Innovative Geothermal Assessment of Akiri – Azara and Environs for Power Generation as a source of Clean Energy in Nigeria

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Abstract

Geological and hydrological studies across *Akiri – Azara* , Nigeria was done to identify potential areas with viable thermal resources. The results of the study reveals that the warm springs, Akiri- Awe have their thermal resources as hyper thermal, and thermal, with no hypothermal evidence. Only warm springs with hyper thermal and thermal resources are viable for the electricity generation. The temperature of the springs at the time of measurement was found to ranged from (54-32.7)ºC . The spectral analysis was carried out on the bouguer of the gravity anomaly data of the study areas. Results of spectral analysis for study area revealed the occurrence of geothermal parameters: Curie point depth varied between 7.39 to 20.71 km, geothermal gradient varied between 28.01 to 78.48 °C/km and heat flow values varied between 70.29 to 197.99 mW/m^{2}.

A recommended threshold value of heat flow for a good source of geothermal energy is set at 80 to 100 mW/m^{2}. These ranges of values can be observed between the light blue colours depicted within southern regions of the heat flow contour map. Values of heat flow above the stated range is considered as excess, however, the entire study area with exception of the extreme Southern parts can be considered in locating potential geothermal reservoirs. The shallow curie depths with corresponding heat flow are observed around the Akiri and Awe hot springs. The observed

anomalies geothermal conditions can be attributed to the intense Cenozoic magmatic activities with numerous volcanic intrusions within the Benue trough.

Introduction

Geothermal study is made through exploration, evaluation, and exploitation of this type of energy. This type of energy manifests on the surface in the form of volcanoes, geysers, fumaroles, hot springs, etc. Geothermal power plants have very low gaseous emissions to the air when compared with all other power generation technologies that emit carbon dioxide (CO2) as a normal part of the operation.

Geothermal energy is mainly one of the important energy sources ascribing substantially to the global sustainable energy supply drive. Geothermal energy sources are used as a means of electricity in many parts of the world (Guo and Wang, 2012, Baioumy *et al.*, 2015). The generation of electricity using geothermal energy could not neglected from the use and need for a world shift from environmentally harmful "fossil fuel" means of energy generation to more clean and renewable sources of energy. Nigeria has not been able to produce enough energy for many decades to meet the needs of people demand both domestic and industrial. The capacity of Nigeria's current electricity generation installed is approximately 6000 MW (NCN, 2014), with maximum output of 4000 MW which is basically produced from two major primary sources such as hydro (36%) and gas-fired (fossil fuel) sources with 64% contribution (NCN, 2014). The currently energy generation from fossil fuel has been impacting the safety of this part of the world negatively. The air pollution, gas flaring issues and crude oil spillage problems are the major negative impacts. However, there is need to look into another means or sources of energy that can be generated without causing no damage or harm to the surrounding (NCN, 2014, Abraham and Edet, 2017). To add to the country quantum of energy, there is need to investigate other healthier and renewable sources of energy for its sustainable development and growth (NCN, 2014, Abraham and Edet, 2017). The high-temperature gradients, shallow Curie point depths, low regional gravity anomalies, the presence of structural lineaments, high heat production, the outcropping of younger volcanic or granitic rocks, and hot or warm spring locations are the major parameters that needs to be considered for reasonable accumulation of geothermal resources. The pattern subsurface geological fissures such as fault and fracture zones enhance the permeability of rocks, which allow easy flowing of hot fluid from the Earth's interior to the surface (Wibowo 2006, Kiavarz *et al.*, 2013). The major occurrence of geothermal energy resources within the Earth is indicated by hot/warm springs. In some major geothermal areas, volcanic rocks occurrence serve as cap rocks. The volcanic rock that occur within the subsurface exhibits low gravity anomaly, while the high-temperature gradients and shallow Curie Point Depth show the high possibility of geothermal resources ((Wibowo 2006). Volcanic rock outcrops, mud volcanoes, fracture distributions, hot springs, hydrothermal alterations, and faults was used to first discovered the majority of the global geothermal energy fields. Geothermal investigation is normally carried out in different phases. The first stage (phase) is by viewing the regions of the major geothermal occurrence involving integration of several data sources in a regional extent, following by identifying the proximity area and further investigation of the regions of high proximity indicated from the results of first phase (Kiavarz *et al.,* 2013). Other studies used subsurface geological properties such as rock distributions, hot/warm springs, structural distributions, and mud pods that revealed geothermal indicators (Kurowska and Schoeneich, 2010, Abdullahi *et al.*, 2014, Musa *et al.*, 2016). The major objective of this research is to use efficient approach to delineate the properties controlling the geothermal energy prospects, identify, and map prospective geothermal zones, and finally construct a geothermal prospectivity map of the study area.

Geology of the Study Area

Akiri -Azara, and other springs like Awe, Keana and Ribi are located in the southern parts of Nasarawa State, Nigeria. The southern part of Nasarawa is covered by sedimentary rocks. The sedimentary rocks belong to Middle Benue Trough which is the part of the sedimentary basin that extends from the Gulf of Guinea and stretches to the part of northeast of Nigeria. The regional geology of the area is being controlled structurally by two troughs; Middle and Lower Benue Troughs. Keana, Awe and Kanje are bounded from the north to the east by alluvia deposits, at the southwest of the area, they are bounded by Basalt intrusions while the southwest is shale and limestone (Fig. 1.1). Azara, Akiri and Ribi are covered towards the southwest by alluvia deposits, at the southeast is shale and limestone boundary them and at the north is feldspathic sandstone,

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poorly sorted medium-coarse grained sandstone except for Ribi that is only bounded from the north to the southeast by a migmatites. The formations in these areas are Eze-Aku Formation, Keana, Awe, and Asu River.The stratigraphic order of the areas is in the order of the Latest Cenomanian-Turonian succession in the central and southern Benue Trough.

The local Geology of Keana Awe and Kanje is siltstone that graded upward to fissile black shale. The black shale (Fig. 1.2a) transits upward into a micaceousarkosic, poorly sorted sandstone bed (Fig. 1.2b.6b), with occasionally interbedded mudrock, planar cross-bedded, characterizes this formation. The partial anticlinelike feature around Awe town indicated that the formation has relatively high dips of 17–32° towards the north and south parts, while towards the northeast, the dip becomes lower in the range of 3–9° in that direction. Longitudinal strike-slip faults parallel to the major fold axis, dominate the area. This observation shows that the area has experienced series of crustal plate movement and the structure is an anticline that has been faulted. Azara, Akiri and Ribi are underlain micacious, poorly sorted cemented sandstone. The sandstone unit is cut across by close conjugate fractures (Joint) with infill of silica material.

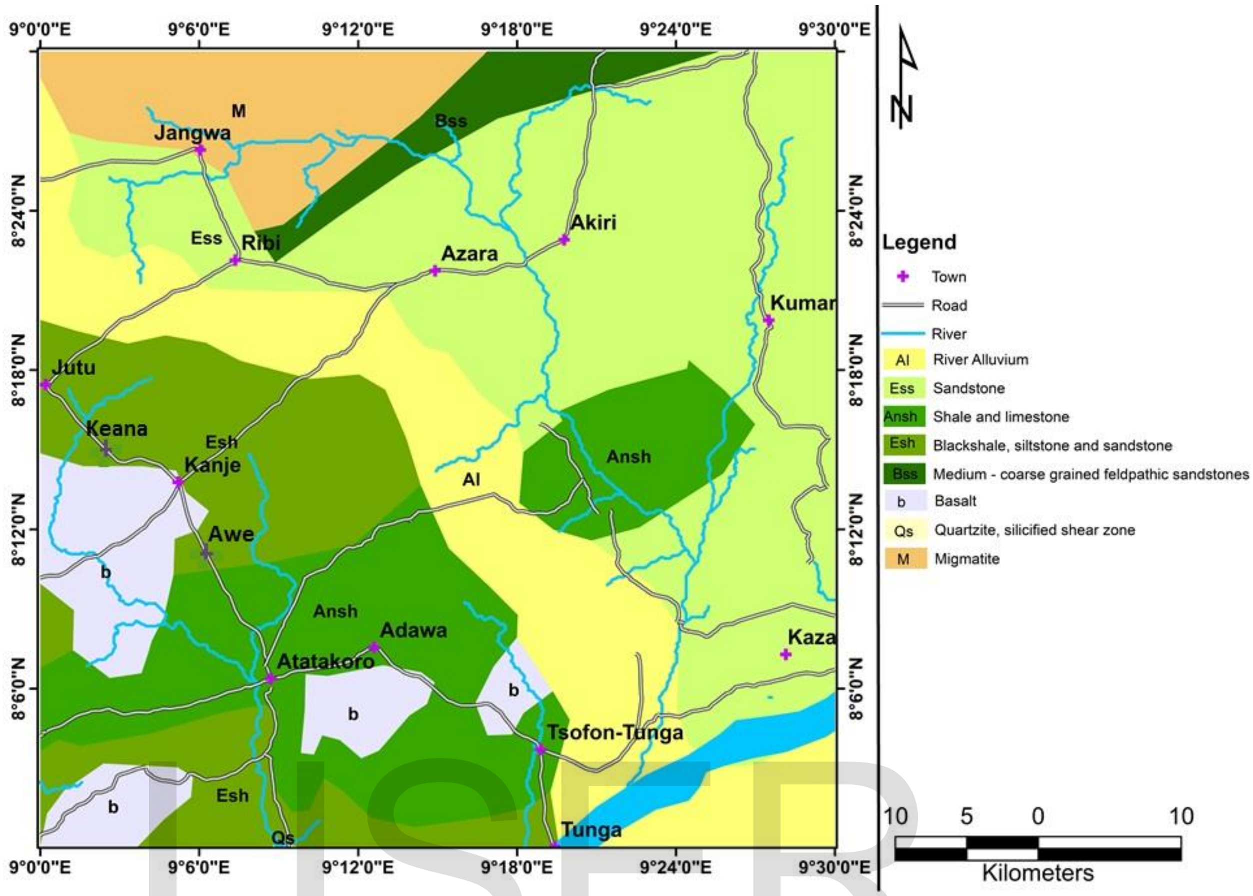

Fig. 1.1: Regional Geological map of southern part of Nasarawa showing part of Middle Benue Trough where the study areas fall.

Fig. 1.2: (a) Keana Formation in Nasarawa showing black shale, siltstone and sandstone lithology units (b) Awe Formation in Nasarawa showing outcrop exposure of black shale

Hydrogeology of Azara, Akiri, Awe, Kanje, Keana and Ribi

Akiri Thermal Spring is located in Akiri, about 4 kilometers north of Azara and less than 3 kilometers west of River Ankwe. It is covered by alluvial deposits of sand. The spring discharges from theses sediments .Pool of the spring serves as a source of water for bathing and livestock and local source for salt. The temperature of the spring at the time of measurement was 54º C. The area is famous for barite mining and traditional salt production based on salty sediments . Awe spring 1 is the most visible among the three springs. It is 67 km away from Lafia town. The area of the spring Awe 1 is about 500m in diameter. It is a low circular depression of seeps warm spring with temperature of 41.5^0C. Awe spring 2 has temperature of 39.2ºC. Awe spring 3 releases water with temperature 32.7ºC. The Keana thermal spring is located in an open slope valley at south Keana inNasarawa State, about two kilometers east of the town. The valley and the slope bordering it are underlain by sandstone and clayey silt deposits. The sandstone is exposed in the sides of the depression which is about 2m deep . The temperature of the spring was measured to be 34ºC .Ribi Thermal Spring is located at Rimi village. It is about 20 kilometer NNE from the Kanje Town. The thermal spring temperature was 33.9ºC. Kanje Thermal Spring is located at Kanje town drains alluvia deposits of sandstone and clayey siltstone. The temperature was measured as 34ºC close to the source of the spring and still remains 34ºC, 10m away from the major source . Azara Thermal Spring is located at Azara village. The spring form offset a stream that drains the underlying sandstone rock units in the area. The temperature of the spring water was measured as 32.7ºC

Materials and Methods

The resources (materials) used for this study include; The global positioning system (GPS), Thermometer, clinometer, Geosoft oasis montaj, surfur,Arc Gis and mat lab software's , airborne gravity data , and geological maps. The geothermal potential of the study area from geological and hydrogeological point of view was determined as the first principle objective of the research using the thermometer, clinometer and GPS. Aeromagnetic data was also applied to generate the geological maps using Oasis Montaj, Malab program, surfur and Arc GIS software's for the geology and Hydrogeology of the study area. The spectral analysis was carried out on the bouguer of the gravity anomaly data of the study area, using Akiri (Sheet 232). Each sub-sheet was further subjected to Fast Fourier Transform, a process that decomposes the gravity data into its energy spectrum and wave number components. The location was labelled A-L (Sheet 232). The energy spectrum was plotted against wave number components using MatLab software (Fig1.3b.). This process deduced gradients in the form of depth to the top (Z_T) and centroid (Z_0) of sources. The depth to top of basement and centroid were used to evaluate Curie point depth (Z_b) and thereafter estimate the geothermal gradient and heat flow of study area. Curie point depths varies with geological situations (Ross *et al*., 2006). Tanaka *et al*. (1999) established that CPD ranging below 10 km are attributable to volcanic and geothermal regions, 10 km to 15 km are attributable to Island arch and ridges, 20 km and above are attributable to Plateaus and 30 km and above are attributable to trenches. The heat flow value between 80mWm^{-2} and 100mWm^{-2} has been established to indicate geothermal anomalous conditions in an area for geothermal prospecting (Jessop *et al*., 1976). It can therefore be deduced from this study that regions that fall within the range of 80 to 100 mWm^{-2} are good spots for geothermal energy resources.

Results and Discussion

The temperature of the Akiri spring at the time of measurement was 54º C, while the temperature of the Azara spring water was measured as 32.7ºC.

Results of spectral analysis for study area revealed the occurrence of geothermal parameters: Curie point depth varied between 7.39 to 20.71 km, geothermal gradient varied between 28.01 to 78.48 °C/km and heat flow values varied between 70.29 to 197.99 mW/m^2. Table 1 presents the summary of the results of the centroid depth, depth to basement, curie depth, geothermal gradient and the heat flow A general trend of low to peak geothermal gradient and heat flow values is observed from the southern to northern region of study area respectively (Fig.1. 3a). An inverse trend is observed for curie point depth. A recommended threshold value of heat flow for a good source of geothermal energy is set at 80 to 100 mW/m^2. These ranges of values can be observed between the light blue colours depicted within southern regions of the heat flow contour map. Values of heat flow above the stated range is considered as excess, however, the entire study area with exception of the extreme Southern parts can be considered in locating potential geothermal reservoirs. Only heat flow results in excess of 80 mW/m^2 indicating anomalous geothermal conditions can be utilized in geothermal electricity generation. The shallow curie depths with corresponding heat flow are observed around the Akiri and Awe hot springs. The observed anomalies geothermal conditions can be attributed to the intense Cenozoic magmatic activities with numerous volcanic intrusions within the Benue trough.

Table 1: summary of the results of the centroid depth, depth to basement, curie depth, geothermal gradient and the heat flow

Blocks	Longitude (Deg)	Latitude (Deg)	Centroid Z_O (km)	Depth to basement Z_t (km)	Curie depth Z_B (km)	Geothermal gradient dT/dZ_b (oC/km)	Heat Flow (mWm^{-2})
A1	9.125	8.375	8.29	2.59	13.99	41.46	104.06
A2	9.207	8.375	4.48	1.57	7.39	78.48	197.00
A3	9.290	8.370	4.58	1.48	7.68	75.52	189.56
A4	9.124	8.380	5.03	1.79	8.27	70.13	176.03
A5	9.125	8.125	11.7	2.69	20.71	28.01	70.29
A6	9.207	8.125	8.51	1.65	15.37	37.74	94.72
A7	9.207	8.125	9.1	2.01	16.19	35.82	89.92
A8	9.380	8.125	11.6	2.79	20.41	28.42	71.33
***Heat Flow ranged from 70.29 – 197.00 (mWm^{-2})**					***13.75***	***55.39***	***144.4***

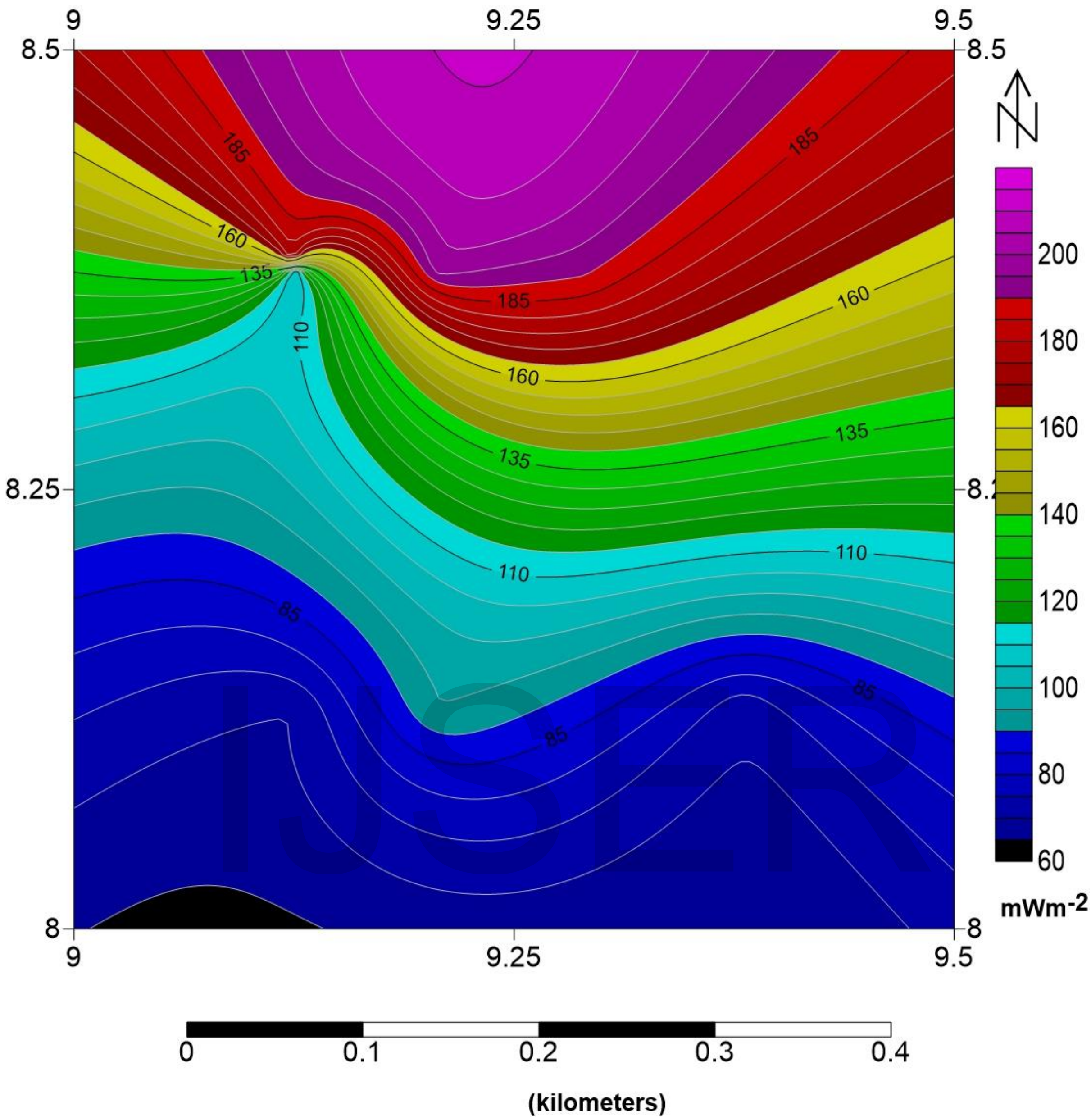

Fig.1.3a Heat flow contour map of sheet 232 corresponding to Akiri

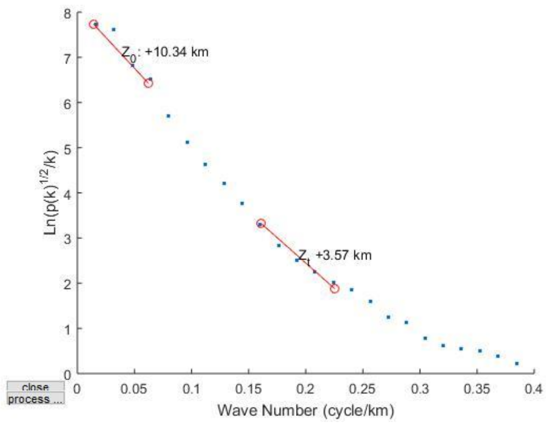

Fig 1.3b: Plots of spectrum energy against wave number (a) spectral block A1.

Conclusion

The results of the Geological and hydrological studies across Akiri-Azara to identify potential areas with viable thermal resources reveals that the warm springs in the areas, have thermal resources as hyper thermal (surface manifestations).The temperature of the Akiri spring at the time of measurement was 54º C, while the temperature of the Azara spring water was measured as 32.7ºC.

Results of spectral analysis for study area revealed the occurrence of geothermal parameters: Curie point depth varied between 7.39 to 20.71 km, geothermal gradient varied between 28.01 to 78.48 °C/km and heat flow values varied between 70.29 to 197.99 mW/m^2. A recommended threshold value of heat flow for a good source of geothermal energy is set at 80 to 100 mW/m^2. These ranges of values can be observed between the light blue colours depicted within southern regions of the heat flow contour map. Values of heat flow above the stated range is considered as excess, however, the entire study area with exception of the extreme Southern parts can be considered in locating potential geothermal reservoirs. Only heat flow results in excess of 80 mW/m^2 indicating anomalous geothermal conditions can be utilized in geothermal clean electricity generation.

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