.

Keller, G. V. and Frischknecht, F. C. 1966: Electrical Methods in Geophisical Prospecting. Pegamon Press, New York. 520p

Kilty, K. T., NORRIS, R. A., Mc Lamore, W. R., Hennon, K. P. and Euge, K. 1986: Seismic Refraction at Horse Mesa dam: An application of the generalized reciprocal method. Geophysics, Vol 51, No. 2. Pp266 – 275.

Ojo, J. S. and Olorunfemi, M. O. 1995: Geoelectric Mapping of a Near Vertical Contact: A case study Around Erusu, Ikare Area, South-Western Nigeria. Journal of Mining and Geology. Vol 13 No 2. Pp 151 – 153.

Olasehinde, P. I. and Adelana, S. M. A. 1999: A Geophysica Investigation of a Proposed Dam Site in Southwestern Nigeria. Water Resources. (Journal of the Nigerian Association of Hydrogeologists, NAH). Vol. 10 Pp 50 – 54.

Orellana, E. and Mooney, H. M. 1966: Master Tables and Curves for Vertical electrical Sounding over layered Structures. *Interciencia, Madrib*.

Sarkar, S, L 1985. The role and effects of harnessing the River Niger at Kainji and Jebba *Scientific Basis for Water Resources Management* (Proceedings of the Jerusalem Symposium, September 1985). IAHS Publ. no. 153. Pp 333 – 339.

Telford, W. M; King, W. F. and Becker, A. 1977: VLF Mapping of Geological Structure. Geological Survey of Canada No 76 25pp.

Thomas, M. F. 1966: Some Geomophological Implications of deep Weathering patterns in Crystalline rocks of Nigeria. Transactions of the Institute of British Geographers, 40, Pp 173 – 193

1994: Geomophology in the Tropics: A study of Weathering and Denudation in the Low Latitudes. Wiley. Chichester. 460 p.