INTERPRETATION OF STRUCTURAL CONTROLS OF GROUND WATER FLOW USING GEOPHYSICAL TECHNIQUES IN THE REGION SOUTH OF LAKE NAKURU

(DELAMERE-ENDERIT AREA)

SGL413: PROJECT IN GEOLOGY

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A Dissertation submitted in partial fulfillment of the requirements for Bachelor of Science in Geology.

University of Nairobi.

3rd June 2011.

DECLARATION AND APPROVAL

Declaration by candidate

I declare that this report is my own original work and has never been presented in any institution for any award;

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I13/2347/2007

Signature……………………………

Date…………………………………

Approval by course advisor

I declare that this report has been submitted for examination with my approval

Prof. J. Barongo

Signature…………………………..

Date………………………………..

Approval by course coordinator

I declare that this report has been submitted for examination with my approval;

Dr. Gichaba/Dr. Olago

Signature……………………………

Date…………………………………

ACKNOWLEDGEMENT

My sincere gratitude to my supervisor Prof.J.O Barongo for the commitment he has shown in guiding me through this report, Regional Centre for Mapping of Resources for Development (Kasarani), Ministry of Environment and Mineral Resources (Industrial Area) for allowing me to use their library services during my research studies, Dr.Gichaba and Dr. Olago the course tutors who have done a great job in coordinating this course, thanks to my loving parents and siblings for the moral support.

DEDICATION

To my loving parents Mr. and Mrs. Mwangi and to my siblings Joan and Louis.

ABSTRACT

Water is one of the vital elements all over the world and due to several factors such as over exploitation, water resources are steadily decreasing. This study is therefore aimed at characterizing the nature of the shallow subsurface infiltration area by applying Electrical Resistivity Tomography and Magnetic methods to understand the conduits and channels through which ground water reaches the aquifer. The objective of this study is to determine structural set up of the Delamere-Enderit area and help in interpreting their complexity in controlling ground water flow. The subsurface geoelectric survey is conducted using Electrical Resistivity Tomography (ERT) in two dimension. Inversion technique is employed in the processing of ERT data. In addition magnetic methods are also employed to identify anomalous zones that include faults and fissures. Using Euler Deconvolution Software, a magnetic map and magnetic profiles are obtained to highlight this. Water bearing rocks are mainly the volcanic sands which host the main aquifer and volcanoclastic sediments that host perched aquifers which are responsible for lateral flow of water. Fracturing is evident in the area from both electrical and magnetic studies. The ERT and magnetic geophysical methods above mentioned are elaborated in this report.

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CHAPTER ONE

1.1 INTRODUCTION

Geophysics has proved to be a powerful tool in exploration of natural resources for decades. It has been useful in delineating boundaries of aquifers, in characterization of subsurface within an area such as structural features and in siting favorable drill hole locations.

Several geophysical methods are available depending o the purpose and intent of the geophysical study. For purposes of this project two methods will be discussed to explain he structural controls of the ground water flow in the region South of Lake Nakuru. These methods include:

- Electrical Resistivity Tomography which is a geophysical method for imaging the subsurface structures from electrical measurements made at the surface or by electrodes in one or more boreholes. It is a direct current method which is related to induced polarization method which measures transient response. This technique evolved from techniques of electrical prospecting that predate digital computers where layers or anomalies were sought rather than images.
- Magnetic methods identify and describe regions of the earth's crust that have unusual (anomalous) magnetizations. In applied geophysics the anomalous magnetizations might be associated with subsurface structures that guide geologists in the location of economic deposits or have an influence in flow of ground water (as in this case).

1.1.1 LOCATION

The study area is bounded by 0º 30'S and 0º29'Sand 36º06'E and 36º08'E that is Delamere-Enderit area. It lies in the Lake Nakuru basin which is mainly sediments, alluvial and reworked sediments. The Lake Nakuru basin lies within the central part of the Kenyan Rift valley. It is defined by the Menengai volcano to the north and Mt Eburru volcano to the south. On the Eastern and western limits the basin is defined by north-south aligned faults of Mau Escarpment to the west and Bahati –Mbaruk-Gilgil Escarpments to the east.

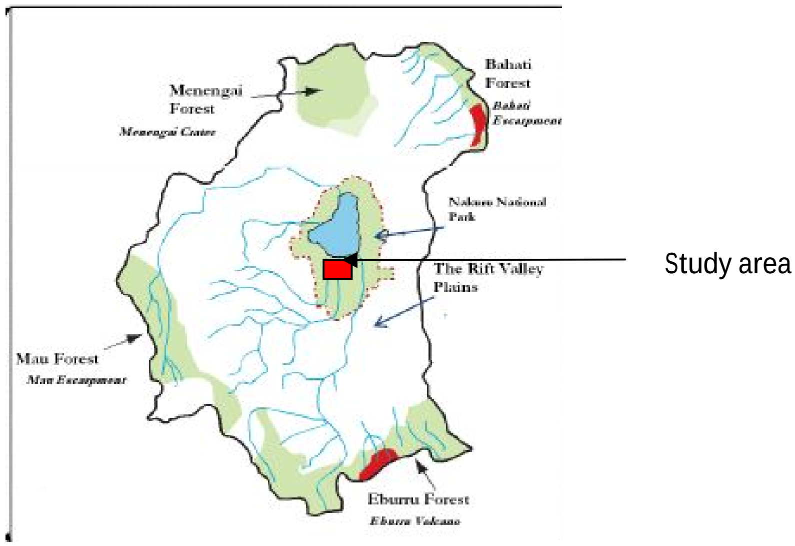


Figure 1.1; Lake Nakuru basin (Kanda and Olago)

1.1.2 DRAINAGE OF LAKE NAKURU

In general the floor of the Rift valley around Nakuru is characterized by very poor runoff due to the porous nature of the pumaceous formations which mantle the older rock surface. Lake Nakuru is at 1758 m above sea level and is a salt impregnated shallow pan of water lying in fault graben between the Lion Hill (2097m in the east) and the Mau Escarpment on the west. The lake is saline due to rapid evaporation of the shallow water body. The lake pan is recharged mainly by rainfall through increased surface drainage during wet weather while underlying ground water is replenished by water losses through infiltration of surface streams particularly from Rivers Njoro, Larmuriak, Makalia, Enderit and Ngusor. The Njoro, Larmuriak, Makalia and Enderit river systems drain Mau Escarpment into Lake Nakuru. (Odada, Raini, Ndetei; 2004).

They apparently loose much of their water through percolation into the generally porous or fissured zones, leaving only very little surface flow to reach the lake.

The bulk of their accrued flow is considered to reach the lake as ground water below the lake. Thus River Ngusor a permanent stream and several minor streams flow as run off on the Bahati plains before disappearing underground to feed the water table under Lake Nakuru.

1.1.3 CLIMATE OF THE STUDY AREA

There is considerable variation in climate within the Lake Nakuru Basin depending on the topography and altitude. The climate ranges from cold to humid to arid and semi-arid characteristics of the Rift Valley floor. Mean annual rainfall is 200 mm with peaks in the months of November –December and April-May. The mean annual evaporation is 1800mm. Rainfall is mainly convective and occurs in the afternoons as heavy storms that last 10 minutes to 1 hour.

The graph below shows the mean monthly rainfall values in a year.

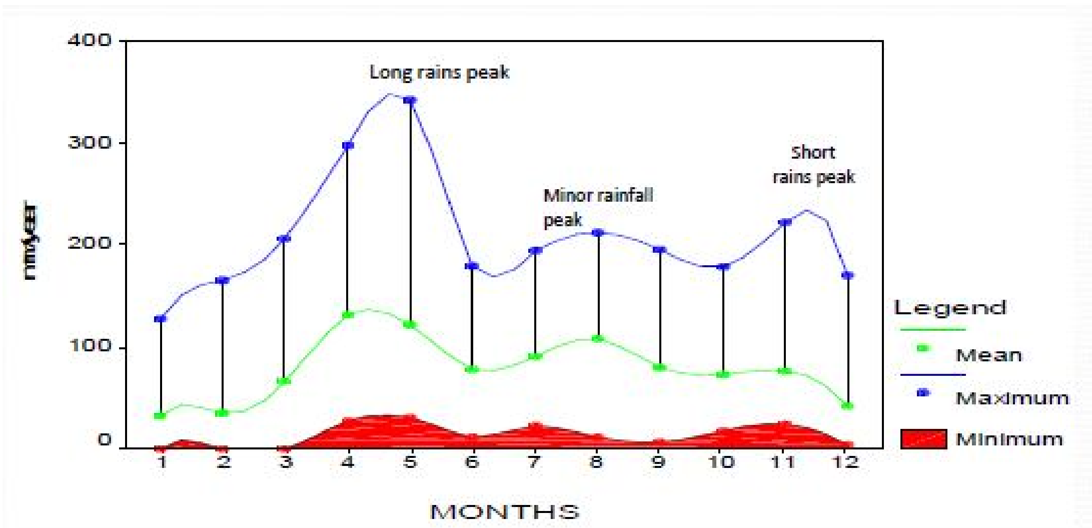


Figure 1.2;Mean annual rainfall; (Kanda and Olago)

1.1.4 TOPOGRAPHY

The amazing topography of this area owes its diversity entirely to the tectonic and volcanic disturbances of the rift valley which have dislocated the peneplained surfaces of the African Shield forming separated ridges and troughs, tending for the most part north-south and piling up great masses of volcanic rock on these structures (McCall, 1967).

1.1.5 GEOLOGY OF THE AREA

The study area is located within the East African Rift system which is a linear graben structure that extends for 900 km from Turkana depression at 5˚ latitude N to the Tanzanian plateau at 3˚ S (Mboya 1993).

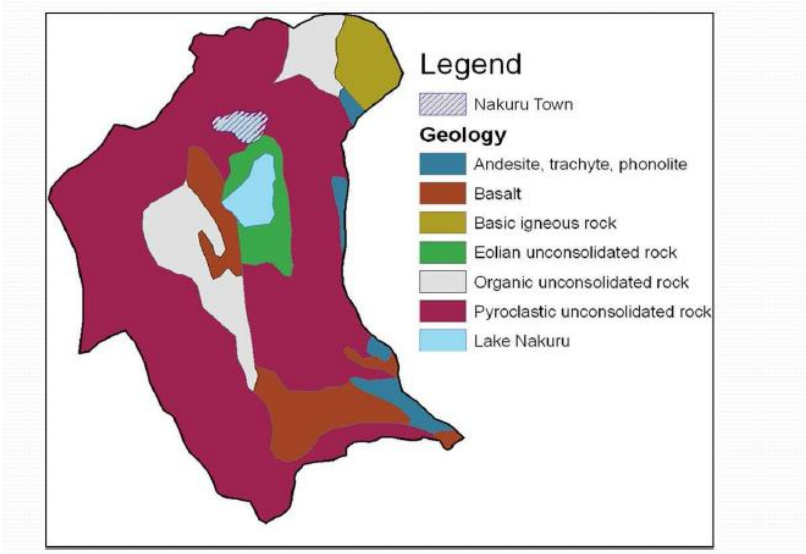
The East African Rift System was developed on a strongly heterogeneous basement which has had a long complex, history from Archean time to present.

The geology of Lake Nakuru and its catchment is made up of volcanic rocks (lava flows and pyroclasts) of Tertiary- Quaternary age which have been affected by a series of faulting. The soil is also of volcanic origin and due to its high porosity, permeability and its loose structure, it is highly susceptible to erosion, land sinking and fractures during and after heavy rain (Odada, Raini and Ndetei 2004).

The floor of rift valley around Nakuru is characterized by porous pumaceous lava. The basin is on flat lying flood lava of the rift valley floor which has been subsequently faulted during the last 2Ma.

The basin is structurally controlled and the rock formations within the central part of the Kenyan rift are predominantly volcanic, discontinuous Pleistocene-Holocene sediments and relatively wide spread Recent alluvial volcanic cover.

In the northern margin of the Nakuru basin the Menengai volcano forms thick succession of phonolites, phonolitic trachytes and tuff. Black porphyritic basalt is exposed at the foot of the Bahati scarp to the east (Mbaruk Basalt). Along the fault scarps to the west of the Lake Nakuru basin are exposed fissile and banded trachytes. A basalt flow forms the escarpment west of Lake Nakuru. The southern part of the lake is dominated by phonolitic phonolites. The north-eastern edge of the basin is underlain by coarse obsidian, pumice tuff and sediments in the Bahati area. Below is a geological map summarizing the geology of Lake Nakuru Basin.



• Geology of Lake Nakuru Basin *(Extracted from ILRIS Maps - Kenya)*

Figure 1.3; Summary of the geology of Lake Nakuru Basin; (Kanda and Olago)

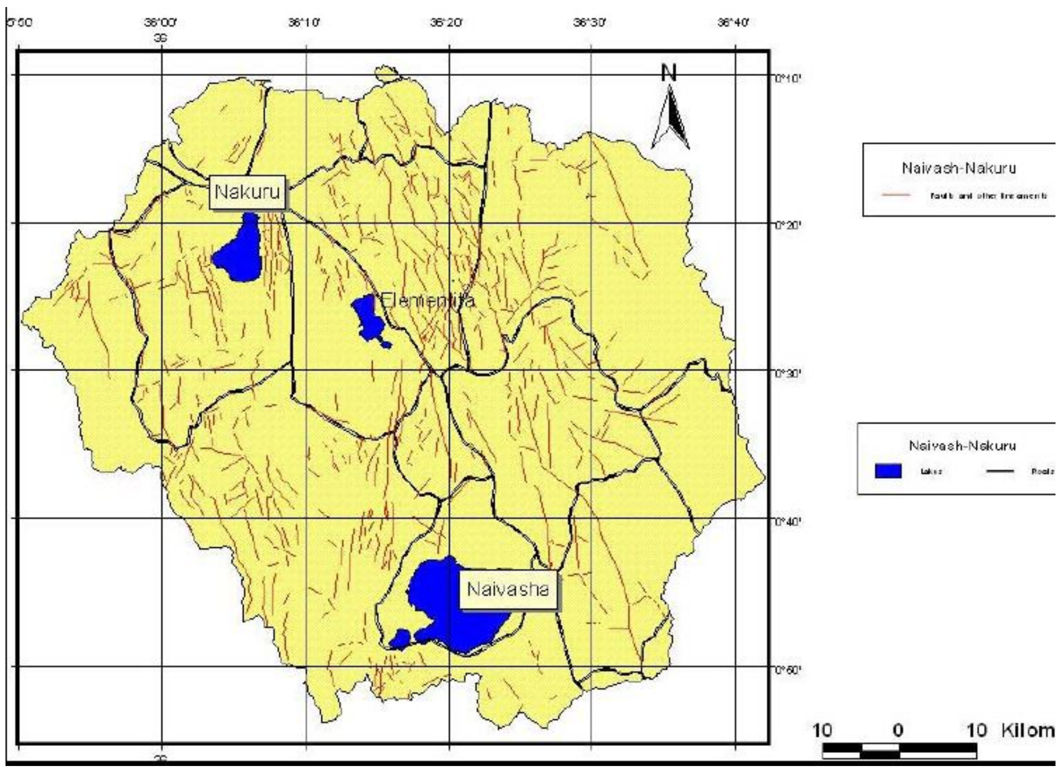


Fig 1.4; Structural map of Lake Nakuru-Elementaita-Naivasha Basin (Alamirew, Korme, Olago and Barongo)

1.1.6 PREVIOUS GEOLOGICAL WORK

- In 1967 G.J. H McCALL, carried out a geological study of the Nakuru-Thomson's Lake Hannington area and described repeated rhythmic successions of lava types erupted at intervals from early Miocene times almost to present day and shows the volcanic activity in the area was accompanied by major episodes of faulting which formed the rift valley as it seen today.

- In 1993, Mboya carried out a study on the lithostratigraphic, analysis and palaeoenvironmental interpretation of the Late Tertiary and Quaternary sediments of the Nakuru, Elementaita and Naivasha Basins.

- In 2006 Prof. Justus Barongo and Simon Onywere wrote a report on vulnerability of ground water to pollution in the East African Rift System this was a project under Sustainable Management of Water Resources in the Rift valley (MAWARI).

- Study of groundwater Geochemistry of Lake Nakuru Basin, the Kenya Rift valley- Kenya by Kanda K.I. and Olago. D.O of Department Of Geology University of Nairobi.

- Geology ,Hydrogeology and Hydrochemistry of the Nakuru- Elementaita-Naivasha watershed, Kenyan Rift by Dr. Daniel Olago and Prof. Justus Barongo of Department of Geology University of Nairobi and Demis Alamirew and Dr. Tesfaye Korme of Geological Survey of Ethiopia.

1.1.7 STATEMENT OF THE PROBLEM

Geological structure splay a key role in governing ground water flow patterns .This project explains how geophysical methods are used in data acquisition and interpretation of structural occurrence in relation to ground water flow in the region South of Lake Nakuru. This is mainly to elucidate areas with good, moderate or poor infiltration of ground water and suggest area where boreholes could be drilled.

1.1.8 JUSTIFICATION AND SIGNIFICANCE.

There is need to delineate the geological and structural controls that control ground water flow in the Region South of Lake Nakuru to avoid cases of drilling boreholes at the wrong sites which results in wastage of money, dry boreholes or boreholes bearing uneconomical yields.

The results obtained from this will be a guide to operators on the best points to drill to avoid the problem of siting uneconomical boreholes.

1.1.9 AIM

The aim of the study is to understand the recharge mechanism of the aquifer located in this region through geophysical methods.

1.1.10 OBJECTIVE

- Establish the influence of geological structures on ground water flow in the region South of Lake Nakuru.

1.1.11 RESEARCH QUESTION

- What are the subsurface features and lithological layering that can be identified from this interpretation?
- How does this affect the flow of ground water?
- What is the relationship between this and surface water?

1.1.12 OUTPUT

- Two dimension tomography pseudo sections showing the subsurface imagery of Delamere-Enderit area.
- Magnetic map and magnetic profiles along the map showing structural anomalies.

CHAPTER TWO

2.1 BASIC PRINCIPLES OF ELECTRICAL RESISTIVITY TOMOGRAPHY

Electrical methods are far more diversified than other geophysical methods. Electrical methods utilize direct currents or low frequency alternating currents to investigate the electrical properties of the subsurface. There are many electrical methods used in electrical prospecting depending on the source field.

Some make use of naturally occurring fields within the earth while others require the introduction of artificially generated currents into the ground (Kearey and Brooks 1984).Electrical methods are therefore divided into:

- Direct Current (DC) methods
- Electromagnetic (EM) methods-which will not be discussed in this report.

The direct current method discussed in detail in this report is the Electrical Resistivity Tomography. This is a geophysical technique for imaging the subsurface structures from electrical measurements made at the surface. Artificially generated electric currents are introduced into the ground and the resulting potential differences measured at the surface. The results are then used to provide information on the electrical properties of the subsurface inhomogeneities.

The basic principle of resistivity surveys is to induce electrical currents in the ground and monitor signals generated by the current distribution at the surface (Hersir and Bjornsson 1991)

Resistivity governs the amount of current that passes through subsurface when a specified potential difference is applied and thus governs properties such as porosity, permeability and salinity.

Resistivity of a material is defined as the resistance in Ohms between opposite faces of a unit cube of the material (Kearey, Brooks and Hill 2002) and is defined through Ohms law, which governs the flow of current in the ground.

Ohm’s Law defines the relationships between (P) Power, (E) Voltage ,(I) Current and (R) Resistance. One ohm metre is the resistance value through which one volt will maintain a current of one ampere.

$$V=IR$$

Where:

V-Voltage

I=Current

R-Resistance in ohms.

Resistivity is resistance multiplied by a geometric factor (A/L)

$$\rho=RA/L$$

ρ=ohms/m

A= area in metres^2

When current is introduced into the ground from a point source, it flows radially away from the source in a homogeneous subsurface and this is represented by the diagram below:

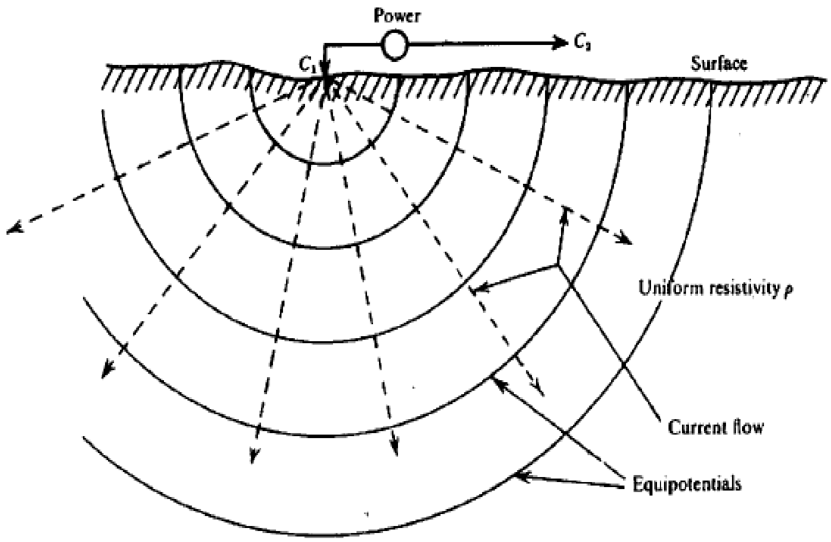


Figure 2.1; Current flowing radially from a point source (Telford, Geldart, Sheriff and Keys 1990).

Electrical conductivity of earth materials is influenced by:

- Metal content in the rock
- Porosity
- Clay content
- Permeability
- Degree of saturation

Resistivity of most rocks is governed to a large degree by the amount of water filling the gaps between mineral grains and the amount of salt dissolved in this water. Electrical methods in groundwater investigations are mainly dependent on rock properties porosity and permeability.

Pure water has a very low electrical conductivity; sea water on the other hand contains high levels of dissolved salts such as NaCl making it a good conductor of electrical current.

Conductivity in minerals and solutions takes place by the movement of electrons and ions through ground water contain din the pores of rocks and along surface layers at the contact of solutions and rocks.

The amount of fluid flowing through the rock can also be largely dictated by the secondary permeability provided by geological structures (fractures). The wider the fractures the higher the fracture porosity hence higher permeability.

$K=D^3/F$

Where;

K is the permeability

D is the mean fracture width

F is the mean distance between the fractures.

Below is a table showing various resistivity values of common rock types

Rock type	Resistivity (Ωm)
Granite,ultrabasic,peridotite	1000-10000
Marble	400-1000
Limestone	200-500
Schist	200-300
Gneiss	30-150
Sediments, sand ,marl	10-100
clay	10-50
Saline water	0.1

Table 2.1; Resistivity values of various rocks (Parasnis, 1996)

2.2 BASIC PRINCIPLES OF MAGNETIC SURVEYS

A magnetic body buried in the ground is subject to geomagnetic or terrestrial field of the earth. The magnetic moments of a ferro-magnetic material contained within such a body (usually magnetite, pyrrhotite and ilmenite) align along this prevailing field. These elemental dipoles produce an induced magnetization vector in the same direction, which in turn produces the dipole-type field.

A magnetometer at or above the Earth's surface measure a total magnetic filed which is the vector sum of the geomagnetic field and the induced field.

In addition, the magnetic body may also possess a remanent (or permanent) magnetization of its own. This is a magnetization that either relates to a past imprinted induced filed differing in direction and/or sign to present terrestrial field, or reflects an internal constituency which provides its own magnetic polarization e.g. loadstone.

The remanent components of magnetization for many such bodies and minerals can infact exceed the induced component by as much as ten times. It is therefore an important and potent factor in magnetic surveying.

It follows that any susceptibility determinations of rocks undertaken analytically from magnetic anomalies or directly from outcrop, or core or hand specimen is merely an apparent susceptibility. The presence of this extra component clearly means that an additional magnetic field would be superimposed on the geomagnetic and induced magnetic fields. In these cases then, the total field would be the vector of three fields.

Remanent magnetic fields unfortunately can be very difficult to recognize from magnetic surveying.

The figure below illustrates the components of the geomagnetic field.

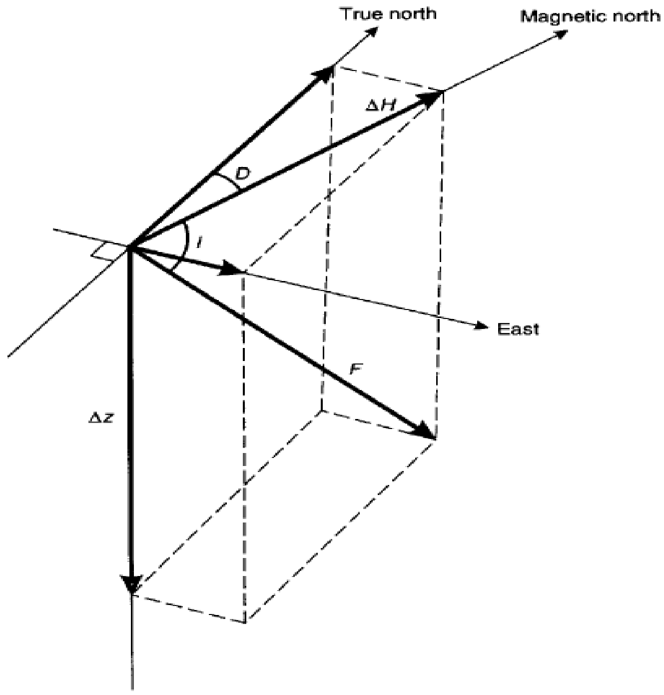


Figure 2.2; Summary of the geology of Lake Nakuru Basin; (Kanda and Olago)

Δz-Vertical field

ΔH-Horizontal field

F-Total field

I-Inclination points towards the ground in the northern hemisphere and upwards away from the ground in the southern hemisphere

D-Declination which is the angle measured between the direction of magnetic north/south pole and geographic north/south pole.

In practice measurements of vertical component are the most commonly measured.

2.2.1 SUSCEPTIBILITY OF ROCKS AND MINERALS

If a magnetic body is placed in a uniform magnetic field (H), the induced magnetization (M) is proportional to the magnetic field. The constant of proportionality is called the magnetic susceptibility k and is usually expressed in electromagnetic units. The magnetic susceptibility of minerals determines their ability to become magnetic under the influence of a magnetizing force such as the earth's field (Melvyne andBorniwell 1989).

Igneous rocks especially mafic varieties can contain magnetite mineral in significant amounts to cause localized and regional distortions in the terrestrial field (anomalies).

Sedimentary rocks normally have very little or no magnetic mineral content hence their susceptibilities are very low and are said to be magnetic sterile. When interpreting magnetic data over sedimentary basins the effect of sedimentary package is often neglected and all disturbances in the magnetic field are attributed to basement rocks of high susceptibility. Below is a table showing magnetic susceptibilities of various rocks.

TYPE OF ROCK	RANGE	AVERAGE
SEDIMENTARY		
Dolomite	0-0.9	0.1
Limestones	0-3	0.3
Sandstones	0-20	0.4
Shales	0.01-15	0.6
METAMORPHIC		
Amphibolite		0.7
Schist	0.3-3	1.4
Phyllite	-	1.5
Gneiss	0.1-25	4
Quartzite	-	-
Serpentine	3-17	6
Slate	0-35	
IGNEOUS		2.5
Granite	0-5-	-

Rhyolite	0.2-35	17
Dolerite	1-35	-
Augite-syenite	30-40	25
Olivine-Diabase	-	55
Porphyry	0.3-200	60
Gabbro	1-90	70
Basalts	0.2-175	70
Diorite	0.6-120	85
Pyroxenite	-	125
Peridotite	90-200	150
Andesite	-	160

Table 2.2; Magnetic susceptibility of various rocks (Telford 1990)

CHAPTER THREE

3.1 METHODOLGY 1

3.1.1 ELECTRICAL RESISTIVITY TOMOGRAPHY

In this DC method four electrode arrays are generally used at the surface; a pair for introducing current into the ground and the other for measuring the potential associated with the current.

For a homogeneous earth and a single current source the relevant equation for the electrical potential at a distance r from the source is given by the equation;

When current I is introduced by two electrodes =I at r_1 and –I at r_2 then the equation becomes;

When I is introduced by electrodes at A and B then the potential difference measured between the electrodes M and N is given by:

Resistivity therefore becomes;

K is the geometric constant and gives the intrinsic properties of the material.

Apparent resistivity ρ_a is defined as the calculated resistivity from V.I and r_1 and r_2 as if the earth was homogeneous.

It is the property that is measured when doing resistivity surveys and is a function of the kind of subsurface inhomogeneity present. Different DC configurations are used to carry out resistivity surveys:

- **Schlumberger array**

  In this arrangement, two electrodes (outer) for current and two electrodes (inner) for potential are placed along a straight line.

  Current electrodes are placed at A and B and the potential electrodes placed at M and N.

  The depth of penetration of the current increases with increasing electrode separation AB. Resistivity at greater depths is obtained by increasing the distance between the current electrodes stepwise while keeping the distance the distance between the potential electrode fixed.ρ_a as a function of AB/2 is then plotted on a bilogarithmic paper with increasing electrode separation. Below is an illustration of the Schlumberger array arrangement.

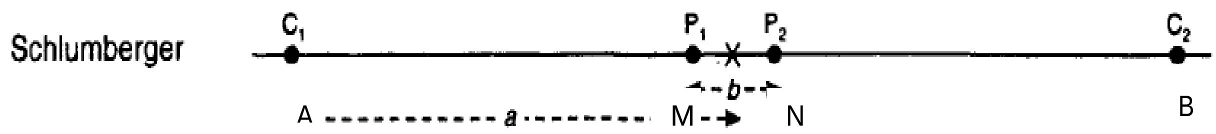


Figure 3.1; Schlumberger arrangement (Lowrie 2007)

3.1.2 INSTRUMENTATION AND FIELD PROCEDURES

Electrical surveying instruments are designed to measure the resistance of the ground to a very high accuracy. Apparent resistivity values are then computed from resistance measurements using relevant formula depending on the electric configuration in use. In electrical methods a transmitter and a receiver are required.

The transmitter provides the current source. Current is introduced to the ground through electrodes that are usually iron or aluminum rods. Power is generated normally by a portable generator although rechargeable batteries can be used where power requirements are not large.

A receiver is basically a sensitive voltmeter. In earlier days meter readings were recorded manually but now there are modern instruments controlled by microprocessor which automatically record both voltage and current, stacks the results and computes related apparent resistivity in real time (Abem 2007)

Instruments form IRIS for example SYSCAL R1 and SYSCAL R2 are common in resistivity surveys.

These instruments measure and compute resistivity and Induced Polarization (chargeability).They also have an internal memory for data storage, serial link for data transfer to pc for plotting and interpretation, a line check/ground resistance measurements which permits to check that the electrodes are properly connected to the resistivity metre and a low pass analog filter which reduces the effect of higher natural frequency and cultural noises (50-6- Hz).

SYSCAL R2 unit is an easy to use geophysical instrument manufactured by IRIS instruments, France and designed for direct current electrical survey applied to ground water exploration, environmental studies, civil engineering structural geology investigation and mineral exploration. It also measure s Induced Polarization and displays apparent chargeability (IP).

SYSCAL R1 is also manufactured by IRIS and also measures resistivity and IP.It has an internal switching board for 72 electrodes, 200W power source, internal memory and USB link for data transfer. The output current is automatically adjusted (automatic ranging) to optimize the input voltage values and ensure the best quality readings.

Four strings of cable with 18 electrodes take-out are connected on the back of resistivity metre. The cables are available with standard of 5 and 10m electrode spacing. This system is designed to automatically perform pre-defined sets of resistivity.

Once in the field, one should make sure that each component of the system is in good working condition. This involves making sure that there is reliable power supply and that all the electrodes are in good working condition. The choice of array to be used should also be made.

When the readings are taken, the data is then downloaded to a pc for processing and interpretation. Elevations, location of stations, orientation and array used should also be noted. Below is a photograph of the SYSCAL R1 resistivity meter (www.irisinstruments.com).

Figure 3.2; SYSCAL RI Resistivity meter. (www.irisinstruments.com)

3.2 METHODOLOGY 2

3.2.1 MAGNETIC SURVEYS

Magnetic surveying identifies and describes regions of the Earth's crust that have unusual magnetizations. High order terms in the energy density spectrum of the geomagnetic field are related to magnetizations of crustal rocks. Magnetic investigation can therefore yield important data about geological structures. The magnetic anomalies result form the contrast in magnetizations when rocks with different magnetic properties are adjacent to each other. Anomalies are measured by sensitive instruments called magnetometers (Lowrie 2007).

3.2.2 INSTRUMENTATION AND FIELD PROCEDURES

- **Proton precession magnetometer**

  Proton precession magnetometers sensors consist of a small vial of water or some other hydrogen content fluid e.g. kerosene or methanol.

  Two wire coils are wound around this bottle, a DC current is passed through one of the coils to generate a dominant static magnetic field which causes the protons to align themselves with this applied field. The other coil records the decay and proton precession which takes place under the influence of the geomagnetic field after the primary current is switched off. Frequency of precession is in kHz range.

  Thus if the signal from the secondary coil is suitably amplified and calibrated, it provides a direct measure of total magnetic field at thatpoint.PPM are quite sensitive can measure field to 0.01nT.

  Newer ground proton magnetometers come with a memory module which can record a day's readings along with their measurement times and grid coordinates.

  The illustration below shows the working principle of proton precession magnetometer.

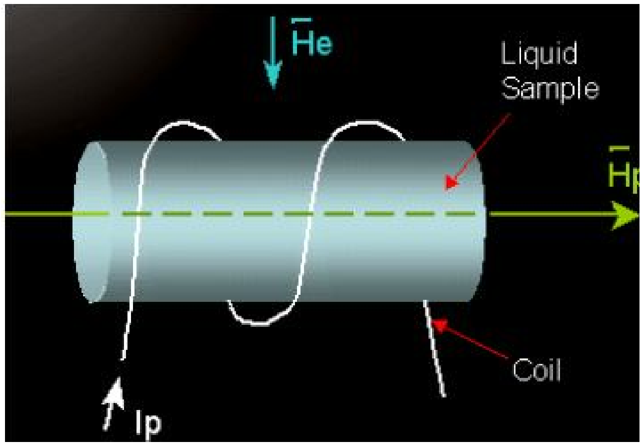


Figure 3.3; Proton Precession Magnetometer (Reynolds, 1997).

CHAPTER FOUR

4.1 RESULTS AND DISCUSSION

4.1.1 ELECTRICAL RESISTIVITY DATA INTERPRETATION.

RES2DINV is the inversion program used to compute the electrical resistivity tomography data. It is a software designed to interpolate and interpret field data of electrical geophysical prospecting (2D sounding) and induced polarization. It is completely automatic and the user does not even have to supply a starting model and has been optimized for inversion of large data sets. On a computer the inversion of a single pseudosection is usually completed within minutes. The results from electrical surveys are normally plotted in the form of a pseudosection which gives an approximate distorted picture of the subsurface geology.

Procedure for 2D inversion

- Loading a sequence of readings using Electre II soft ware
- Taking the readings in the field with SYSCAL switch instrument
- Transfer data to a computer using PROSYSII software.
- Interpret data using RES2DINV software.

Below are pseudo sections obtained from the ERT data and from this various faults can be deduced. The tomography was carried out in the east-west direction and from the above illustrations faults running northeast-southwest can be seen. The blue colour represents regions of low resistivity which is the path followed by the water as it infiltrates to recharge the aquifer.

The high resistivity areas show breaks that are occupied by very low resistivity material which suggests that there are planes of weakness in between. These planes trend in the north-south direction perpendicular to the survey orientation. From the illustrations below it can be seen that they are actually followed by water upto to depths of about 50 metres.

Pseudo sections obtained from Electrical Resistivity Tomography.

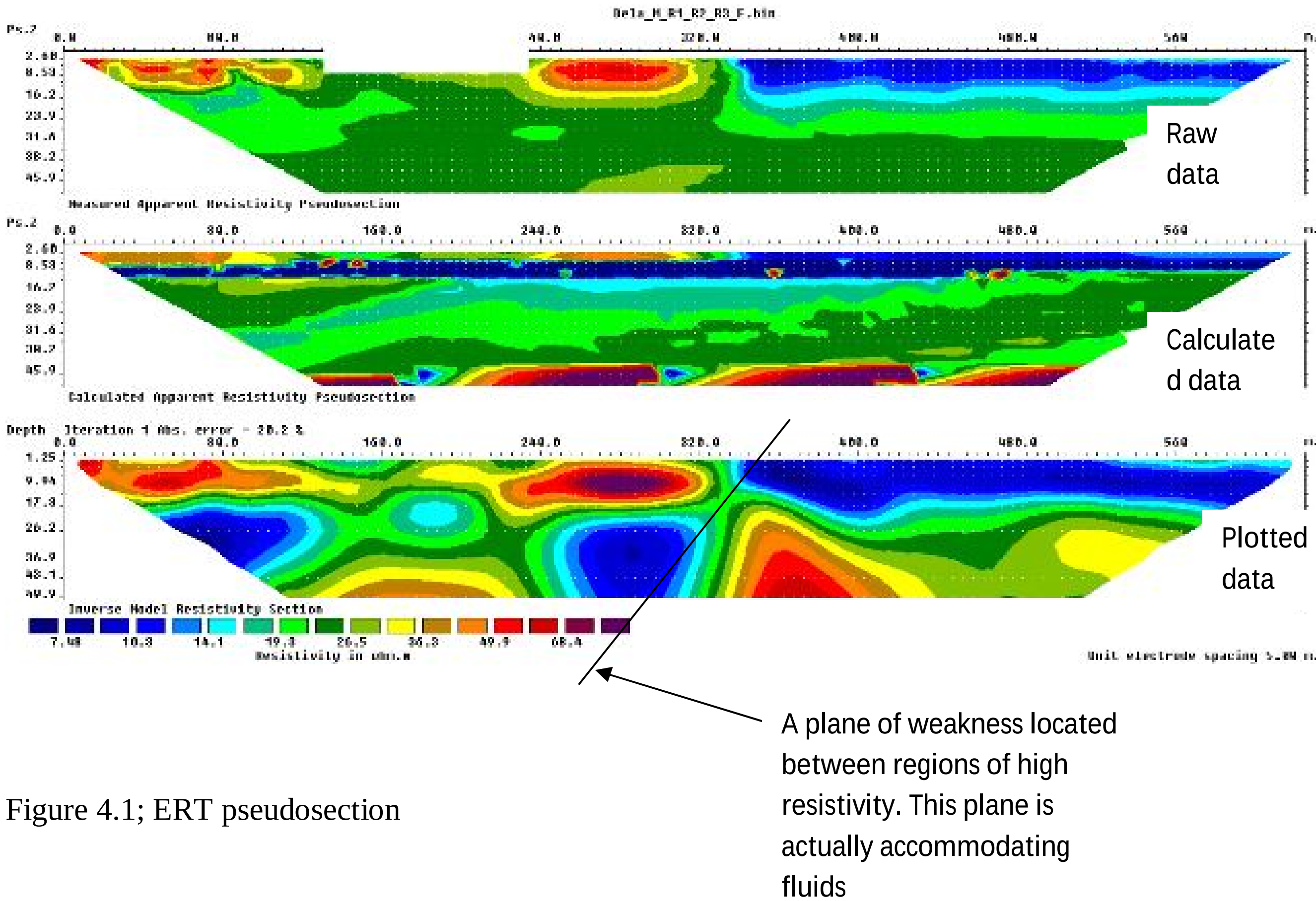


Figure 4.1; ERT pseudosection

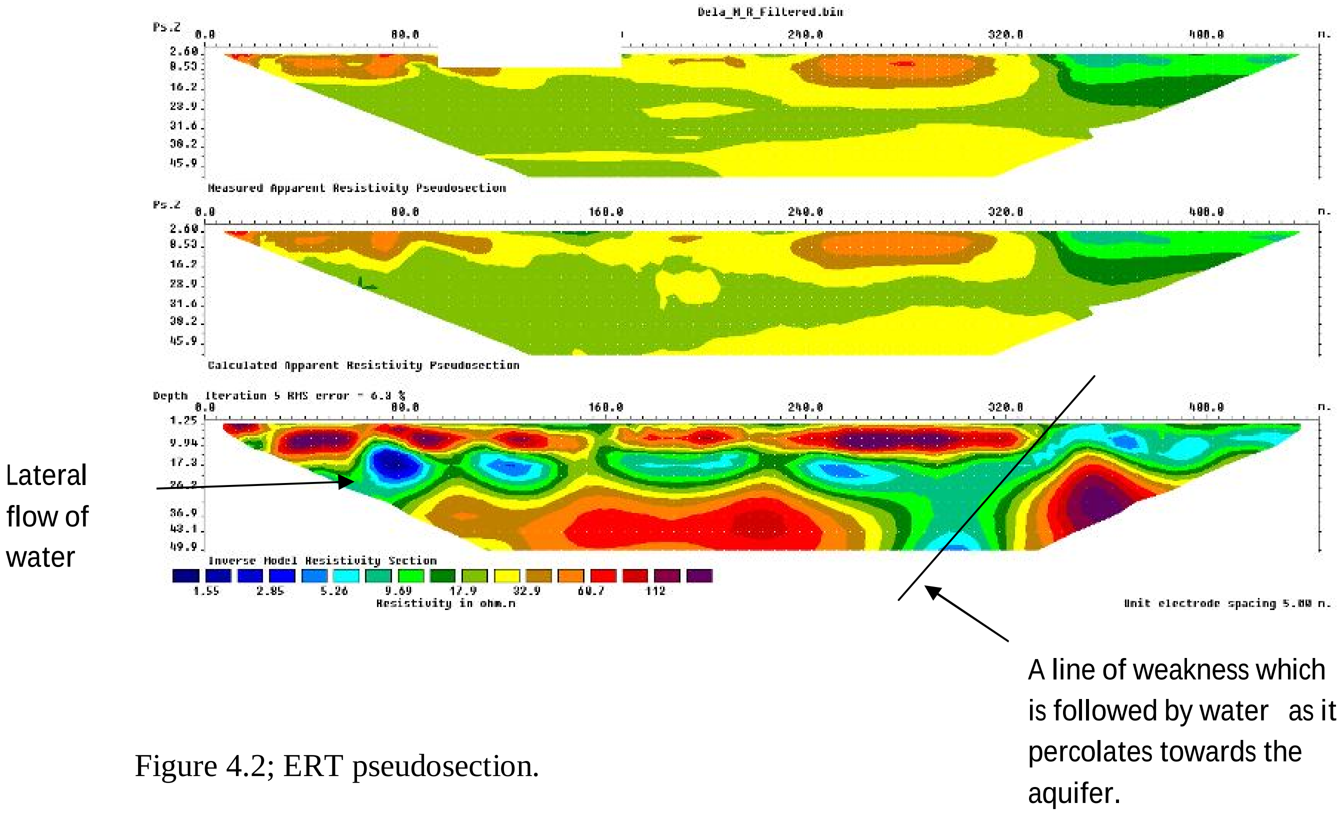


Figure 4.2; ERT pseudosection.

4.1.2 MAGNETIC DATA INTERPRETATION

Before interpretation is done the data must be corrected for diurnal effects by running a correction program on a computer. Using Euler Deconvolution Software, a magnetic map is plotted .A combination of contouring and colour shading is used to highlight anomaly patterns. Below is a magnetic map showing the fault zones that cause anomalies in the magnetic data.

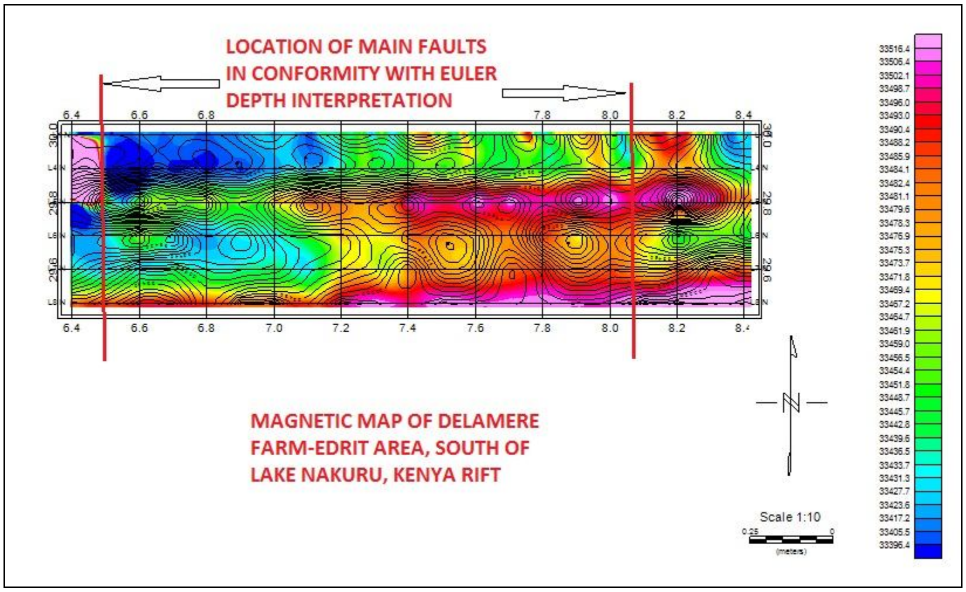


Figure 4.3; Magnetic map plotted using Euler Deconvolution Software.

When the Euler Deconvolution Software is run on the map in three profiles, that is the northern, middle and the southern portion of the already plotted magnetic map, the sections below actually show the position of various faults within the Delamere-Enderit Region.

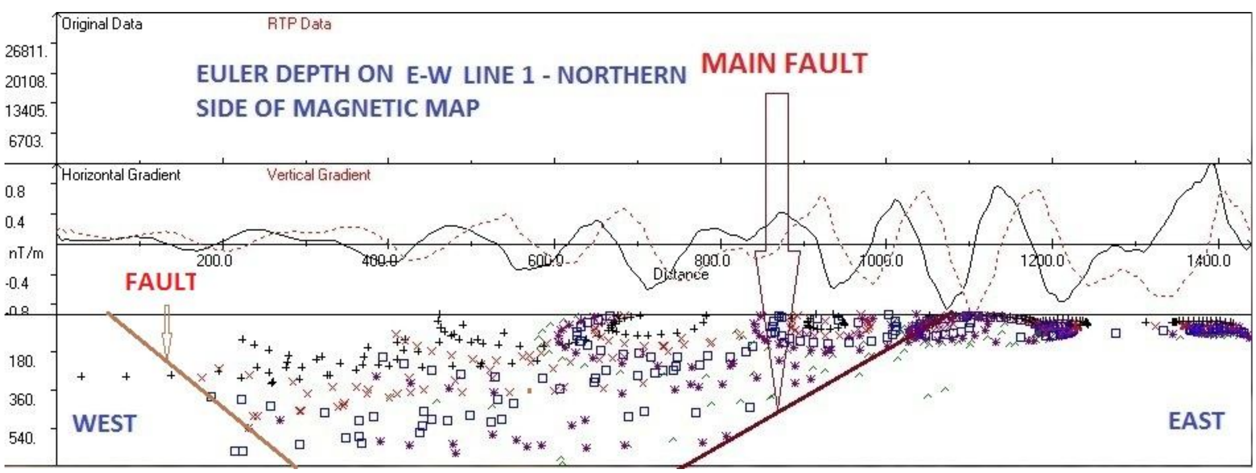


Figure 4.4; Profile on the northern portion of the magnetic map.

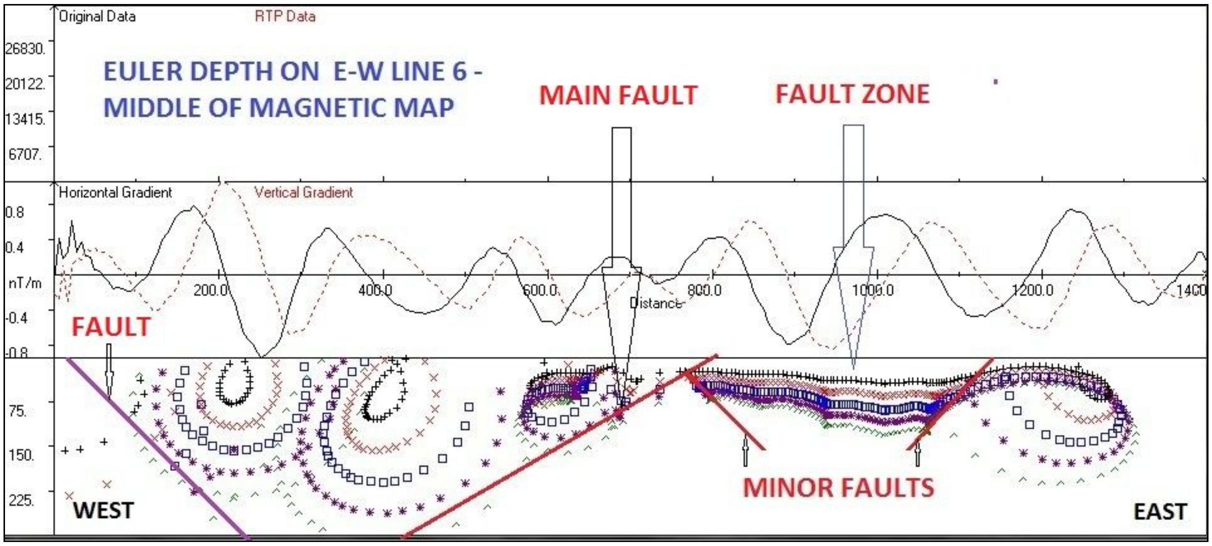


Figure 4.5; Profile at the middle of the magnetic map.

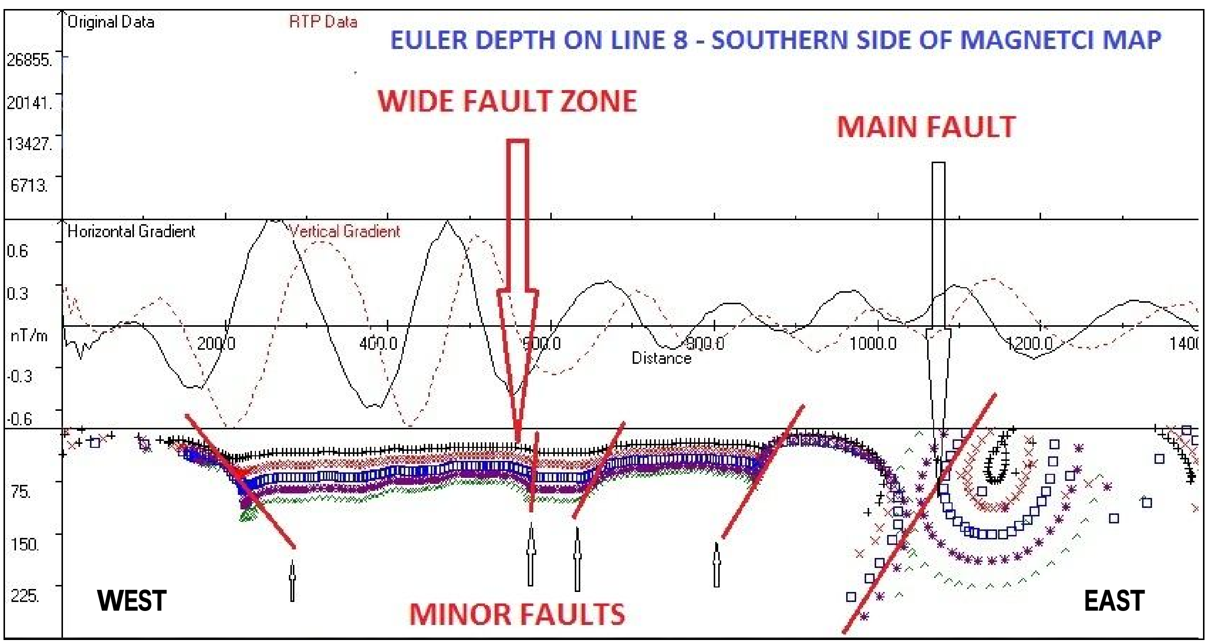


Figure 4.6; A profile in the southern part of the magnetic map

4.1.3 DISCUSSION

When the magnetic map is compared to the resistivity pseudo sections, it can be deduced that the fractures are actually trending towards north/south almost perpendicular to the magnetic survey carried out in the east-west direction. These faults do not act as barriers to the percolation of towards the aquifer. From the above illustrations, we can see that the central part and slightly towards the eastern of the study area experience very high volume of ground water recharge .These areas are good sites for borehole sinking. The dip of the faults controls flow of ground water towards a central region as seen in figure 4.4 and figure 4.6 above.

CHAPTER FIVE

5.1 CONCLUSION AND RECOMMENDATIONS

5.1.1 CONCLUSION

Geophysical methods have been successful in lithological and structural studies allover the world and from the interpretation above, it has been established that;

- The lithology at different parts where imaging was carried out varies greatly from high resistive material to low resistive material.
- Geologically, the area is predominantly comprised of phonolitic lava flows, basalts, trachytes and tuffs.
- Water will be struck at about 50m deep-from the pseudo sections above.
- The area is intensely faulted and buried faults have been established. These faults act as path ways for ground water during percolation towards the aquifer.
- Ground water in Delamere-Enderit area is structurally controlled.
- From the above findings the objectives of this report have been met.

5.1.2 RECOMMENDATIONS

Geophysical configurations and methods that penetrate greater depths such as magnetic and magnetic resonance can be used in future so as to delineate the extent and depth of faults and see how they control ground water level at greater depths.

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APPENDIX I

Example of a magnetic data file.

Raw data obtained from Prof. Barongo.

	25th Agust 2008		**Monday**					
S No.	Time	Lat	Long	Alt		Remarks		
Base	10:29:29	33396	0º29.9113	36º06.546	1832	File no. 134		
10w	10:39:45	33394	0º30.000	36º06.413	1835			36º06.413
	10:44:54	33389	0º30.000	36º06.437	1834			36º06.437
	10:48:16	33394	0º30.000	36º06.462	1832			36º06.462
	10:53:48	33393	0º30.000	36º06.487	1833			36º06.487
	10:56:26	33378	0º30.000	36º06.511	1833			36º06.511
	10:59:03	33386	0º30.000	36º06.536	1831			36º06.536
	11:01:24	33378	0º30.000	36º06.562	1832			36º06.562
	11:03:42	33388	0º30.000	36º06.588	1831			36º06.588
	11:06:10	33393	0º30.000	36º06.615	1832	Low battery		36º06.615
								36º06.641
Base	11:14:58	33369	0º29.9113	36º06.546				36º06.666
Base	12:11:54	33377	0º29.9113	36º06.546				36º06.691
	12:21:55	33397	0º30.000	36º06.641	1830			36º06.718
	12:26:03	33387	0º30.000	36º06.666	1838			36º06.744
	12:28:25	33393	0º30.000	36º06.691	1837			36º06.771
	12:31:15	33399	0º30.000	36º06.718	1837			36º06.798
	12:33:52	33397	0º30.000	36º06.744	1836			36º06.825
	12:36:24	33388	0º30.000	36º06.771	1835			36º06.852
	12:38:40	33388	0º30.000	36º06.798	1837			36º06.881
	12:42:06	33396	0º30.000	36º06.825	1833			36º06.908
	12:44:26	33399	0º30.000	36º06.852	1836			36º06.935
	12:46:41	33399	0º30.000	36º06.881	1836			36º06.967
	12:49:07	33408	0º30.000	36º06.908	1836			36º06.995
	12:51:36	33410	0º30.000	36º06.935	1833			36º07.021
	12:54:38	33415	0º30.000	36º06.967	1836			36º07.049
	12:56:15	33407	0º30.000	36º06.995	1836			36º07.077
	12:59:15	33416	0º30.000	36º07.021	1836			36º07.105

	13:03:09	33414	0º30.000	36º07.049	1837			36º07.134
	13:05:26	33405	0º30.000	36º07.077	1837			36º07.172
	13:07:50	33385	0º30.000	36º07.105	1836			36º07.200
	13:10:17	33424	0º30.000	36º07.134	1837			36º07.230
Base	13:24:56	33378	0º29.9113	36º06.546				36º07.257
	13:37:43	33417	0º30.000	36º07.172	1839			36º07.284
	13:40:09	33422	0º30.000	36º07.200	1839			36º07.314
	13:42:38	33412	0º30.000	36º07.230	1840			36º07.341
Base	15:46:24	33337	0º29.9113	36º06.546				36º07.369
	16:33:23	33401	0º30.000	36º07.257	1830	File no. 134		36º07.397
	16:26:07	33369	0º30.000	36º07.284	1830			36º07.424
	16:28:42	33409	0º30.000	36º07.314	1830			36º07.452
	16:30:34	33378	0º30.000	36º07.341	1830			36º07.480
	16:32:31	33387	0º30.000	36º07.369	1829			36º07.506
	16:34:07	33411	0º30.000	36º07.397	1829			36º07.535
	16:35:46	33421	0º30.000	36º07.424	1829			36º07.561
	16:37:57	33429	0º30.000	36º07.452	1828			36º07.589
	16:39:36	33397	0º30.000	36º07.480	1828			36º07.617
	16:40:55	33418	0º30.000	36º07.506	1826			36º07.632
	16:44:35	33383	0º30.000	36º07.535	1828			36º07.670
	16:46:05	33434	0º30.000	36º07.561	1826			36º07.700
	16:47:48	33383	0º30.000	36º07.589	1829			36º07.727
	16:49:26	33403	0º30.000	36º07.617	1827			36º07.754
	16:51:33	33397	0º30.000	36º07.632	1828			36º07.781
	16:56:12	33397	0º30.000	36º07.670	1828			36º07.809
	16:58:38	33402	0º30.000	36º07.700	1828			36º07.837
	17:00:04	33427	0º30.000	36º07.727	1828			36º07.865
	17:01:26	33452	0º30.000	36º07.754	1827			36º07.893
	17:02:54	33381	0º30.000	36º07.781	1827			36º07.921
	17:04:17	33396	0º30.000	36º07.809	1828			36º07.956
	17:05:40	33430	0º30.000	36º07.837	1828			36º07.982
	17:07:13	33427	0º30.000	36º07.865	1828			36º08.008
	17:09:56	33429	0º30.000	36º07.893	1828			36º08.036
	17:12:39	33436	0º30.000	36º07.921	1827			36º08.065
	17:17:55	33443	0º30.000	36º07.956	1827			36º08.093

	17:21:04	33428	0º30.000	36º07.982	1827			36º08.122
	17:22:53	33431	0º30.000	36º08.008	1828			36º08.151
	17:24:57	33390	0º30.000	36º08.036	1828			36º08.179
	17:26:23	33460	0º30.000	36º08.065	1828			36º08.208
	17:28:07	33457	0º30.000	36º08.093	1828			36º08.237
	17:29:26	33456	0º30.000	36º08.122	1828			36º08.266
	17:31:21	33470	0º30.000	36º08.151	1829			36º08.294
	17:32:34	33447	0º30.000	36º08.179	1829			36º08.319
	17:33:58	33472	0º30.000	36º08.208	1829			36º08.360
	17:35:27	33456	0º30.000	36º08.237	1829			36º08.386
	17:36:51	33428	0º30.000	36º08.266	1828			36º08.412
	17:38:17	33453	0º30.000	36º08.294	1827	Crossing road to enderit		
	17:39:51	33416	0º30.000	36º08.319	1828			
	17:47:01	33392	0º30.000	36º08.360	1828			
	17:48:35	33419	0º30.000	36º08.386	1829			
	17:50:51	33407	0º30.000	36º08.412	1829	File no. 175		
Base	17:13:27	33392	0º29.9113	36º06.546				