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Dynamics of Geothermal Variability in the Nigerian Sector of the Chad Basin

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Abstract Having a sedimentary fills of approximately 10km is an indication that the Nigerian sector of the Chad Basin is deep enough for attainment of geothermal field. Geothermal gradients of more than 3.0°C/100m in the region were reported by earlier workers. This work is set out to determine the spatial distribution of temperatures at different depth within the Chad Basin. Isothermal maps were prepared on the basis of previously produced "Map of Geothermal Gradient and of mean annual air temperature in the area using computer program and other calculations using "Grid Math" option. Maps of depth to Isothermal temperature of 100°C, 125°C, 150°C and 175°C were produced and the results shows that isothermal surface of 100°C vary from 1200mbgl west of Dikwa town to about 2400mbgl around Kala area. Isothermal temperature of 125°C can be reached at 1800mbgl west of Dikwa to about 2200mbgl around Kukawa while isothermal surface 175°C which happens to be a major important temperature for generation of electricity occur in the study area at 2600mbgl west of Dikwa and 3000mbgl north of Bida. The spatial distribution of these temperatures at varying depths suggest occurrence of geothermal resources that can be harnessed for different applications such as binary technology for electricity generation.

Keywords: *geothermal, gradient, bida, energy, nigeria, chad basin*

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1. Introduction

From Seismic reflection data [1] inferred that the strata that fill the Chad Basin attained a thickness of approximately 10 km and probably are of Pre-Aptian to Tertiary age. Using spectral analysis of gravity data [2] revealed sediment thickness ranging from 420m to 8000m in the Southwest part of the Chad Basin. Interpretation of seismic profiles also revealed the base of Cretaceous/top of Basement range between 500mbgl to 6500mbgl north of Maiduguri [3].

The sedimentary thickness of the Nigerian sector of the Chad Basin is found to be enough for geothermal field potential assessment. Higher than normal geothermal gradients were reported in some of the abortive oil wells in the area [4]. The present work involves calculation and construction of maps of depth to some isothermal temperatures in the region. Different useful temperatures at varying depths and locations suggest the occurrence of geothermal resources for different applications.

2. Regional Geology

The Chad Basin belongs to a series of Cretaceous and later rift basin in Central and West Africa (Figure 1). The origin is generally attributed to the Rift system that develop in the early cretaceous when the African and South American lithospheric plates separated and the Atlantic opened.

According to [5], the Cretaceous Rift system of West and Central Africa extend for over 4,000km from Nigeria northwards into Niger and Libya and eastwards through southern Chad into Sudan and Kenya.

The Bornu Basin (Nigerian sector of the Chad Basin) makes up approximately 10 percent of the basin and lies between longitudes 8˚ 21^{1}49^{11} and 14°40'22"E and latitude 11˚N and 13˚45'38''N in north-eastern Nigeria [6]. The history of the Chad Basin according to [7] began before the beginning of Upper Cretaceous when continental sediments consisting of Bima sandstone were deposited on the Pre-Cambrian Basement probably during Albian. The Gongila Formation (mixed limestone/shale) was deposited by marine transgression on the Bima sandstone in Early Cenomanian. Marine Fika shales of Cenomanian to Turonian age overlie these beds. Towards the end of the Cretaceous, an estuarine-deltaic environment prevailed, and the Gombe sandstone was deposited with intercalations of siltstone, shales and ironstones. Based on well logs, the Gombe sandstone was observed to be limited in its aerial extent [8]. The Paleocene marked the period of deposition of the continental Kerri-Kerri Formation. The Chad Formation of Pliocene to Recent age overlies these sediments in the basin.

[9] Combined Seismic refraction evidence as well as gravity log to identify a "Maiduguri Trough" containing

about 3000km of Quaternary and Cretaceous sediments. According to [1], strata that fill the Chad Basin attained a thickness of approximately 10km and probably are of Pre-Aptian to Tertiary age. [1], inferred this total thickness from Seismic reflection data. From spectral analysis of gravity data, [2] revealed sediment thickness ranging from 420m to 8000m in the Southwest of the Chad Basin.

[1] Using seismic reflection data in the Maiduguri area of the Chad Basin revealed a significant juxtaposition of faults and fold. The primary structured orientation of which is Northeast-Southwest and parallel to the surface structural pattern in the contiguous Benue trough. Sharing the same view, [2] assert that the structural styles in the southwest of Chad Basin consist of fault and simple symmetric folds most of which have a dominant northeast-southwest trend. And this result according to [2] is an evidence to propose that the tectonic history of the Chad Basin and Benue Trough are closely related.

3. Materials and Method

Isothermal maps were prepared on the basis of previously produced “Map of Geothermal Gradient” by [4] and the map of mean annual air temperature in Nigerian sector of the Chad Basin by [10]. These two were digitized and gridded in Surfer program. The calculations were carried out digitally using Surfer program and its “Grid Math” option. This option allows the user to use mathematical formulae to undertake the computations on the digital grids representing the distribution of some physical quantity in the research space instead of only calculations. This process represents in fact the conventional method known in geology as “superposition”.

The result of temperature distribution on the given depths were obtained in form of grid as well. The final grid “T” was transferred to Global Mapper and MapInfo software contour visualization and map enhancement.

The following formula was used to determine and produce the isothermal maps i.e. maps of depth to some specified temperature:

$$h = (T - T_a) / G$$

Where:

T – Temperature on the particular depth,

T_a – Mean annual air temperature at the ground Level,

G – Geothermal gradient (°C/m)

h – The depth (m).

In the process of calculations, the Surfer digital grids for Ta and G were used and T was represented by: 100, 125, 150, 175°C. In the result the new grids representing the depths to temperatures of 100, 125, 150, 175°C were then obtained.

4. Results and Discussion

Map of depth to Isothermal surfaces 100°C, 125°C, 150°C and 175°C (Figure 3, Figure 4. Figure 5 and Figure 6, respectively) were constructed. Depth to Isothermal surface of 100°C vary from 1200mbgl west of Dikwa town to about 2400mbgl around Kala area, while Kukawa and Gulumba areas had this temperature (100°C) at the depth of 1600mbgl. Isothermal temperature of 125°C can be reached at 1800mbgl west of Dikwa to about 2200mbgl around Kukawa. The depth to Isothermal surface of 150°C start from 2200mbgl west of Dikwa to the depth of 2800mbgl around Gulumba area.

Isothermal surface of 175°C which happens to be a major important temperature for generation of electricity occur in the study area at 2600mbgl west of Dikwa and 3000mbgl north of Bida.

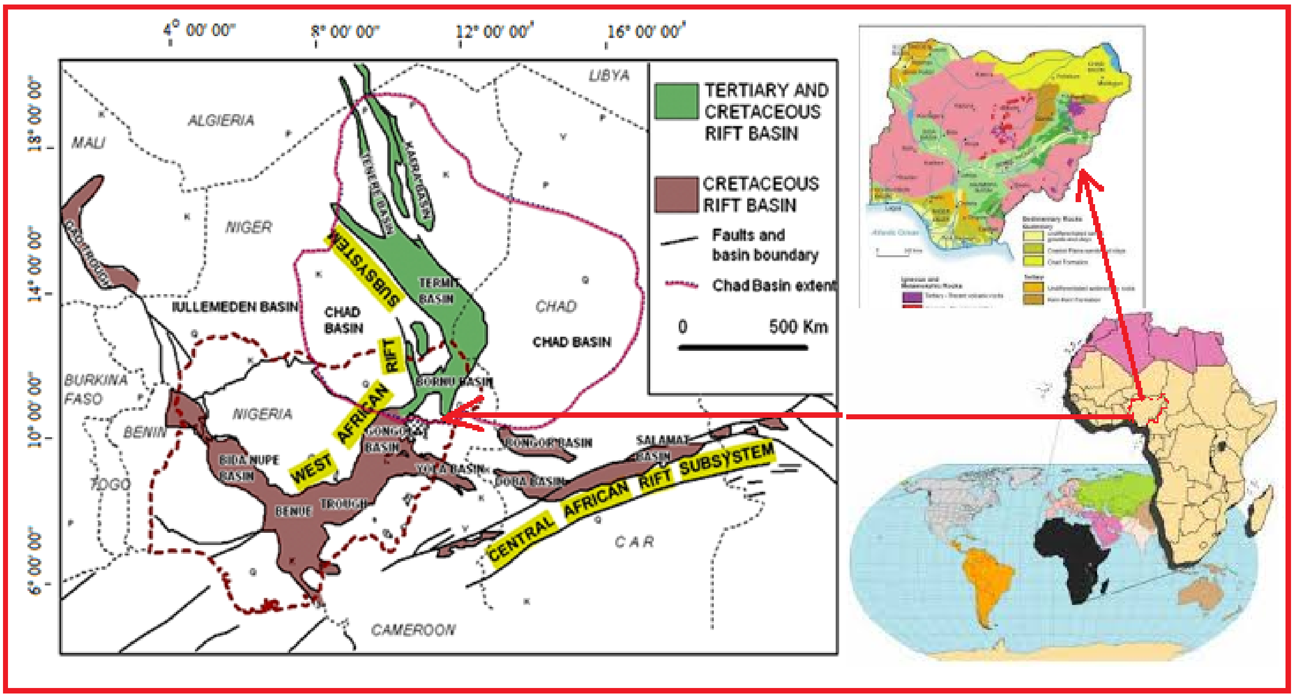

Figure 1. Regional geological map of West and Central African Rift System (modified after [12])

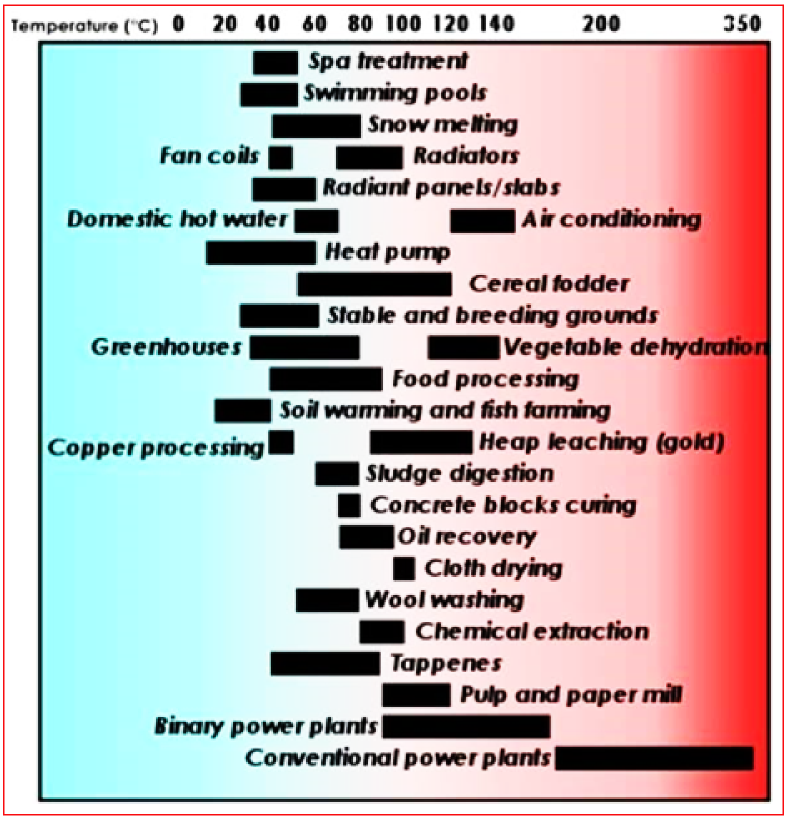

Figure 2. Diagram showing utilization of geothermal fluids derived from Lindal (1973)

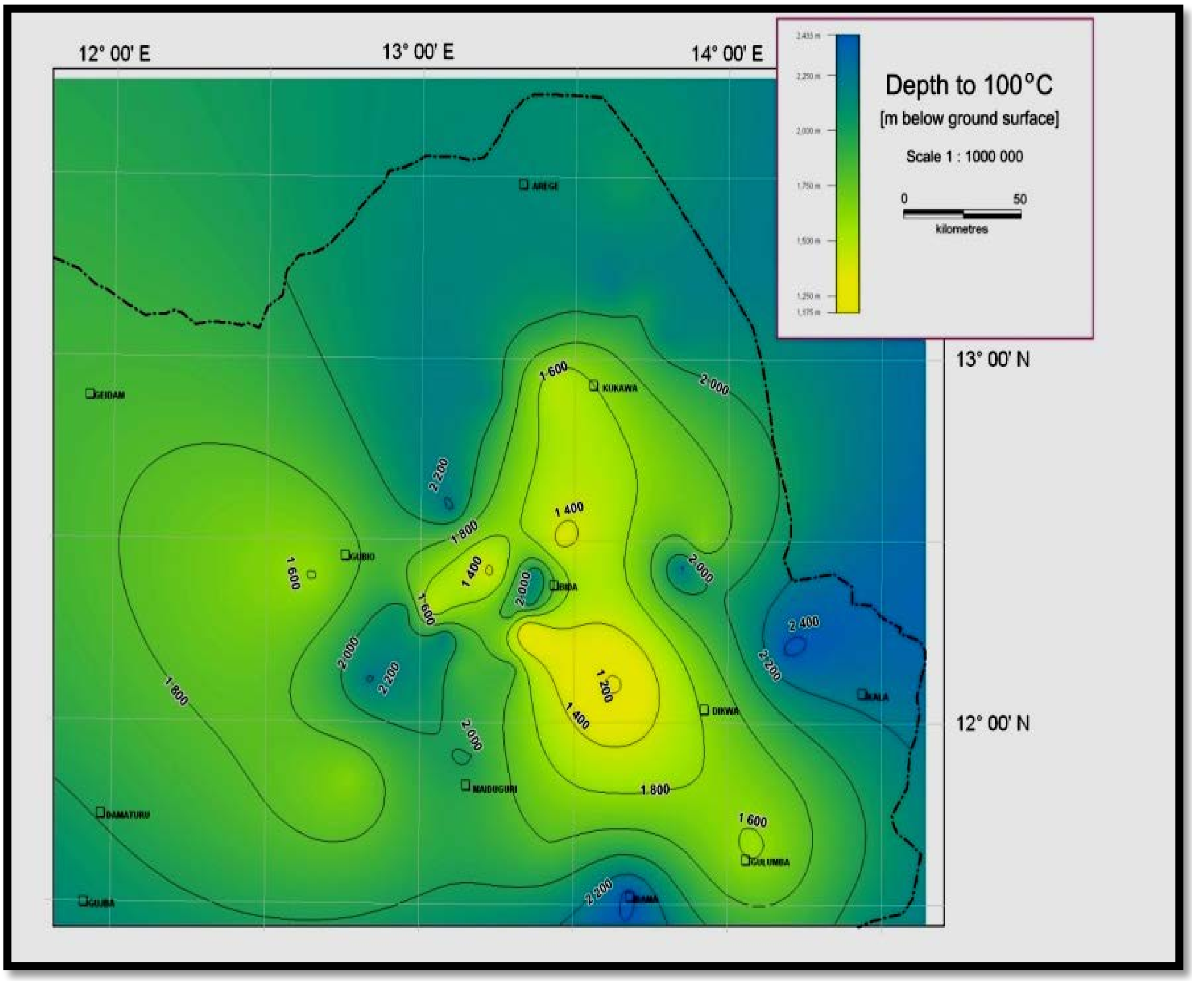

Figure 3. Map of depths at which a temperature of 100°C can be obtained in the Chad Basin

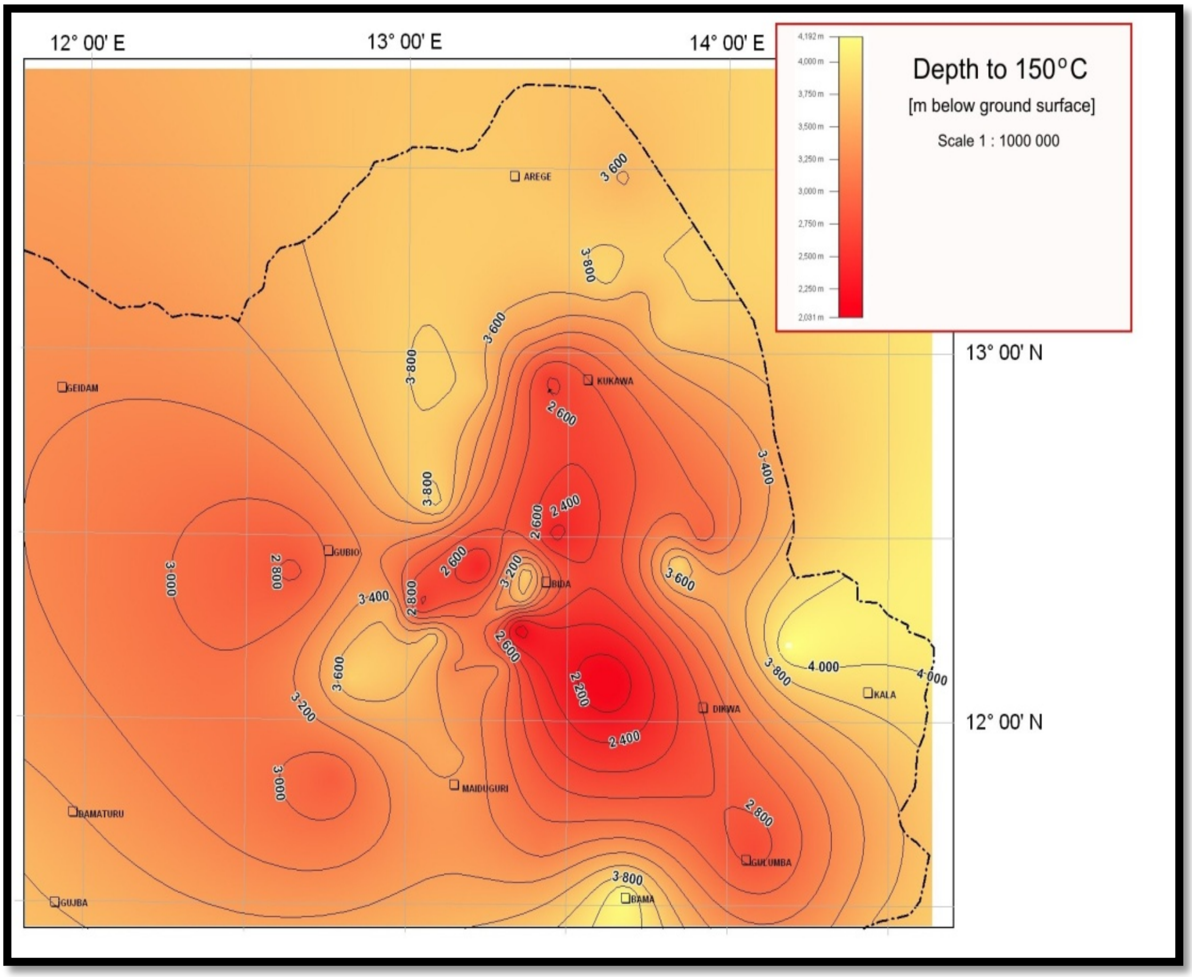

Figure 4. Map of depths at which a temperature of 150°C can be obtained in the Chad Basin

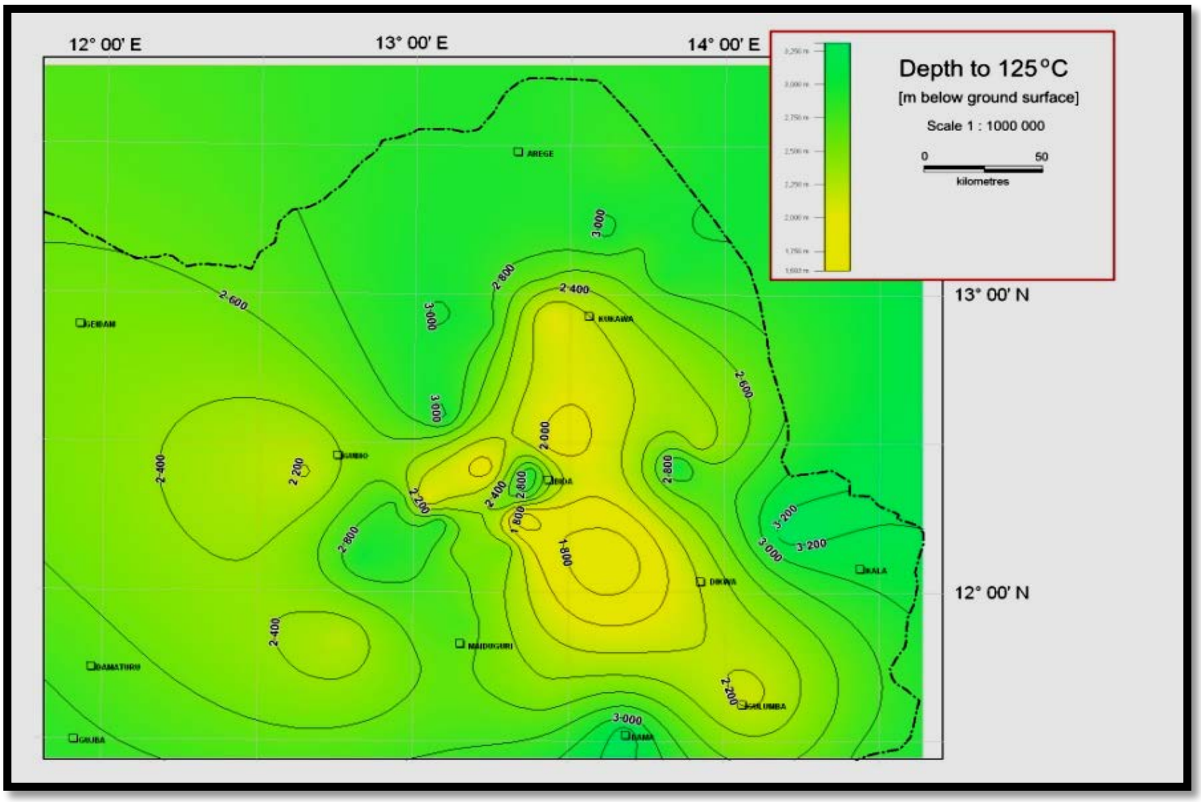

Figure 5. Map of depths at which a temperature of 125°C can be obtained in the Chad Basin

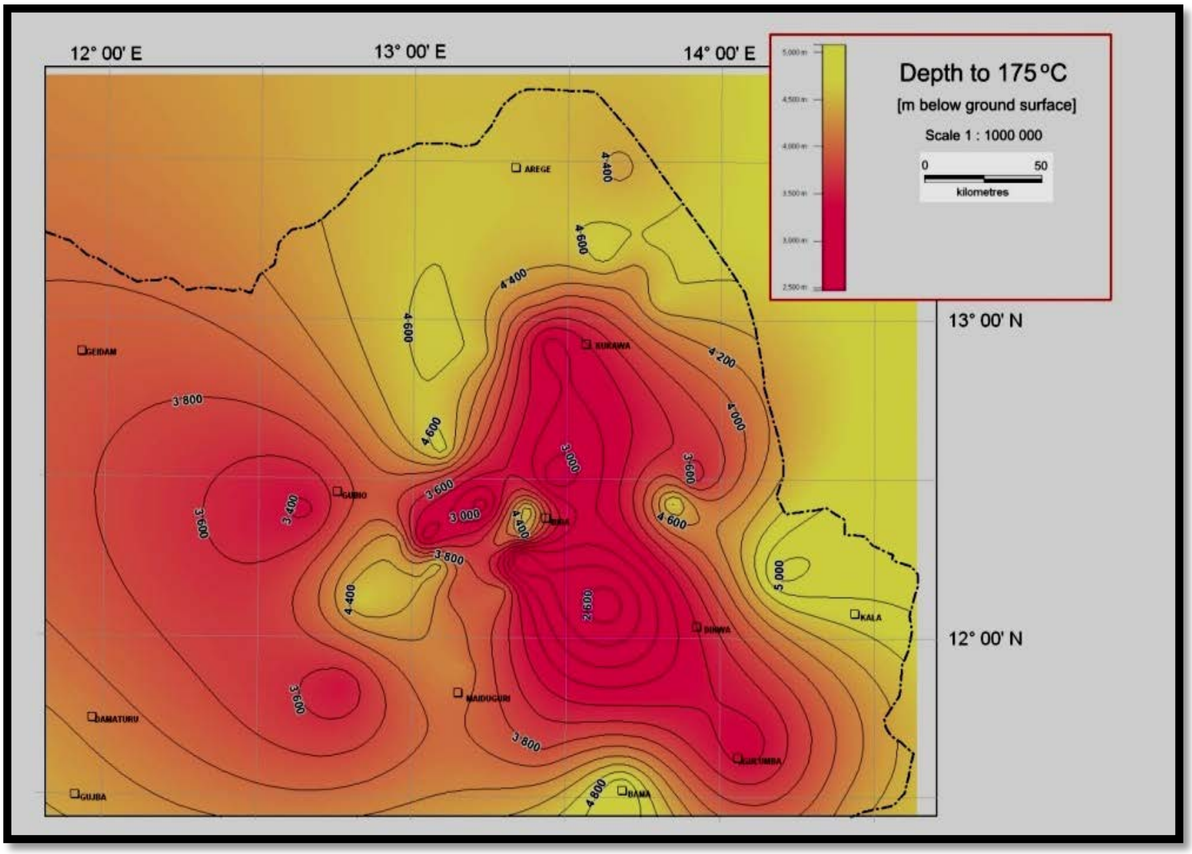

Figure 6. Map of depths at which a temperature of 175°C can be obtained in the Chad Basin

The maps of depth to Isothermal temperature surfaces of 100°C, 125°C, 150°C and 175°C indicates a depth at which a particular required temperature can be encountered. This provide the idea on how deep a particular projected borehole should be in a particular area and in a situation of the need to reach a zone with a needed temperature. This is important in the assessment of the cost of such drilling which constitute part of total geothermal installation cost. Different useful temperatures at varying depths and locations suggest occurrence of geothermal resources for different applications.

For binary power plant the [11] (Figure 2) shows that a temperature of 80°C to about 175°C is required. Temperature for oil recovery according to the diagram falls between 70°C and 100°C, green house starts around 40°C to about 80°C. The most attractive application for Nigeria power generation is restricted to the highest values of temperature which must be higher than 80°C on the well head. This means that the water pumped from deep geothermal reservoir to the surface must have a minimum temperature of 80°C at the ground surface, when it is directed to the turbine of a geothermal plant. On its way from a reservoir to the surface water is cooled and the cooling rate depends on temperature of water, temperature at the surface and the pressure and flow rate. Therefore, to project such exploitation, it is necessary to determine other parameters which currently is not available for Chad Basin. However this work presents some important projections about the subsurface temperatures of the rock mass and their depths so we can predict to what depth it must be drilled to reach the proper temperature, knowing that it will be cooled down a little bit during its transmission to the surface.

5. Conclusion

This work sets out to determine the depths at which isothermal temperatures of 100°C, 125°C, 150°C and 175°C can be found within the Nigeria sector of the Chad basin for different purposes. It was found out that the temperature gradient and subsurface temperatures are of the medium type which is adequate for geothermal energy generation using the binary technology. Different useful temperatures at varying depths and locations suggest the occurrence of geothermal resources for different applications. Temperature of 100°C to 175°C which is considered important and adequate for electricity generation with the Binary system design were attained at accessible depth of 1200 to 2600mbgl west of Dikwa town. Useful temperatures of less than 100°C for applications in spa, swimming pools, green houses, food processing or even domestic use can be accessed at depths less than 1000mbgl in the region. Further research and especially practical test work are needed for which the present work can be the foundation.

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