IOSR Journal of Applied Geology and Geophysics (IOSR-JAGG)
e-ISSN: 2321–0990, p-ISSN: 2321–0982.Volume 11, Issue 5 Ser. I (Sept. – October. 2023), 42-48
www.iosrjournals.org

Geophysical Investigation Of Flammable Natural Gas In Kipeto Area, Kajiado County, Kenya

Odek Antony[1], Ochieng Ombaka[1], Willis Ambusso[2], Duncan Kiama[2],
[1]*Chuka University, Department of Physical Sciences*
[2]*Kenyatta University, Department of Physics*

Abstract
Hydrocarbon reservoirs have an associated water aquifer due to the prior conditions of high porosity and permeability, as the hydrocarbon migrates to the reservoir rocks, it displaces water due to it's low density. Attempts to drill for ground water in Kipeto area of Kajiado county, Kenya, have resulted to a number of dry boreholes and in the recent past a well with flammable natural gas in Inkorkirdinga village. This new revelation has unearthed the potential of this area as one of the flammable gas fields within the Kenyan rift system. The water well failures is attributed to a possibility of water being displaced by the gas in this area as a result of the over pressure in conversion of kerogen to oil and gas or biogenic processes. This makes it possible to apply inverse problem of prospecting for gas exploration. In this study, the location, depth and extent of the natural gas reservoir was mapped using geophysical resistivity technique. Ground apparent resistivity tomography data was collected using LS 2 ABEM Terra-meter and its accessories across the gas discharging well, water discharging well and other dry wells in the study area. Data modeling was conducted using RES2DC and Aarhus software. A high resistivity zone extending to a depth of 40 m was mapped within the second layer under the gas discharging well, below which a low resistivity zone which appears to be split in the middle by an extension of moderate resistivity was also delineated. This was interpreted as a gas pathway through the porous groundwater aquifer rocks to form a water top gas bubble.

Key words: *Apparent resistivity, tomography, flammable gas, anomaly*

Date of Submission: 09-09-2023 Date of Acceptance: 19-09-2023

I. Introduction

Background Information

Kipeto area in Kajiado County, Kenya (Figure 1.1) has in the recent past been experiencing high population density due to its proximity to Nairobi which is the capital city. In order to support the domestic and economic growth of the area; there has been several attempts to access groundwater by drilling bore holes. This has led to accidental occurrences of dry shallow water wells with some ending up with discharge of natural flammable gas. The gas occurrences is suspected to be as a result of suppression of ground water table by the natural gas. Preliminary tests done by National Oil Cooperation Kenya (NOCK) has revealed presence of methane gas which is suspected to be of biogenic origin (oilnewskenya.com). This might not be adequate for industrial use purposes but can be subjected to further studies focusing on the direct uses. There was need therefore to understand the composition and characteristics of the gas and to investigate any presence of poisonous components which may be harmful to the locals. This research project involved the application of electrical resistivity tomography method to investigate and characterize the hydrocarbon prospect.

According to a report by US Energy Information Administration (EIA) in 2013, the Kenyan part of the Eastern Rift system running from the red sea in the north to Lake Malawi in the south, host approximately 7.78 Billion cubic feet of gas (Hyne, 2012). Exploration for oil and gas in East African Community (EAC) countries was started in 1930s by colonial Britain, but in the recent decades the interest has increased. In the recent past, geophysical methods have become useful in characterization and delineation of these gas deposits (Bataynel, 2006). Sufficient contrast between the regional background resistivity and the gas bearing reservoir is prerequisite for making a proper distinction possible. Most of this natural gas are found in geologic traps which can either be structural or stratigraphic (Dousts and Omatsola, 1990).

Geophysical methods can be applied to study variations of resistivity with depth or horizontally due to differences in electrical properties of rocks in the subsurface and structural differences as a result of changes in porosity, permeability and rock type (Keller, *et al.*, 1996). Electrical resistivity survey therefore, is based on the principle that, the distribution of Electrical potential in the ground around a current carrying electrode, depends on the Electrical resistivity and distribution of materials in the subsurface (Figure 1.2)

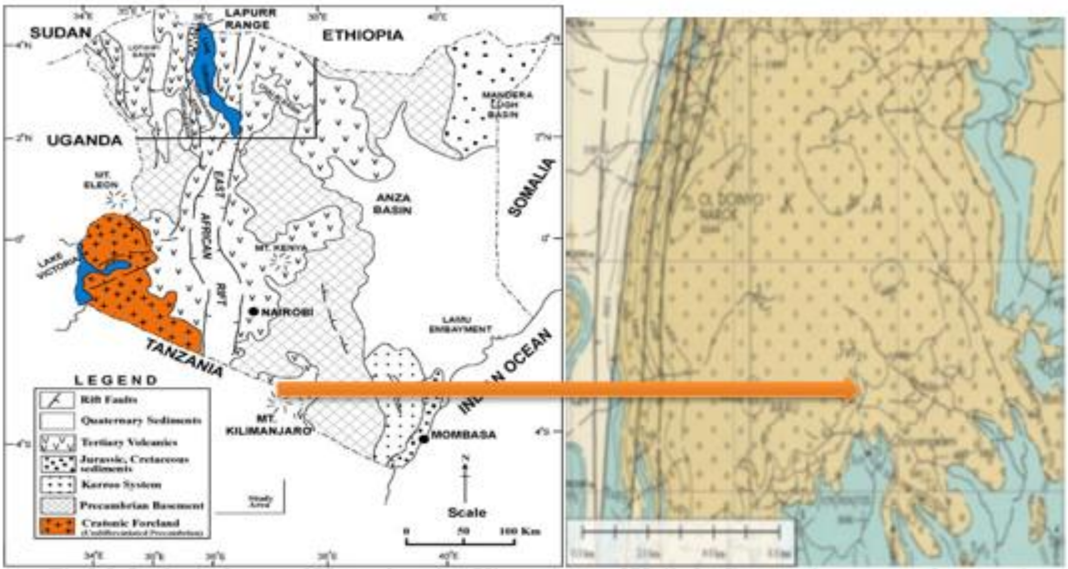

Fig 1.1 Geological map of Kenya locating Kipeto area, of Kajiado County. (www.epgeology.com).

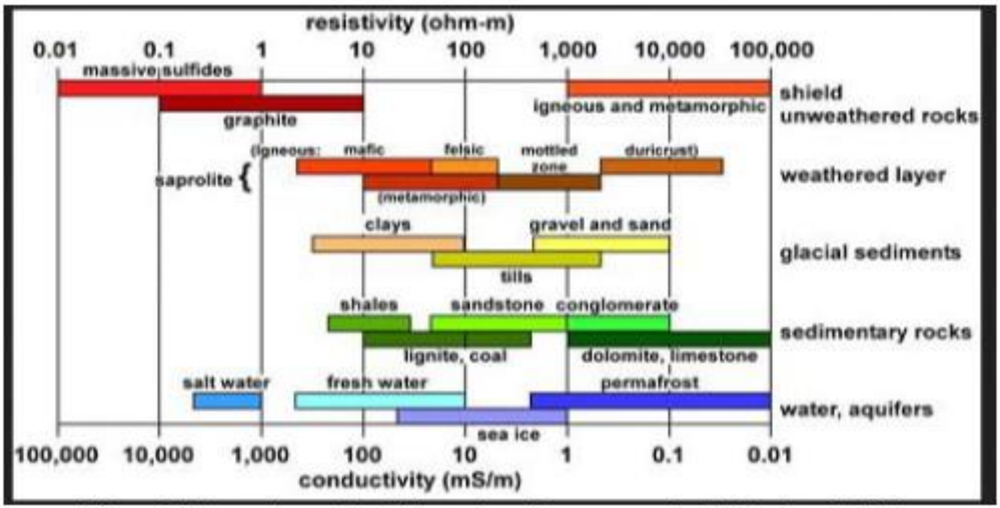

Figure 1.2 Approximate Resistivity values of common rocks (Telford et al., 1990).

Geological setting of the area

The geology of Kipeto area comprises Pleistocene volcanic rocks, which include kapiti phonolite and the Upper Athi series, and the Precambrian metamorphic rocks. This is as a result of volcanism and tectonic activities of the Rift Valley (Figure 1.3). The Kenyan Rift Valley is an integral part of the East African Rift Valley system, which extends for over 3000 km from southern Mozambique through Tanzania, Kenya and Ethiopia to join the red sea and the Gulf of Aden rifts at the Afar triple junction (KenGen, 1998). The area is characterized by tertiary volcanic rocks which overlay the Archaean Basement system which forms an unconformity. Due to weathering of these volcanic rocks over time the area is overlain by relatively shallow mainly black cotton soils. The oldest rocks of the area are the gneisses limestone and quartzite of the Basement system. The formation is the Precambrian age. The volcanicity has been marked by cyclic quiet lava flows to explosive tuffs and intermediate to basic rocks in the succession. This volcanic field lies on the eastern shoulder of the main East African Rift System. The basement system of the area is part of the metamorphic Mozambique belt that stretches from Mozambique to the south into Ethiopia to the north.

According to Baker, 1954, these rocks range from intermediate fields parthoidal types to trachytes and basalts. The kapiti phonolites overlie the Mozambiquan rocks and an erosional unconformity, the sub- Miocene surface. The end- cretaceous peneplain is only preserved on the hill tops in the Precambrian hilly areas. Matheson, 1966 noted that this Mozambiquan belt has undergone intense compressional folding and metamorphism which has produced intense isoclinal folds on mainly NNW-SSE axes with lineation pluging 20-30 ENE. This has resulted to formation of mountain chains of the area which with time has been eroded to the cones. Further to the south of Kipeto area lies the Obrgesaline Biotite phonolite formed by the basement system. To the north is characterized by the upper Athi tuffs where it is predominantly Magadi Trachyte that outcrops beneath the Olorgesallie ophonolite nephelinite and gently slopes upward to the south.

II. MATERIALS AND METHODS

Field Equipment

The survey was conducted over an area of approximately 25 km^2. Resistivity measurements were conducted using LS 2 ABEM terrameter and its accessories which include copper electrodes and electric cables among others (Figure 2.1).

Figure 2.1: Resistivity Data Acquisition process using LS 2 ABEM terrameter

Electrical Resistivity Tomography (ERT)

According to Lowrie, 2007 the availability of fast, inexpensive computers and the development of efficient software has led to the development of electrical resistivity tomography. Electrical resistivity tomography method gives a more accurate data on resistivity changes in the horizontal direction along the survey line. This method assumes that changes in resistivity doesn't occur in the direction that is perpendicular to the survey line. The best array that is suited for carrying out ERT is the dipole-dipole array (Figure 2.2) as it is very sensitive to horizontal changes in resistivity and it also has better horizontal data coverage compared to wenner array and schlumberger array (Hemeda, 2013)

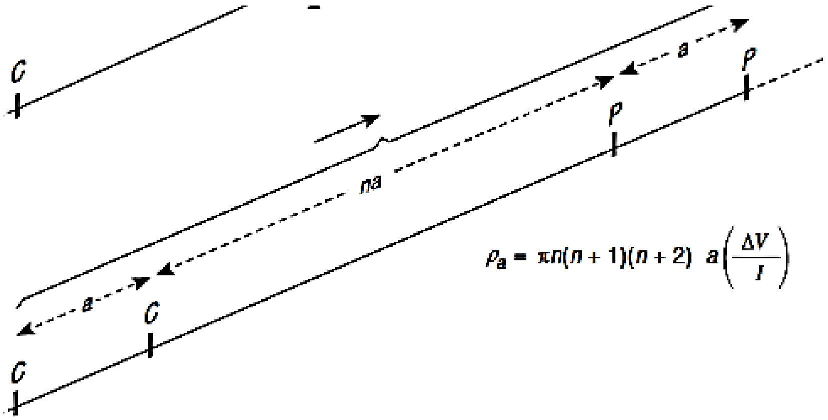

Figure *2.2*: Dipole-dipole array used in electrical resistivity tomography (Musset and Khan, 2000)

In the dipole-dipole array all four electrodes are fixed in the line at measurable distances from each other (Figure 2.3). Both current electrodes C_1, C_2 and potential electrodes P_1, P_2 are next to each other at a distance *a* and separated from the current electrode at a distance *na* (Sigdel & Adhikari, 2020). A 2D ERT resistivity method was carried out using 42 electrodes that are connected to a multi-core cable that is fed into the ABEM LS2 Terrameter which has a software that picks the relevant four electrodes for each measurement (Hemeda, 2013).

According to Pratt *et al.*, 2005 the apparent resistivity for a Dipole-dipole array is given by

$$\rho_a = 2\pi n^3 a\left(\frac{\Delta V}{I}\right) \qquad 2.1$$

If a body is very elongated horizontally its electrical structure can be investigated using a pseudo section. Pseudo sections are usually inverted using a RES2DINV software to give a true resistivity of the subsurface (Musset & Khan, 2000).

ERT is one of the most common technique that is applied for shallow subsurface imaging and has applications in hydrogeological, engineering and ore prospecting (Gunther & Rucker, 2012). In this research it was extended to gas exploration. In order perform electrical resistivity tomography, a global positioning system (GPS) was used to determine the coordinates of the survey point, two or four multi core cable were laid along the survey line with electrodes staked to the ground and the electrode positions were taken using a GPS.

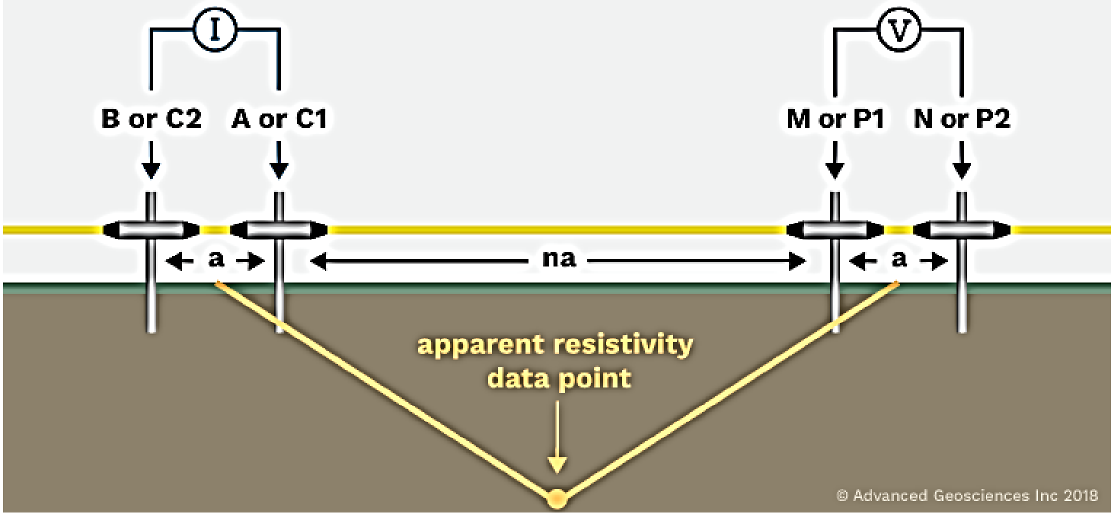

Figure 2.3: Dipole- dipole array used in electrical resistivity tomography (https://www.aguisa.com)

Resistivity Data Presentation, Analysis and Interpretation

The main aim of resistivity data analysis is to determine true resistivity and thickness of the subsurface layers so as to establish generalized structural and geological models. The general distribution of high resistivity zones and discontinuities of the contour pattern was treated as points of interest. Aarhus software and RES2DC software were used for qualitative and quantitative analysis respectively to generate pseudo cross-sections and residual resistivity maps. Modeling of the resistivity data was done in the process of determining the characteristics of the gas reservoir. It is done by generating a hypothetical model of the earth and its resistivity structure using RES2DC application software. Electrical resistivity response was then calculated from the model and optimization done. These were achieved by adjusting the hypothetical earth model so as to create a response that nearly fits the observed data. Gas and water have different resistivity values, therefore the modeled resistivity values was associated with the materials concealed.

III. RESULTS AND DISCUSSIONS

Resistivity Tomography Results

Six resistivity tomography profiles were taken across and at various distances from discharging gas and water wells. The resistivity tomography profile laid across the gas well in the W-E direction, captured a relatively low resistivity black top soil layer with a resistivity of 25-174 Ωm up to a depth of 10 m with occurrences of high resistivity of about 454-1184 Ωm associated with the hard granitic rock matrix which protrudes to the surface. It also mapped an enclosed resistivity high anomaly with a resistivity range of 174-454 Ωm, just below the gas well (Figure 3.1) within the second layer. The enclosed high resistivity zone extends from a depth of about 20 m to 60 m and is associated with the gas infiltrated zone of the subsurface. This is evident by the gas discharge at the surface, gas being a poor conductor offers high resistance to flow of electric current. A third layer of low resistivity of the range 3.78-46.9 Ωm, is mapped from a depth of 90 m to some unknown depth, this was interpreted as a highly fractured porous zone likely to host the aquifer.

The S-N oriented profile across the gas well, similarly delineated a top low resistivity layer of resistivity value of about 44-236 Ωm to a depth of 10 m, this layer is associated with the dump black cotton soil. The gas infiltrated zone, with a resistivity of 545-1262 Ωm at a depth of 10-50 m is also mapped within the second lithological layer. The other occurrences of high resistivity within this layer is interpreted as granitic rock matrix. There is a third lithological layer consisting of low resistivity of 8.22-44 Ωm. The layer seems to have been split at the middle by a moderate resistivity of about 50 Ωm with its surface curving downwards. This was interpreted as a highly fractured porous zone hosting water aquifer subjected to pressure as a result of the trapped gas above it (Figure 3.2). The splitting of the aquifer shows a possibility of a gas pathway from a deeper reservoir.

Profiles 3 and 4 taken at a distance of 20 m South and North of the gas well respectively (Figures 3.3 and 3.4) shows a reduced effect of the gas infiltration given the reduced area of high resistivity. Profile 5 taken at a distance of 150 m from the gas well (Figure 3.5) along a fault line, mapped a top resistive granitic rock that spreads along the rift with a weathered low resistivity 1.96-67.5 Ωm layer below it.

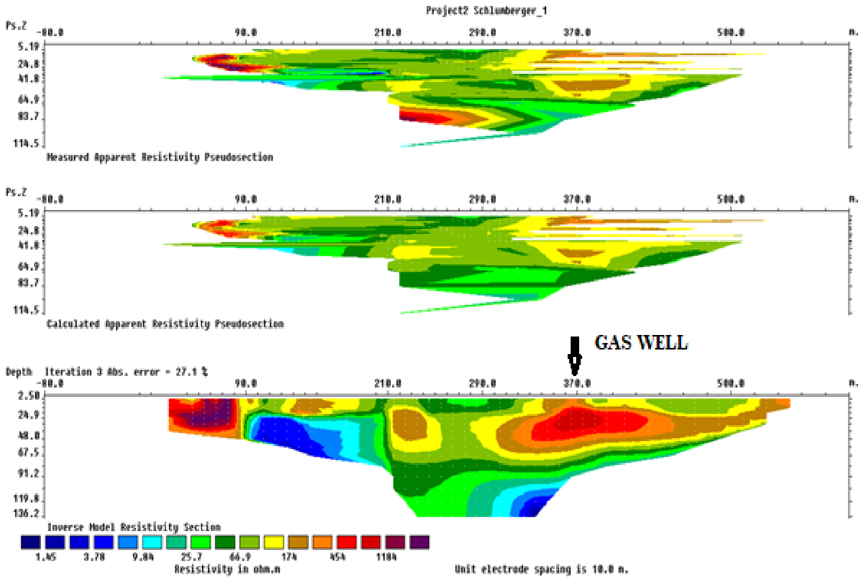

Figure 3.1: W-E Profile -across the gas well

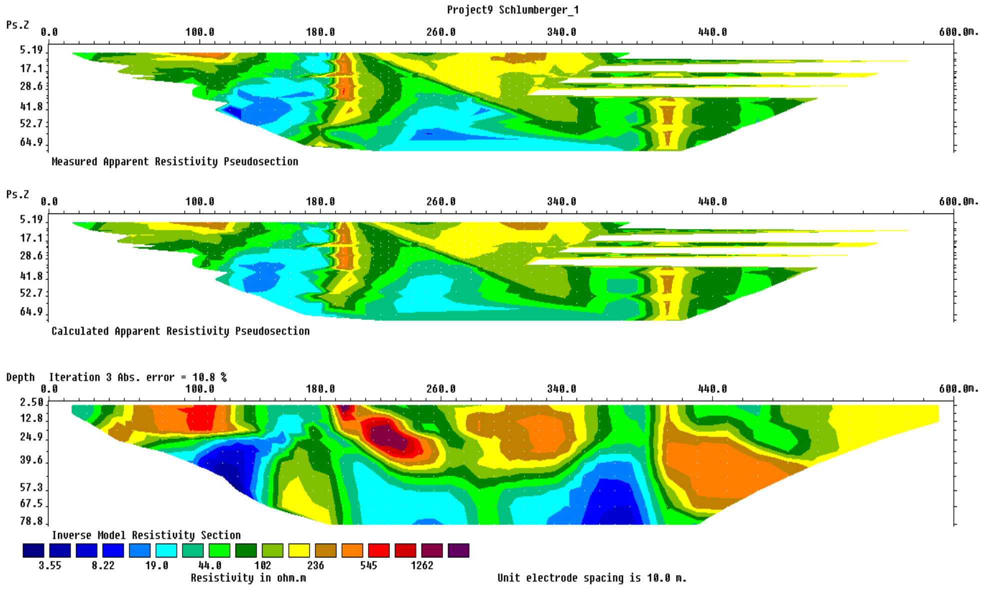

Figure 3.2: S-N Profile: across the gas well

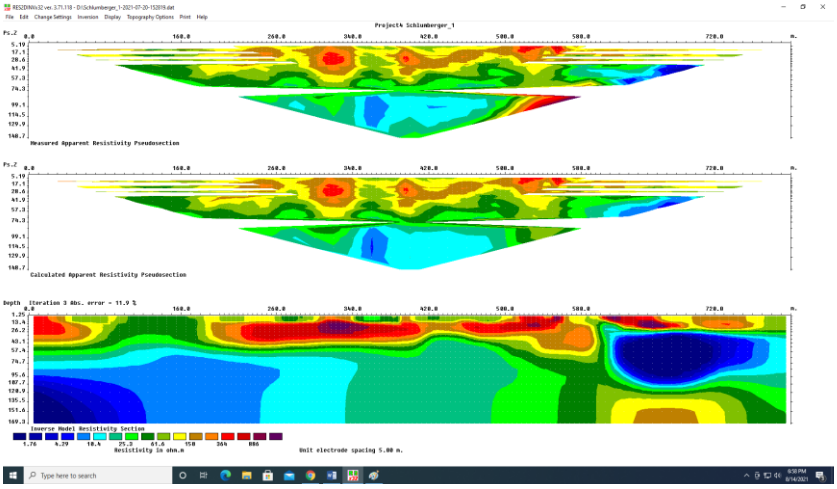

Figure 3.3: W-E Profile: Approximately 20 m to the South of the gas well

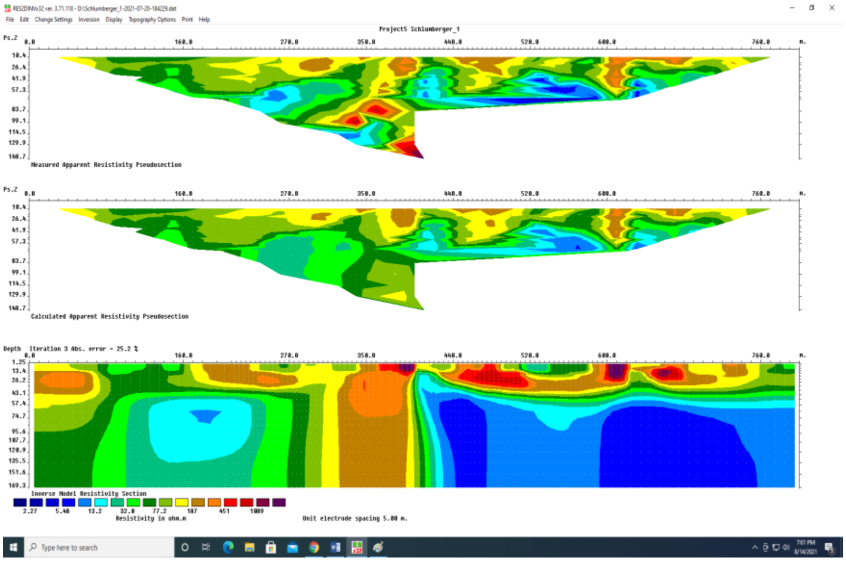

Figure 3.4: W-E Profile: Approximately 20 m to the North of the gas well

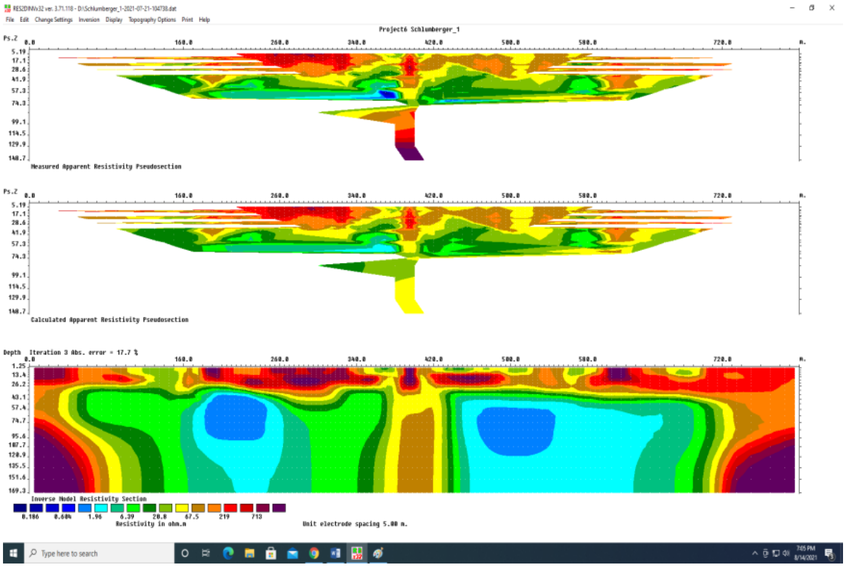

Figure 3.5: W-E: Approximately 150 m South of the gas well-Adjacent to the Fault

IV. CONCLUSION

The preliminary findings of this research is a possible displacement of water aquifer by flammable gas, which appears to be an extension of an extensive gas zone below the aquifer. The water aquifer appears split into two by the flammable gas as it migrates to the top of the aquifer where it is trapped, given that gas is less dense than water. In addition it was noted that the migration is enhanced by the fractured subsurface. The VES results revealed that the area has 3 geo-electric layers up to a depth of about 160 m from the surface: Dump black cotton soil with resistivity average and thickness of 120 Ωm and 10 m respectively; slightly weathered layer with 861 Ωm and 40 m; highly weathered volcanics with clay 25.7 Ωm to unknown depth. The flammable gas, if proven safe, can be subjected to small scale use locally by the County Government. Further studies will be conducted in this project to determine the chemical composition of the gas, as a process of determining its safety.

V. ACKNOWLEDGEMENT

We wish to express our gratitude and special thanks to Chuka University for funding the project and availing the research equipment for the data collection. We are also grateful to both Kenyatta University and Ministry of Mining and Petroleum for providing logistics and availing the Geological report.

REFERENCES

[1]. Baker, B.H. Geology Of Southern Machakos District Report. Geological Survey Of Kenya. 27, (1954). The Government Printer.
[2]. Batayneh, A. T. Near Surface Geophysics, Risha Area, North-East Jordan., Vol. 4, (2006), P.304 – 316.
[3]. Batayneh, A.T. 2D Electrical Imaging Of An LNAPL Contamination, Al Amiriyya Fuel Station, Jordan. Journal Of Applied Sciences 5, (2005), 50-57
[4]. Doust, H, Omatsola, E. In Edwards JD, Santogrossi PA. (Editors).Divergent/Passive Margin Basins, AAPG Memoir. American Association Of Petroleum Geologists: Tulsa, (1990); 48: P. 239-248.
[5]. Günther, T. And Rücker, C. Electrical Resistivity Tomography (ERT) In Geophysical Applications-State Of The Art And Future Challenges. In Schlumberger Symposium--100 Years Of Electrical Imaging, Paris, (January), (2012).
[6]. Guth, A And Wood, J. Geology Of Magadi Area, Kenya, (2013).
[7]. Hemeda, S. Electrical Resistance Tomography (ERT) Subsurface Imaging For Non-Destructive Testing And Survey In Historical Buildings Preservation. Australian Journal Of Basic And Applied Sciences, 7(1), (2013), 344-357.
[8]. Https://Oilnewskenya.Com/Kajiado-Well-Gas-Shows-Biogenic-Thermogenic-Methane-Gas-Formation/
[9]. Hyne, N. J. Nontechnical Guide To Petroleum Geology, Exploration, Drilling, And Production, 3rd Edition. Sage Publishers, New York, (2012)
[10]. Keller, G. V., Anderson, L. A., And Pritchard, J. I. Geological Survey Investigations Of The Electrical Properties Of Crust And Upper Mantle. Geophysics, 31(6): (1966), 1078 – 1087
[11]. Keller, G.V. And Frischknecht, F.C. Electrical Methods In Geophysical Prospecting. Pergamon Press Inc., Oxford, (1966), Pp 506
[12]. Kengen. Surface Scientific Investigations Of Longonot Geothermal Prospect. Kengen Internal Report, (1998).
[13]. Lowrie, W. Fundamentals Of Geophysics Second Edition Cambridge, New York, (2007)
[14]. Mussett, A. And Khan, M. Looking Into The Earth: An Introduction To Geological Geophysics. Cambridge University Press, (2000).
[15]. Sigdel, A. And Adhikari, R. Application Of Electrical Resistivity Tomography (ERT) Survey For Investigation Of The Landslide: A Case Study From Taprang Landslide, Kaski District, West-Central Nepal. Journal Of Nepal Geological Society, 60, (2020), 103-115.
[16]. Telford, W.M., Geldart L.P And Sheriff ,R.E. Applied Geophysics 2nd Edition. Cambridge University Press. New York, (2004).