AN INTEGRATED GEOPHYSICAL INVESTIGATION OF A SPRING IN IBUJI, IGBARA-OKE, SOUTHWESTERN NIGERIA.

Bayode S. * and Akpoarebe O.
Department of Applied Geophysics, Federal University of Technology, Akure

(Received: January, 2011; Accepted: March, 2011)

ABSTRACT

An integrated geophysical investigation involving the magnetic and electrical resistivity methods was used to investigate a spring in Ibuji, near IgbaraOke, southwestern Nigeria. This was with a view to determining its nature and source and the feasibility of developing it as a groundwater resource. Magnetic profiling and 2-D subsurface resistivity imaging with the dipole-dipole array and thirteen Schlumberger Vertical Electrical Soundings (VES) were carried out along three traverses. The total field magnetic measurements were taken at 5 m interval and corrected for diurnal variation and offset. Magnetic anomaly that is typical of a thin dipping dyke model (suspected to be a fault/fracture or shear zone) was delineated along each of the three traverses. Quantitative interpretation of the magnetic anomalies gave depths to the magnetic basement bedrock of between 13.2 and 20.1 m. The geoelectric sections and the inverted 2-D resistivity structures delineate maximum of four subsurface geological units consisting of the topsoil, weathered layer, the fractured basement and the fresh basement rock. The VES gave depths to basement bedrock of 7.4-25.1 m. Also the resistivity structures identify a major low resistivity vertical discontinuity (F1) typical of a fault zone across the three traverses and another suspected strike slip fault (F2) across fault zone F1 on which the Ibuji Spring is located. The width of the anomalous zone varies from 10-17.5 m. It can be concluded that the Ibuji Spring is structurally controlled. The 10-17.5 m wide suspected fault zone F1 is favourable to groundwater development.

Keywords: Geophysical, Investigation, Fracture Delineation, Spring, Ibuji.

INTRODUCTION

Integrated geophysical methods, especially seismic refraction, Electromagnetic (EM), magnetic and electrical resistivity methods are commonly used in the mapping of subsurface geologic discontinuities. Recent advances in groundwater exploration and exploitation have shown that groundwater can occur within rocky terrains, provided there are discontinuities within the rock. These discontinuities can occur as lineaments, shear zones, fractures, joints and faults. The quality and quantity of groundwater present within the fractured rock depend on the lateral extent, width of openings, type and amount of infilling within the fractured zone, frequency of occurrence of the fractures, the depth of the fractures from the surface and the composition of the host rock (Teme and Oni, 1991). Many authors have used integrated geophysical methods in the detection of groundwater in fractured media e.g. Teme and Oni, 1991, Richard and Paul, 2004, Sharma and Baranwal, 2005, Sultan et al., 2009 and Nabeel, 2010.

The rural sector in southwestern Nigeria relies mainly on groundwater for their domestic needs. Ibuji is a rural community located about 6 km north of Igbara-Oke, Ondo State. Several attempts made by the Ondo State Gorvenment to provide potable water for the people in the community through groundwater development have not been successful. Consequently, the villagers have continued to depend on water from streams, rivers and a prominent spring. This study utilizes an integrated magnetic and electrical resistivity method to map the referenced spring. It intends to determine the nature of the spring, its source and evaluates the feasibility of developing it as a groundwater resource.

SITE DESCRIPTION

Ibuji, the study area, is located in Ifedore Local Government Area of Ondo State (Fig. 1). It is situated about 6 kms North of Igbara-Oke along Igbara-Oke and Igbara-Odo Road. It is lies between the geographic co-ordinates of Easting's 727880 and 728240 mE and Nothing's 824160 and 824680 mN in Universal Traverse Mercator (UTM) Minna zone 34 (Fig. 1).

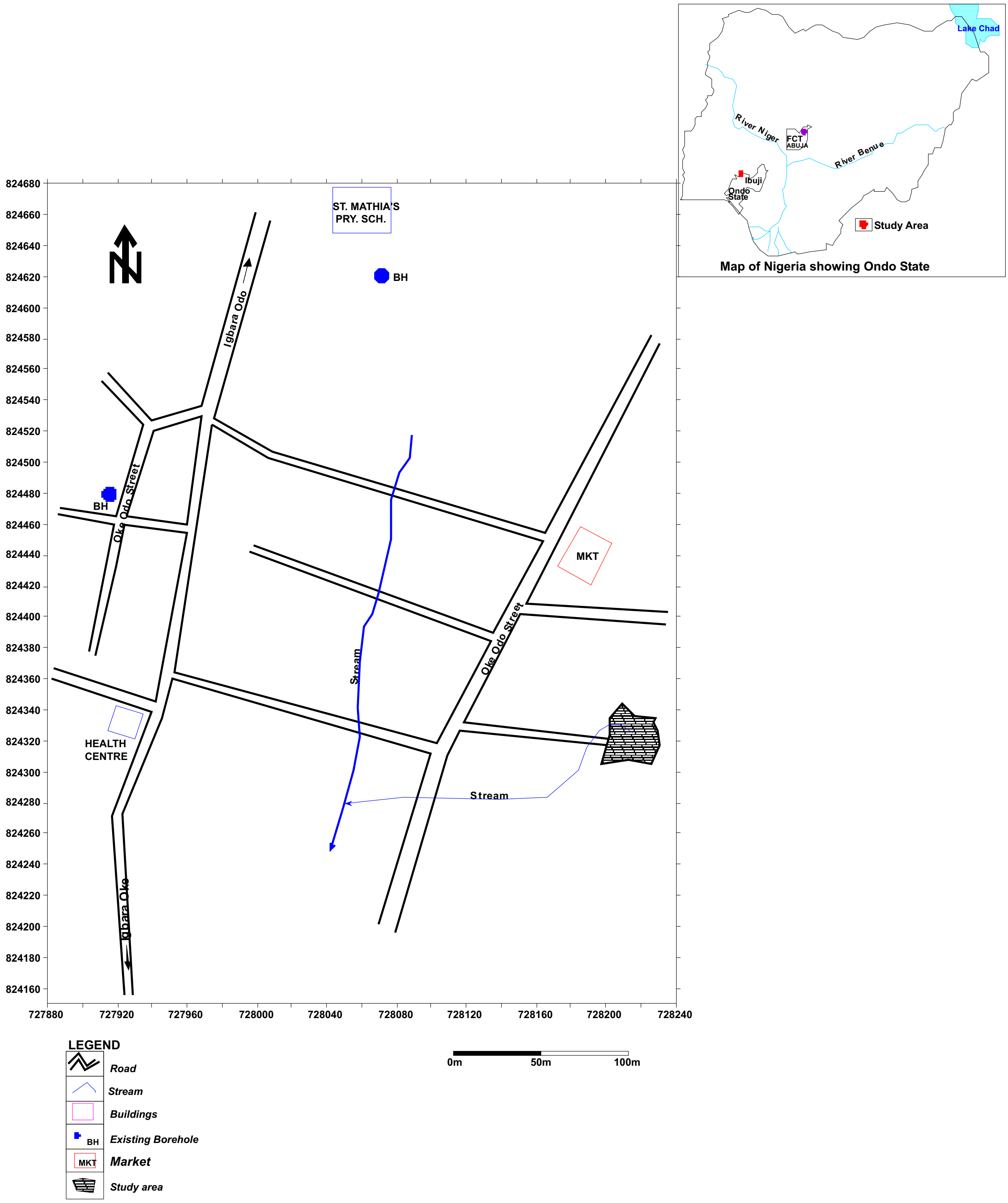


Fig. 1: Map of Ibuji Showing the Study Area.

GEOLOGY AND HYDROGEOLOGY

The study area is underlain by the Precambrian Basement Complex Rocks of southwestern Nigeria (Rahaman, 1976). The lithologic unit identified in the study area is the migmatite gneiss (Fig. 2). The migmatite gneiss outcrop show evidence of structural deformation by series of approximately parallel East West fractures, joints and lineaments defined by vegetation alignment.

Groundwater is found in the weathered layer, fractured and jointed column in a typical basement terrain. The weathered layer in the study area is generally thin due to the near-surface nature of the basement bedrock. The basement rocks are mainly exposed in the northern part and in the area around the spring. Structural discontinuities (shear zones, faults, fractures and joints) within the basement bedrock are possible conduit for spring discharge.

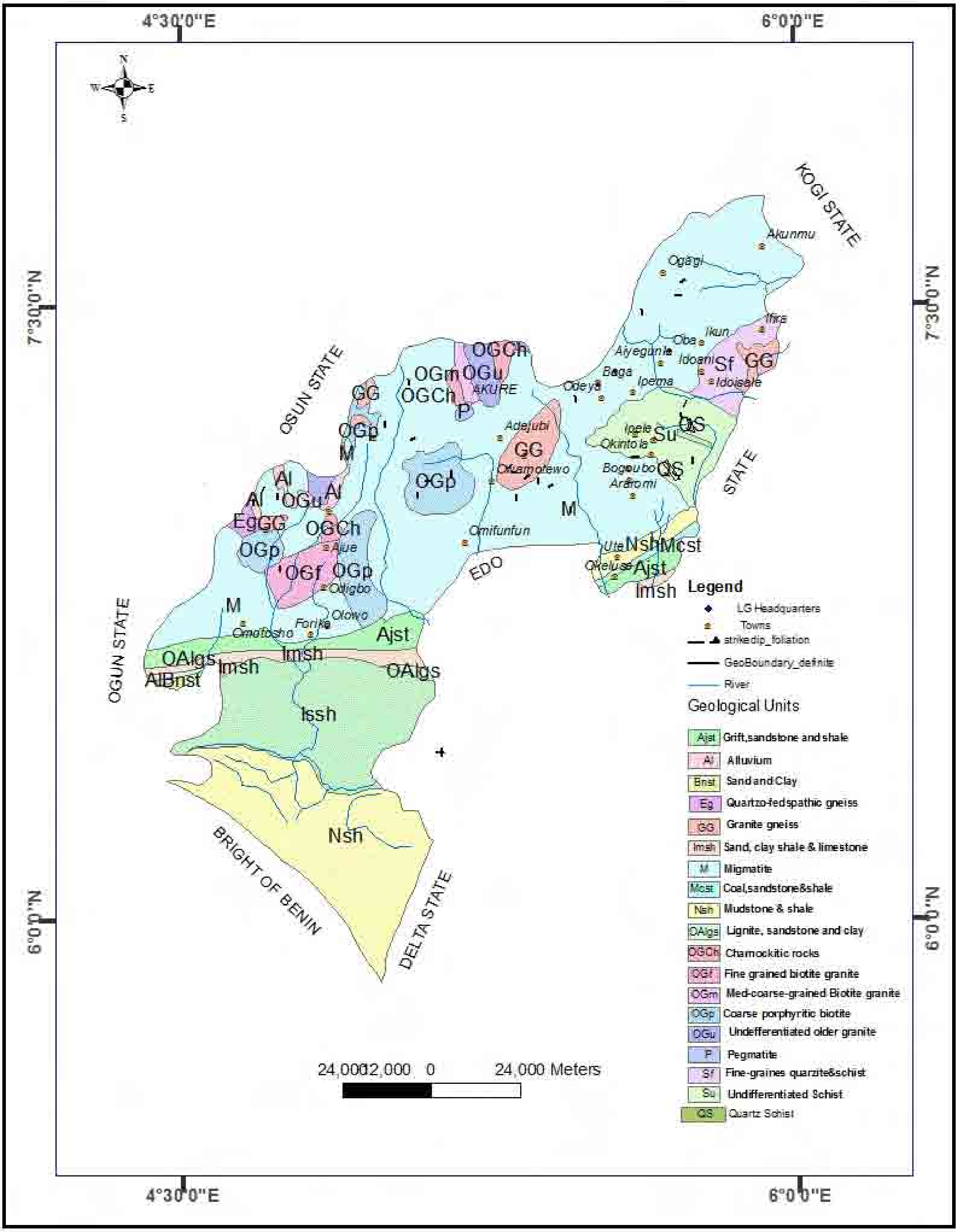


Fig. 2: Geological Map of Ondo State Showing the Study Area (Adapted from the Nigeria Geological Survey Agency, 2006).

MATERIALS AND METHODS

Three (3) traverses 100 m long and approximately 20 m apart were established in an approximately N-S direction (Fig. 3). The electrical resistivity and the magnetic prospecting methods were used in this survey. The electrical resistivity method utilized the Vertical Electrical Sounding (VES) and the dipole dipole profiling techniques.

The magnetic method was carried out using the Proton Precision Magnetometer along the three traverses. Measurements were taken at 5 m interval along each of the traverse lines. Total field

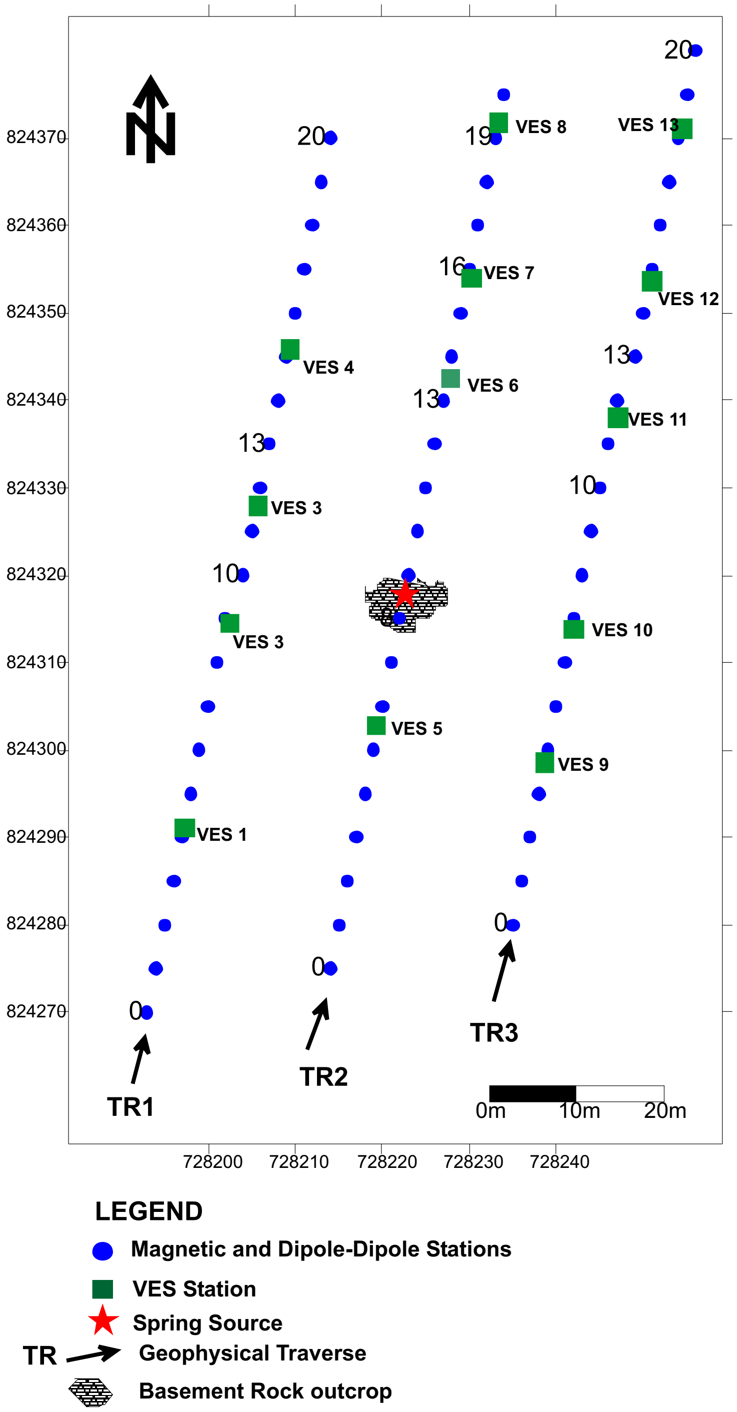


Fig. 3: Geophysical Data Acquisition Map Showing the Magnetic, Dipole-Dipole, VES Stations and the Spring Source.

measurements were taken at a base station located outside the survey area before and at the close of the profiling. The raw field data were corrected for diurnal variation and offset by subtracting the base station regional magnetic reading from the reading recorded along the traverse line at corresponding time. A three point running mean filter was applied to the residual magnetic anomalies for the removal of possible spikes. The corrected magnetic data were presented as magnetic profiles. The isolated magnetic anomalies were quantitatively interpreted for location of the top edge and depth to the edge of the magnetic basement using Parasnis (1986) anomaly characteristic feature technique.

2-D subsurface imaging was carried out with the dipole dipole array profiling. Measurements were made with electrode spacing of a = 5 m and an expansion factor n, varying from 1 5. The dipole dipole data were inverted into 2-D resistivity structures using the DIPRO for windows (2004) software. The 2-D resistivity inversion modeling corrected for the effect of topographic variations.

Thirteen Schlumberger Vertical Electrical Soundings (VES) were carried out (Fig. 3). The electrode spacing (AB/2) m was varied from 1-100 m. The VES data interpretation involved the partial curve matching technique and 1-D computer aided forward modeling involving the WinRESIST version 1.0 (Vander Velper, 2004) software. The VES interpretation results (layer resistivities and thicknesses) were used to generate geoelectric sections.

RESULTS AND DISCUSSION

The residual total field magnetic profiles along Traverses 1 - 3 are shown in Figures. 4(a-c). The amplitude of the magnetic field varies between +100 nT and -250 nT. One major magnetic anomaly with characteristic negative peak was observed along each of the traverses (Figs. 4a and c). The anomalies are typical of thin dipping dyke models (suspected fractured, shear or faulted zones) (Parasnis, 1986). The anomalies were identified between distances 0 - 70 m along Traverse 1, between 0 - 75 m along Traverse 2 and between distances 0 - 95 m along Traverse 3. A summary of the results of quantitative interpretation of the magnetic anomalies are presented in Table 1.

The 2-D resistivity structures (Figs. 5 - 7 a (iii)) delineate three subsurface geologic layers. These are the topsoil, weathered layer and the basement rock. The topsoil virtually merged with the weathered layer due to overlapping low resistivity values and relatively small thicknesses. The topsoil is characterized by light - deep bluish/greenish/yellowish - reddish color band. The topsoil resistivity values range from 21 - 214 ohm-m. The thickness varies from 0.4 - 2 m along the three Traverses. The topsoil is composed of clay, clayey sand and lateritic clay.

The weathered layer is the second layer. It is characterized by bluish/green color bands. The layer resistivity values range from 21 - 150 ohm-m. The thickness varies from 2.5 - 15 m. The weathered layer is made up of clay and sandy clay.

The third layer is the basement bedrock. It is characterized by yellowish reddish colour bands. The resistivity values generally range from 149 - 3901 ohm-m along the three Traverses. The estimated depth to the basement bedrock varies from 2.5 - 15 m along the three Traverses.

Table 1: Results of the Quantitative Interpretation of the Magnetic Anomalies.

Traverse (TR) No	Magnetic Anomaly Width	Location of Top of magnetic basement (m)	Estimated Depth to magnetic basement (m)
TR 1	0 – 70 m	28	13.3
TR 2	0 – 75 m	33	15.0
TR 3	0 – 95 m	43	20.1

One major vertical discontinuity (between distances 50 - 60 m, 37,5 - 55 m and 50 - 65 m along Traverses 1 - 3 respectively) suspected to be a fractured/fault zone was delineated from the 2-D structures. The fractured/fault zone manifests as low resistivity zones (characterized by light to deep bluish colour bands) within the high resistive basement bed rock with a depth extent greater than 15 m. The investigated spring source is located within this structural feature along Traverse 2 (Fig. 1). Another suspected vertical discontinuity is situated between distances 65 - 80 m along Traverse 2. This feature appears localized beneath Traverse 2.

Figures 5 - 7 (b) display the geoelectric sections developed along the three traverses. Four subsurface layers comprising the topsoil, weathered/partly weathered layer, fractured basement and the fresh basement bedrock were delineated. Table 2 confirms a summary of the geoelectric parameters of the subsurface layers. The fractured basement is localized beneath VES 11 along Traverse 3. The fractured/fresh basement constitutes the basement bedrock in the 2-D resistivity structures.

a

b

c

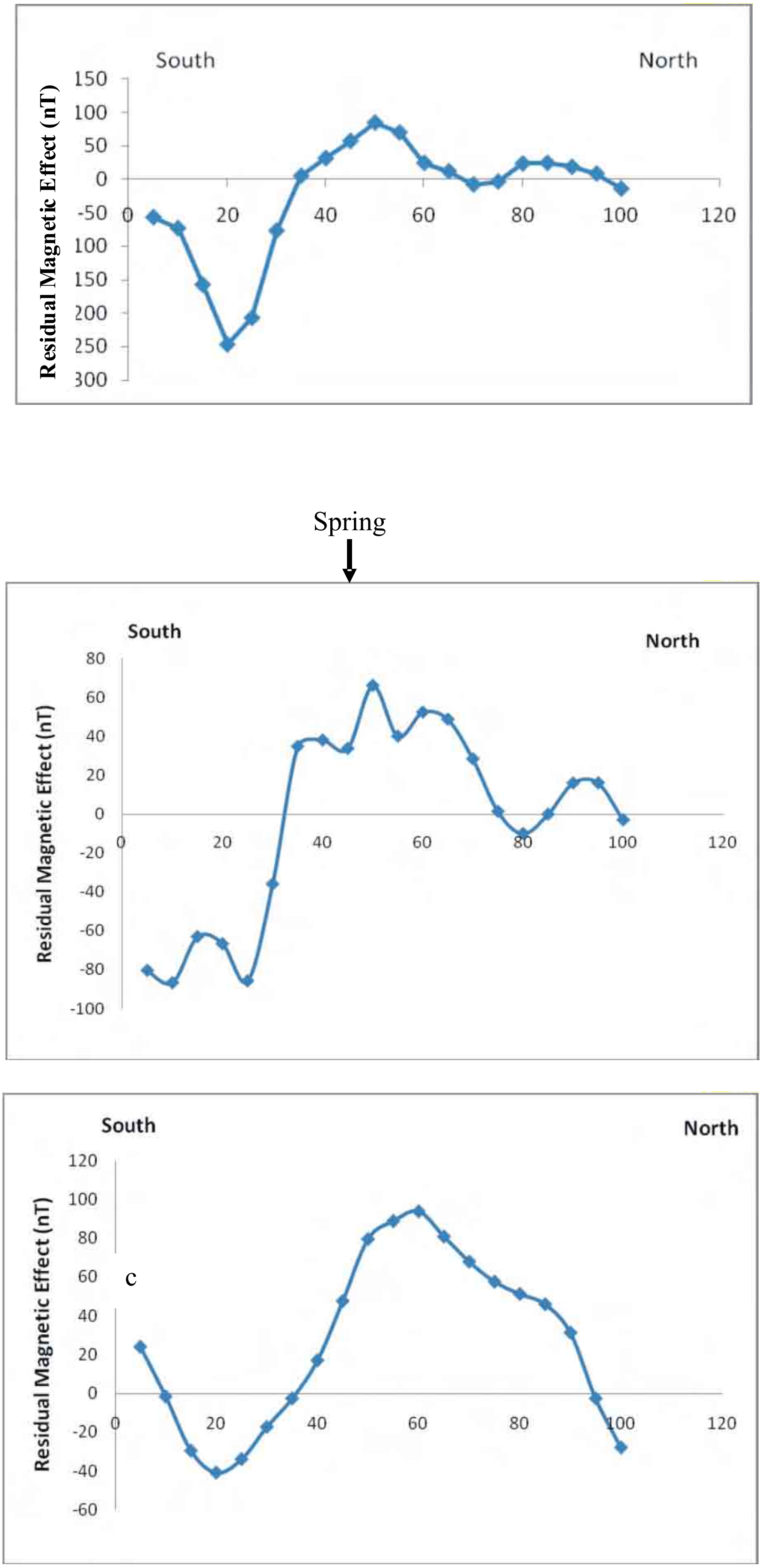


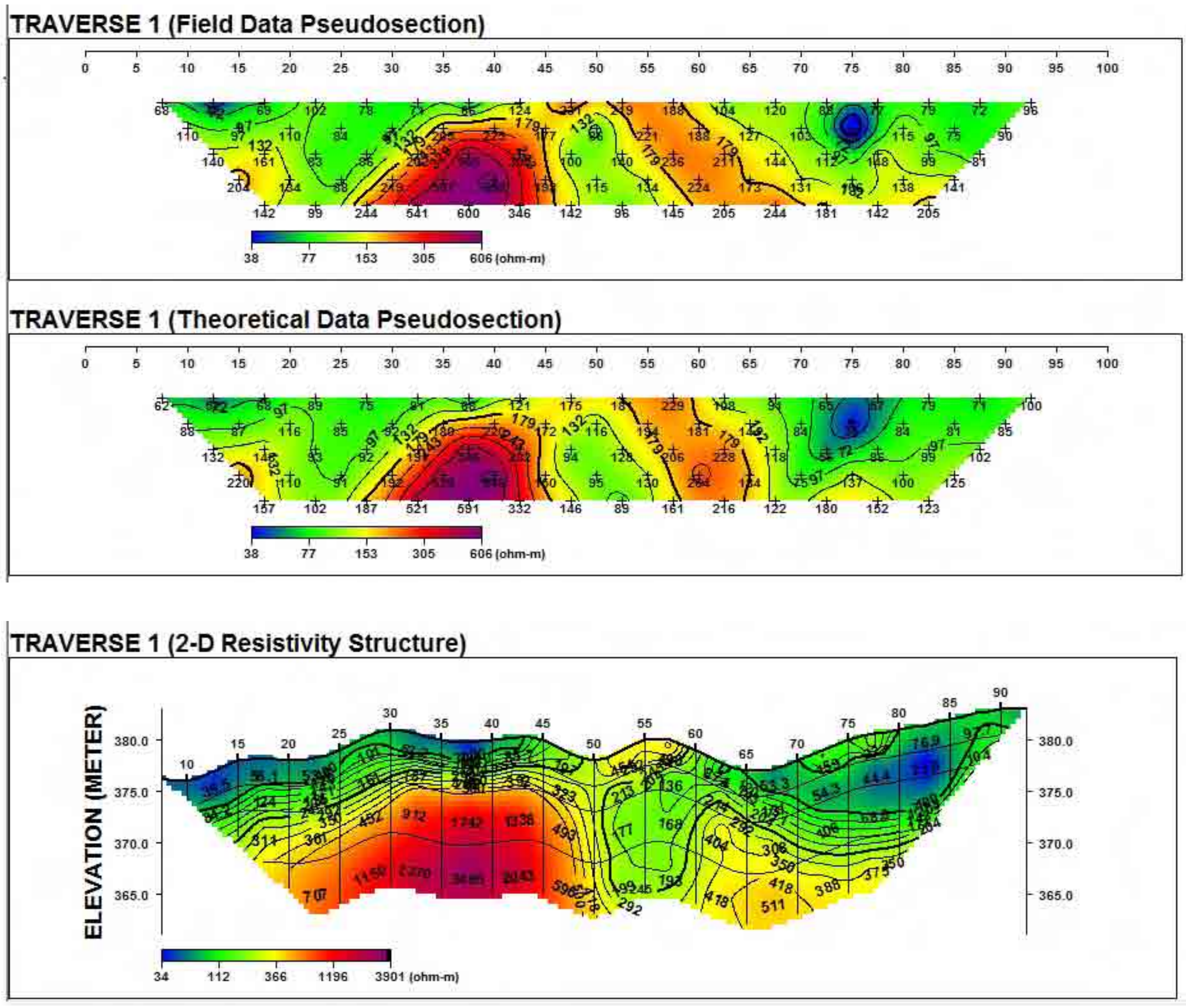
Fig 4 (a c) Magnetic Profile along Traverses 1 3.

(a)

i

ii

iii



(b)

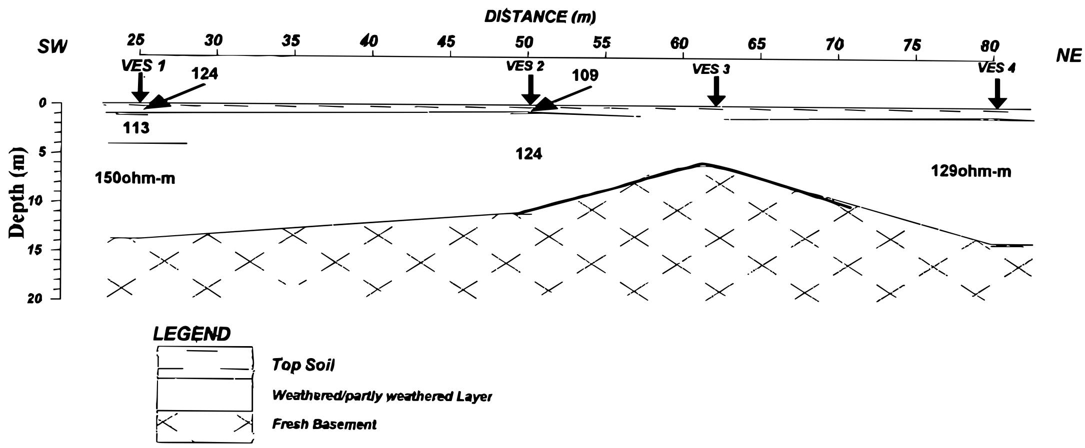


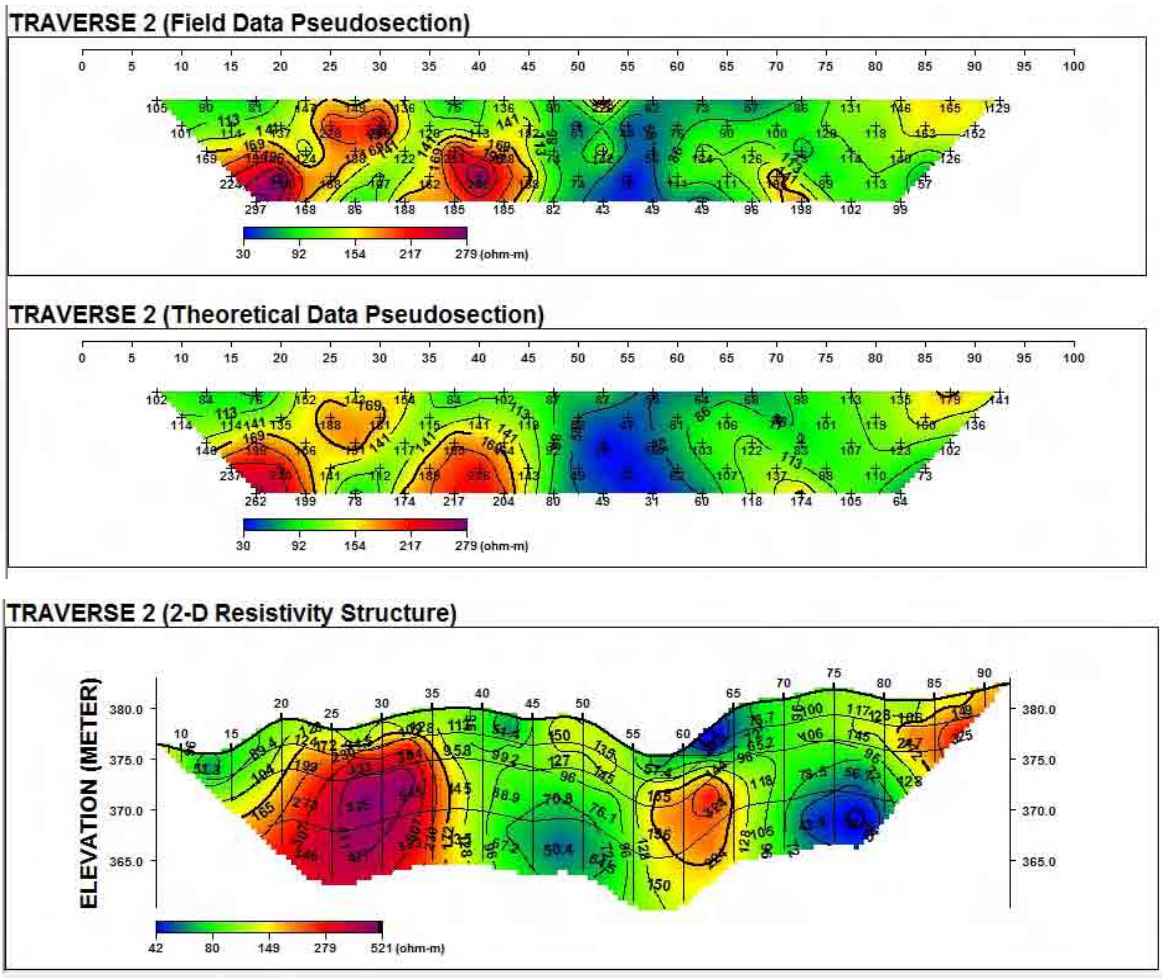
Fig. 5: (a) S N Dipole Dipole Resistivity Pseudosection, Calculated Resistivity Pseudosection, 2-D Resistivity Structure and Corresponding Geoelectric Section Along Traverse 1.

(a)

i

ii

iii



(d)

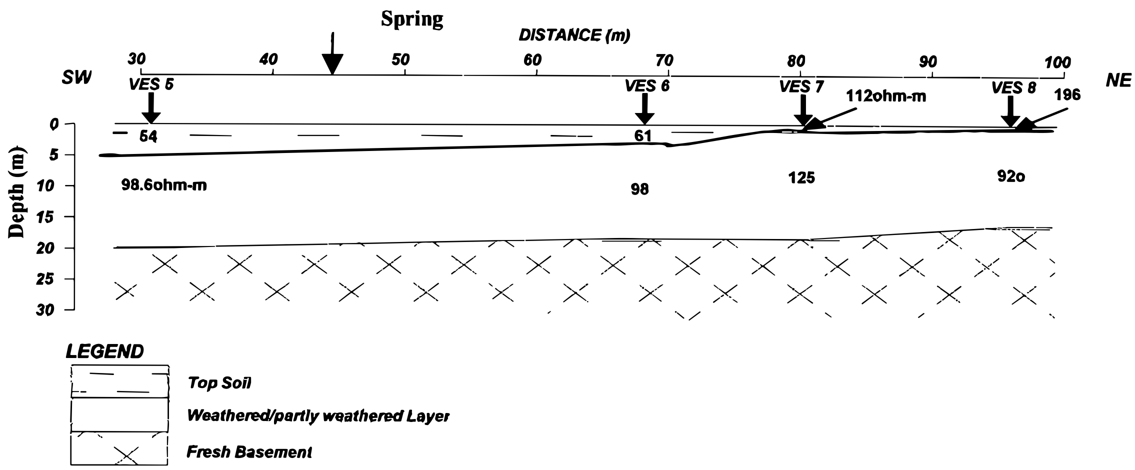


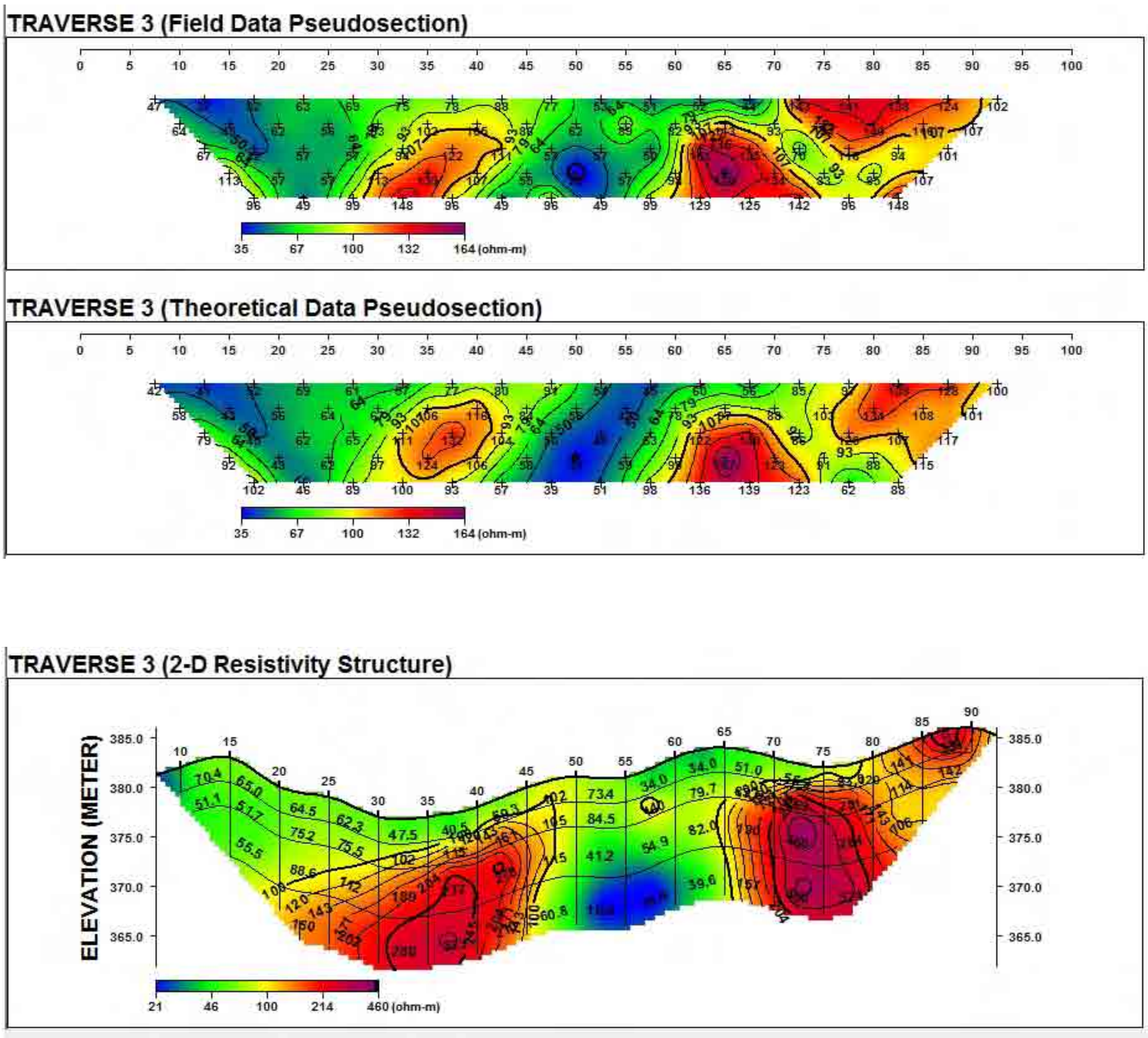
Fig. 6: (a) S N Dipole Dipole Resistivity Pseudosection, Calculated Resistivity Pseudosection, 2-D Resistivity Structure and Corresponding Geoelectric Section Along Traverse 2.

(a)

i

ii

iii



(d)

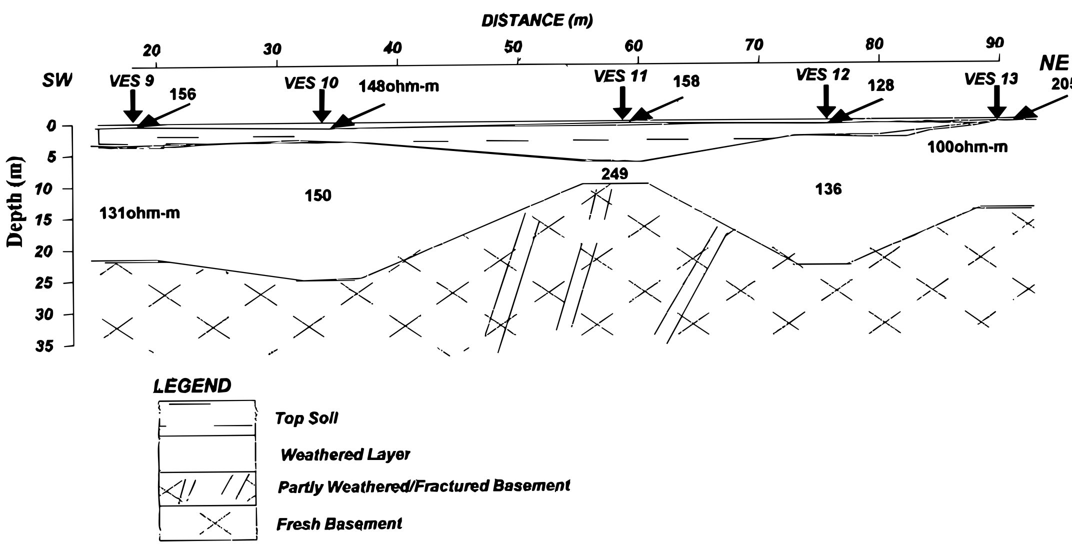


Fig. 7: (a) S N Dipole Dipole Resistivity Pseudosection, Calculated Resistivity Pseudosection, 2-D Resistivity Structure and Corresponding Geoelectric Section Along Traverse 3.

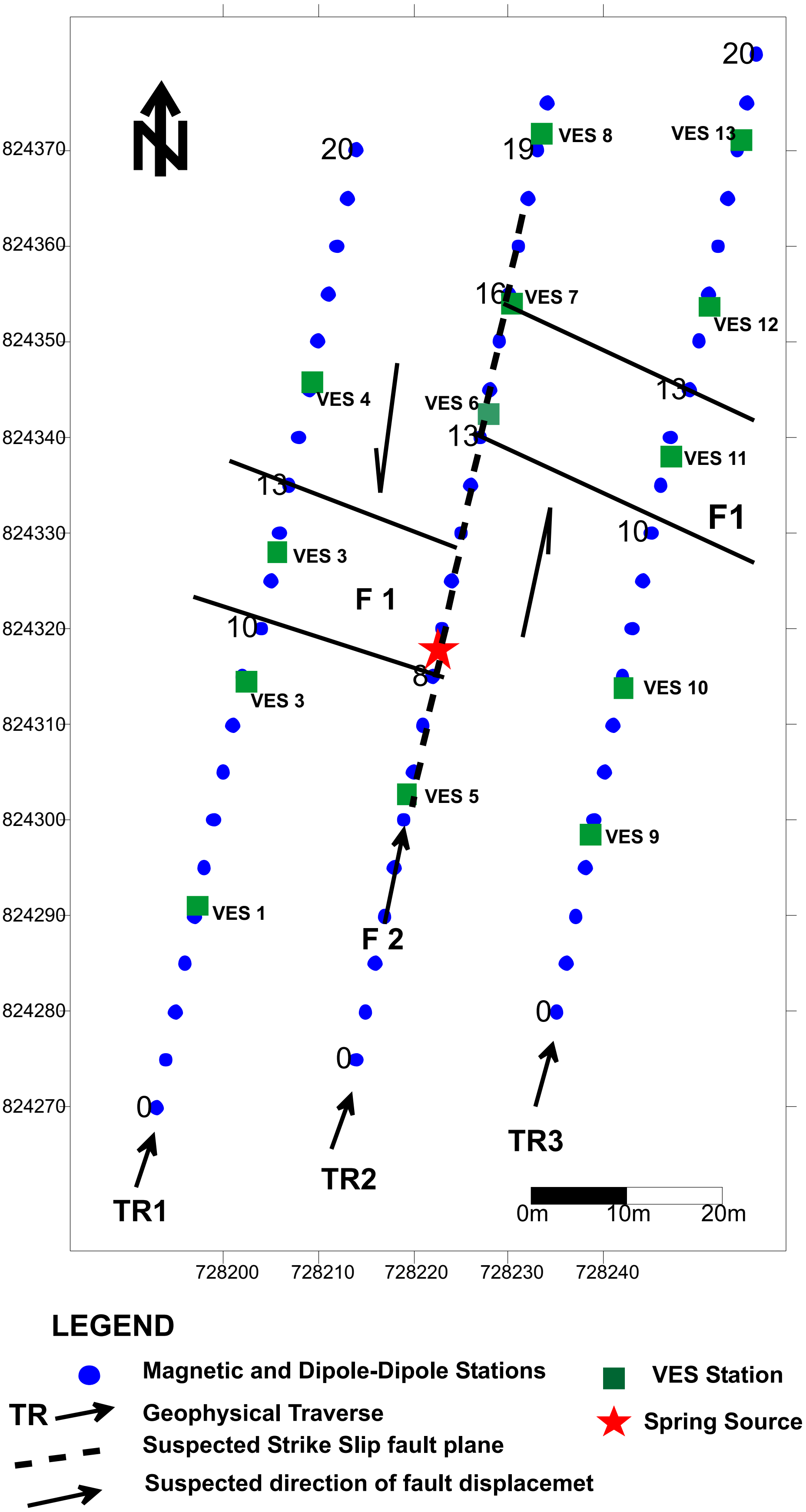


Fig. 8: Geophysical Structure Map of the Study Area.

SYNTHESIS OF RESULTS

The geophysical structural map developed from the 2-D resistivity structure is displayed in Figure 8. A 10 - 17.5 m wide major vertical discontinuity within the basement bedrock designated F1 is delineated. The discontinuity is suspected to be a major fault zone within which the spring source is located. The southern edge of the structure partially coincide with the top edge of the magnetic dyke models along Traverses 1 - 3 (see Table 1). The suspected fault zone appears flexured by what looks like strike slip faulting, F2. The spring source may be located along this suspected strike slip fault.

Table 2: Geoelectric Characterization along the Investigated Traverses

Layering	Resistivity Range (ohm-m)	Thickness (m)	Lithologic Description
Topsoil	59 – 205	0.4 – 5	Clay and sandy clay and lateritic clay.
Weathered layer	60 – 180	2.1 – 17.2	Clay and sandy clay
Fracture basement (localized beneath VES 11)	797	ND	Partly weathered/ Fractured basement rock.
Basement Bedrock	507 – 11,546	*7.4 – 25.1	Basement Bedrock

ND = Not Determine, *Depth to Bedrock

CONCLUSIONS

An integrated geophysical investigation involving the magnetic and electrical resistivity methods was used to investigate a spring at Ibuji near Igbara - Oke, southwestern Nigeria. The magnetic profiles along the three traverses are typical of thin dykes that are characteristic of fractured/faults in a typical basement complex environment. The magnetic profiles gave depths to magnetic basement (equivalent of the overburden thickness) of between 13.3 and 20.1 m.

The 2-D resistivity structures delineated the subsurface layers which include the topsoil, weathered layer and a resistive basement bedrock. Estimated overburden thicknesses of 2.5 - > 15 m corroborates depths to magnetic basement of between 13.2 and 20.1 m. The resistivity structures identify a major low resistivity vertical discontinuity (F1) that is typical of a fault zone across the three traverses. The width of the anomalous zone varies from 10 - 17.5 m.

The VES delineates four subsurface geoelectric layers. These are the topsoil, weathered/partly weathered layer, fractured basement and fresh basement bedrock. The fractured/fresh basement constitutes the basement bedrock in the 2-D resistivity structures. Estimated depths to the basement bedrock range from 7.4 - 25.1m. which correlate significantly with the estimated overburden thickness from magnetic profiles and the 2-D structures.

This study concludes that the Ibuji spring is structurally controlled. The suspected fault zone within which the spring is located constitutes a favourable zone for groundwater development.

ACKNOWLEDGEMENTS

The authors are grateful to Mr. A. Afolabi, Mr. A. J. Ikuomola, Mr. A. O. Kolawole, Mr. A. Salawu, who assisted with the field work.

REFERENCES

2004. DiproTM Version 4.0 Processing and Interpretation software for Dipole Dipole electrical resistivity data. KIGAM, Daejon, South Korea.

Nabeel, H. A. 2010. Geoelectric detection of subsurface faults at the western embankment of Badoosh reservoir, North Iraq. *Journal of Applied Science in Environmental Sanitation*, 5 (1): pp. 65 72.

Nigeria Geological Survey Agency 2006. Published by the Authority of the Federal Republic of Nigeria.

Parasnis, D. S. 1986. Principles of applied geophysics. 4th Edition. London, Chapman and Hall. Pp. 33-35.

Rahaman, M. A. 1976. Review of the basement geology of southwestern Nigeria, in geology of Nigeria, edited by C. A. Kogbe, Elizabethan Publ. Co. Lagos. pp. 41 58.

Richard, K. and Paul, B. 2004. Mapping groundwater in regolith and fractured bedrock using ground geophysics: A case study from Malawi, SE Africa. Canadian Society of Exploration Geophysics (CSEG), pp. 24 33.

Sharma, S. P. and Baranwal, V. C. 2005. Delineation of groundwater-bearing fracture zones in a hard rock area integrating Very Low Frequency Electromagnetic and Resistivity data. *Journal of Applied Geophysics,* Vol. 57, pp. 155 166.

Sultan, S. A:, Hatem, M. M:, Santos, F. A. M. and Abd Alla, M. 2009. Geophysical measurements for subsurface mapping and groundwater exploration at the central part of the Sinai Penisula, Egypt. *The Arabian Journal for Science and Engineering,* Vol. 34, No. 1A, pp. 103 119.

Teme, S. C. and Oni, S. F. 1991. Detection of groundwater flow in fractured media through remote sensing techniques-some Nigerian cases. *Journal of Applied Earth Sciences,* Vol. 22 No.1, pp. 401 466.

Vander Velper, B. P. A. 2004. WinRESIST Version 1.0 Resistivity Depth Sounding Interpretation software. M. Sc Reseach Project, ITC, Delft Netherland.