J. Basic. Appl. Sci. Res., 2(5)4733-4739, 2012
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ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Geothermal Exploration in surrounding area of N'Djamena Region

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ABSTRACT

The geothermal gradient of a surrounding area of N'Djamena which constitute also a part of the Chadian sector of the Chad Basin were estimated in order to highlight the geothermal groundwater potential in the area. Geothermal gradient, water temperature at depths of 500 m, 1000 m and 1500 m below the groundwater and depths to geothermal surfaces 100°C are evaluated from the geothermal information obtained from 19 water well drilled in N'Djamena region.
Results show that geothermal gradient varies from 1.6929^{0}C/100 m to 8.3817^{0}C/100 m, temperature at depth below ground surface at 500 m ranges from 37.44^{0}C to 70.885^{0}C. At 1000 m below it varies from 45.9^{0}C to 112.79^{0}C and up to 1500 m below ground surface it is between 54.36^{0}C to 154.695^{0}C.While at 100^{0}C depth below ground surface varies from 847.490 m to 4195.168 m. the results indicate also a average temperature of 49.95^{0}C, 76.96^{0}C and 100.95^{0}C respectively at 500 m, 1000 m and 1500 m below ground surface.
This study has helped to increase our knowledge and understanding of the geology, petroleum prospect and potentials of the Chad Basin by establishing the geothermal gradient of the basin.
Zones with potential of hot groundwater were identified around same boreholes for future evaluation.
Key words: Geothermal gradient, groundwater, N'Djamena region, Chad Republic.

INTRODUCTION

The geothermal gradient is the change in temperature with respect to change in depth in the earth. The gradient depends on the heat flow in the region, which, in turn, is related to the thermal conductivity of the rock.

The purpose of this paper is to evaluate geothermal gradient and groundwater temperature in the part of Chad Republic, which constitutes a part of Chad Basin. The identification of "cool or warm" zones as well as the possibility of geothermal resources development could derive from this evaluation.

For the purpose of drilling oil, information on temperatures in the basin will be needed. This paper is also written to produce information to geologists who may like to know temperatures optimal for oil, who may want to construct maps of temperatures, who may also want to know depth to temperature of natural cracking, below which no liquid hydrocarbons are expected.

For selection of temperature-resistant drilling fluid, for designing cementation of casing, for packer setting and for geophysical logging, drilling Engineer may need to know depth of critical temperature in odder to manage the risk. This paper is therefore enlightening those questions for drilling Engineer who, especially for deep drilling, may need to know expected temperature.

Study Area.

N'Djaména sheet ND-33-IV is situated mid way between the northern and southern parts of Chad at the extreme west of the country. It is located between latitude 12^o and 13^0 N and longitude 15^o and 16^0 E. The present study area constitutes a part of the sheet and located between latitude 12^{o}15' and 12^{o}65' N and longitude 15^o 15' and 15^{o}40' E (Fig 1). The terrain is flat and shows progressive sloping towards Lake Chad. The study area has a number of trunks roads linking it to the neighbouring sub prefecture and the neighbouring country Cameroon. Some few roads and footpaths link the town to surrounding cantons and villages.

Climatically, the city has a tropical climate characterized by two seasons. A wet season from June to September with a maximum rain in August, annual rainfall of about 500 mm, and the temperature varies between 20^{o}C and 25^{o}C and a dry season characterized by a dry wind coming from east from October to May. Maximum temperature frequently rises above 40ºC in dry season. In terms of its drainage and relief, N'Djaména and its environs areas are generally flat with an altitude observed in Massenya locater near N'Djamena of about 330 m, with an average of 320 m.

Geology of the area

The studied area covers a great part of the Chad Basin. Therefore the geological description of the area will focus also on some aspect of the geology of Chad as a country and also Lake Chad Basin. The Geology of Chad Republic is made of:

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- Crystalline rocks and granitoids which constitutes the Precambrian basement.
- Sediments covering the platform
- Recent and sub-recent volcano

The basement complex outcrop essentially in the massifs located at the border of Chad Republic: Tibesti, Ouaddai, Guera, Mayo-Kebbi and Baibokoum or Yade.

Sedimentary rocks occupy the major part of Chad republic. Volcanic rocks spread essentially in Tibesti and the entire massif of the basement and near Lake Chad

Precambrian represented by various metamorphic rocks which the only hydrogeological interest is their general characteristics of impermeability in the absence of cracks. These rocks usually called basement complex form the impermeable zone to sedimentary formation overlying them.

Metamorphic rocks outcrop also in the central massif of Chad Republic. This massif is located in the central of Chad Basin with a height of 1613 m.

During the middle cretaceous, sediments of continental facies were deposited and some outcrop can be shown around Lake Chad Basin and deep in the centre of the Basin They represent sandstones and clayey formation of continental intercalaire.

Continental terminal formations are essentially made up of sand, sometimes, sandstones, clays and laterite. They have been found during the exploration of water in the Chad Basin and they have been covered by recent depositions, they equally extend in Sudan, Eastern part of Niger, and Northern part of Nigeria.

Tertiary Formation represents about 88% of surface area of Chad Republic. Most part of Chad Basin less studies was recently mapped by geologists, most especially tertiary and quaternary terrain (After Kusnir, 1993).

Eolian sedimentation is itself the cause of depositions, whereas winds have changed fluvial sandy formations to produce a sandy landscape frequent in the northern part of the country (Gerard, 1958)

Pliocene or end of tertiary is marked in Chad Basin by a very large lacustrine extension provoking a clayey sedimentation rarely interrupted with slight white sand and especially by the abundance of diatom towards the upper part. These clays are hydraulically very important because they separate the lower sandy layer, product of Continental Terminal.

Pliocene formations are largely spread in Chad Basin, but covered by Quaternary depositions of about 10 m thick. Lower Pliocene deposits are composed of sand and the thickness range between 80 to 90 m. They are discordant on the continental terminal and made up partly of Continental Terminal erosion. Upper and Middle Pliocene are essentially clayey and intercalated by sand and the thickness reaches 300 m.

Sediments deposits of Quaternary Period occupy almost the centre of the Basin and cover previous formations. The formations are of continental origin and range between sand and clay according to the climatic conditions and tectonic movements, (Bardeau, 1956)

By maintaining the continental lacustrine characteristics of the landscape, the Quaternary can differentiate itself by successful regressions and transgression of Lake Chad. The limit between Quaternary Pliocene is not exact; it is likely that lake fluctuation has already affected the upper part of Pliocene.

MATERIALS AND METHODS

This study involves the establishment of geothermal gradient map. The temperature data for this study are of tow types. They include data on mean annual ground surface temperature, collected from the direction of meteorology and geological research (DREM), and the second is the data of groundwater temperatures measured at the end of the pumping test. The second set of data is obtained from the ministry of water and environment. Temperature data were taken over a period of time extending from 1997 to 2007.

The average of daily minimum and daily maximum temperatures added for a period of one year and divided by the number of days in that year represents the average surface temperature for such year. The mean of such values when added for each year over a period of about 10 years depending on the number of years of daily temperature record available, represents the mean annual ground surface temperature.

Temperatures of groundwater temperature from various boreholes tapping water at different depth in the Quaternary aquifer were provided.

The data of groundwater temperature in each of boreholes together with the depth to its mid-screen position, as well as the mean annual ground surface temperature at the borehole site were substituted into a linear regression equation to calculate the geothermal gradient for each borehole. The gradient obtained was used to prepare the map of geothermal gradient in N'Djamena region. Also by substituting the geothermal gradient in each borehole and the mean annual surface temperature at the borehole site in the linear regression equation, temperatures at various depths in the Quaternary sediments were obtained for each borehole location on the basis of which the subsurface temperature map were produced. The method is based on the concept of uniform increase of temperature with depth, that is geothermal gradient tends to be linear in a vertical borehole penetrating a horizontally layered sequence of formations with repletion in lithology. This is represented by linear regression equation combining surface temperature and groundwater temperature measured during pumping test.

Principle of the method

The groundwater temperature measured in the study area after sufficient time of pumping test could at least be close to bottom- hole temperature. It can be noticed that temperature of water after pumping it to the ground surface is lower than in aquifer and the resulting geothermal gradient will tend to appear lower than the true geothermal gradient. But with a long pumping, coupled with high rate of pumping, cooling may be reduced.

The mean annual ground surface temperature at the borehole site on Y-axis is plotted against the zero position on the X-axis representing the well head. The groundwater temperature T on the Y-axis plotted against the mid-screen position were then joint together with a straight line as illustrated in figure (2)

This technique assumes a uniform increase of temperature with depth. The equation,

$T_D = 0.01GxD + T_S$ …………………………………………………………. (1)

T_D= Groundwater temperature measured during pumping test in ^0C

G= Geothermal gradient in the borehole ($^0C/100$ m)

D= Depth to the mid-screen (m)

T_S= Mean annual Stevenson screen surface temperature (^0C) is the basic linear regression equation used in the prevent study to express mathematically the uniform increase of temperature with depth.

There are three possible sources of errors by analyzing this equation as mentioned by Schoeneich and Askira (1987) during their study. The first refers to the cooling of the water while it ascends, during the pumping, from the screen to the surface. Although this source of error cannot be expressed quantitavely, it is however likely that after a sufficient long pumping the cooling will be considerably reduced.

The second source of error is the value "D" observed in the equation, water entering the borehole through bottom to the top of aquifer, and as well on the position of the section of screen.

The third source of error is that as it can be seen from the geothermal logs of oil wells in similar structural condition in other parts of the world, geothermal gradient tends to be higher in upper most, superficial section of the borehole (Schoeneich, 1973)

Calculation of Geothermal Gradients

From the equation below, the geothermal gradient are computed.

From equation (1)

$G = ((T_D - T_S)/D) \times 100$ ……………………………………… (2)

Making G the subject of the equation

Example of geothermal gradient temperature in borehole FN^0 13

In borehole number FN^{0}13 the depth from the surface to the mid screen position is 54.50 m the water temperature is 30^{0}C and the mean annual surface temperature for that location is 28.98^{0}C therefore.

$$G = \frac{(90- 28.98) \times 100}{54.50} = 1.8715^0C/100\ m$$

In borehole number FN^{0}24 the depth from the surface to the mid screen position is 60.25 m the water temperature is 30^{0}C and the mean annual surface temperature for that location is 28.98^{0}C

$$G = \frac{(30- 28.98) \times 100}{60.25} = 1.6929^0C/100\ m$$

In borehole number FN^{0}30 the depth from the surface to the mid screen position is 30.30 m the water temperature is 30^{0}C and the mean annual surface temperature for that location is 28.98^{0}C

$$G = \frac{(30- 28.98) \times 100}{30.30} = 3.3663^0C/100\ m$$

RESULTS AND DISCUSSION

Using the procedure demonstrated in the methodology, the geothermal gradients of selected boreholes are calculated (Table1).

Geothermal gradients computed from the equation above range from 1.6929^{0}C/100 m to 8.3817^{0}C/100 m.

Temperature at 500 m, 1000 m and 1500 m below ground level vary respectively as follow. In the first case it varies from 37.44^{0}C to 70.885^{0}C, in the second temperature are between 45.9^{0}C and 112.79 ^{0}C and the third temperature varies between 54.36 0C and 154.695^{0}C. These are shown on Table 2. Anomalies are observed on Figure (3). The three curves show a similitude.

The peak of this geothermal anomaly is marked by the geothermal gradient 8.3817^{o}C/100 m around borehole FN^{0}42 (Fig.4).Two other important peaks are located in borehole FN^{0}12 and borehole FN^{0}34. These points shows warm anomaly observed on figure (4). While in boreholes FN^{0}54, FN^{0}25, the geothermal is low, observed on the figure, this is the cool anomaly. It will be therefore useful in assessing the geothermal potential of the area, in understanding more about the geology and structure of the basin as well as the general hydrogeology especially groundwater flow velocities and artesian water flow.

The high geothermal gradients in the basin indicate the possibility of having geothermal reservoirs at deeper levels in the sediments especially within the geothermal anomaly. This is because such geothermal gradient in similar shallow boreholes (15 to 150 meters deep) has led to the discovery of most economically productive geothermal reservoirs (Lovering and Geods, 1963; Burgassi et al, 1979; Jones, 1970; Comb and Rex 1971).

The implication of this is the economic geothermal temperatures for conventional power (electricity) generation (160-200^{0}C) will not be attained in the basin except the thermal regime within granitic rock below the sediments is high. However at depths generally deeper than 500 m in the basin, groundwater temperatures above 70.885^{0}C will be encountered. It could therefore be developed for the uses such as domestic hot water supply and for lower temperature refrigeration (50-70^{0}C). The energy could be utilized by sinking several thermal wells to abstract the thermal energy.

Among the main uses of geothermal energy including space heating, agriculture and husbandry, industrial and electricity, only electricity generation could be more interesting for the country if available. This is because, space heating, alimentation of greenhouses is not needed in the present climate condition of the country (Sahel)

Table1 Geothermal Gradient temperature

S/N	Borehole number	Longitude	Latitude	Geothermal Gradient ^{0}C/100 m	Depths at 100^{o}C
1	FN^{0}42	15^{0}05'30’’	12^{0}55’00’’	8.3817	847.49 m
2	FN^{0}41	15^{0}05’30’’	12^{0}55’00’’	7.8906	900.05 m
3	FN^{0}14	15^{0}05’40’’	12^{0}22’30’’	5.6448	1258.149 m
4	FN^{0}52	15^{0}34’20’’	12^{0}56’00’’	5.7062	1244.611 m
5	FN^{0}54	15^{0}39’30’’	12^{0}58’30’’	3.1875	2228.078 m
6	FN^{0}50	15^{0}29’00’’	12^{0}53’50’’	5.4594	1300.978 m
7	FN^{0}38	15^{0}33’10’’	12^{0}54’40’’	5.7714	1230.550 m
8	FN^{0}49	15^{0}24’50’’	12^{0}50’50’’	5.2467	1353.612 m
9	FN^{0}12	15^{0}07’15’’	12^{0}22’15’’	6.3578	1117.053 m
10	FN^0 55	15^{0}44’00’’	12^{0}59’40’’	5.9411	1195.401 m
11	FN^{0}53	15^{0}36’20’’	12^{0}57’10’’	3.1875	2228.078 m
12	FN^{0}25	15^{0}34’10’’	12^{0}40’40’’	1.7816	3986.304 m
13	FN^{0}2	15^{0}02’50’’	12^{0}10’50’’	2.3776	3986.304 m
14	FN^{0}51	15^{0}33’00’’	12^{0}55’00’’	3.2535	2228.078 m
15	FN^{0}34	15^{0}50’30’’	12^{0}57’50’’	7.9473	893.636 m
16	FN^{0}43	15^{0}58’10’’	12^{0}52’20’’	6.1064	1163.042 m
17	FN^{0}30	15^{0}34’30’’	12^{0}59’40’’	3.3663	2109.734 m
18	FN^{0}24	15^{0}34’10’’	12^{0}40’40’’	1.6929	4195.168 m
19	FN^{0}13	15^{0}02’40’’	12^{0}23’40’’	1.8715	3794.816 m

Table 2: Temperature at 500 m, 1000 m, and 1500 m below ground level

S/N	Borehole number	Longitude	Latitude	Temperature at depth of 500 m (^{0}C)	Temperature at depth of 1000 m (^{0}C)	Temperature at depth of 1500 m (^{0}C)
1	FN^{0}42	15^{0}05'30’’	12^{0}55’00’’	70.885	112.79	154.695
2	FN^{0}41	15^{0}05’30’’	12^{0}55’00’’	68.43	107.88	147.33
3	FN^{0}14	15^{0}05’40’’	12^{0}22’30’’	57.2	85.42	113.64
4	FN^{0}52	15^{0}34’20’’	12^{0}56’00’’	57.51	86.04	114.57
5	FN^{0}54	15^{0}39’30’’	12^{0}58’30’’	44.915	60.85	76.785
6	FN^{0}50	15^{0}29’00’’	12^{0}53’50’’	56.275	83.57	110.865
7	FN^{0}38	15^{0}33’10’’	12^{0}54’40’’	57.83	86.44	115.545
8	FN^{0}49	15^{0}24’50’’	12^{0}50’50’’	55.21	81.44	107.67
9	FN^{0}12	15^{0}07’15’’	12^{0}22’15’’	60.765	92.55	124.335
10	FN^0 55	15^{0}44’00’’	12^{0}59’40’’	58.685	88.39	118.095
11	FN^{0}53	15^{0}36’20’’	12^{0}57’10’’	44.915	60.85	76.785
12	FN^{0}25	15^{0}34’10’’	12^{0}40’40’’	37.885	46.79	55.695
13	FN^{0}2	15^{0}02’50’’	12^{0}10’50’’	40.865	52.75	64.635
14	FN^{0}51	15^{0}33’00’’	12^{0}55’00’’	45.245	61.51	77.775
15	FN^{0}34	15^{0}50’30’’	12^{0}57’50’’	68.715	108.45	148.185
16	FN^{0}43	15^{0}58’10’’	12^{0}52’20’’	59.51	90.04	120.57
17	FN^{0}30	15^{0}34’30’’	12^{0}59’40’’	45.81	62.64	79.47
18	FN^{0}24	15^{0}34’10’’	12^{0}40’40’’	37.44	45.9	54.36
19	FN^{0}13	15^{0}02’40’’	12^{0}23’40’’	38.335	47.69	57.045

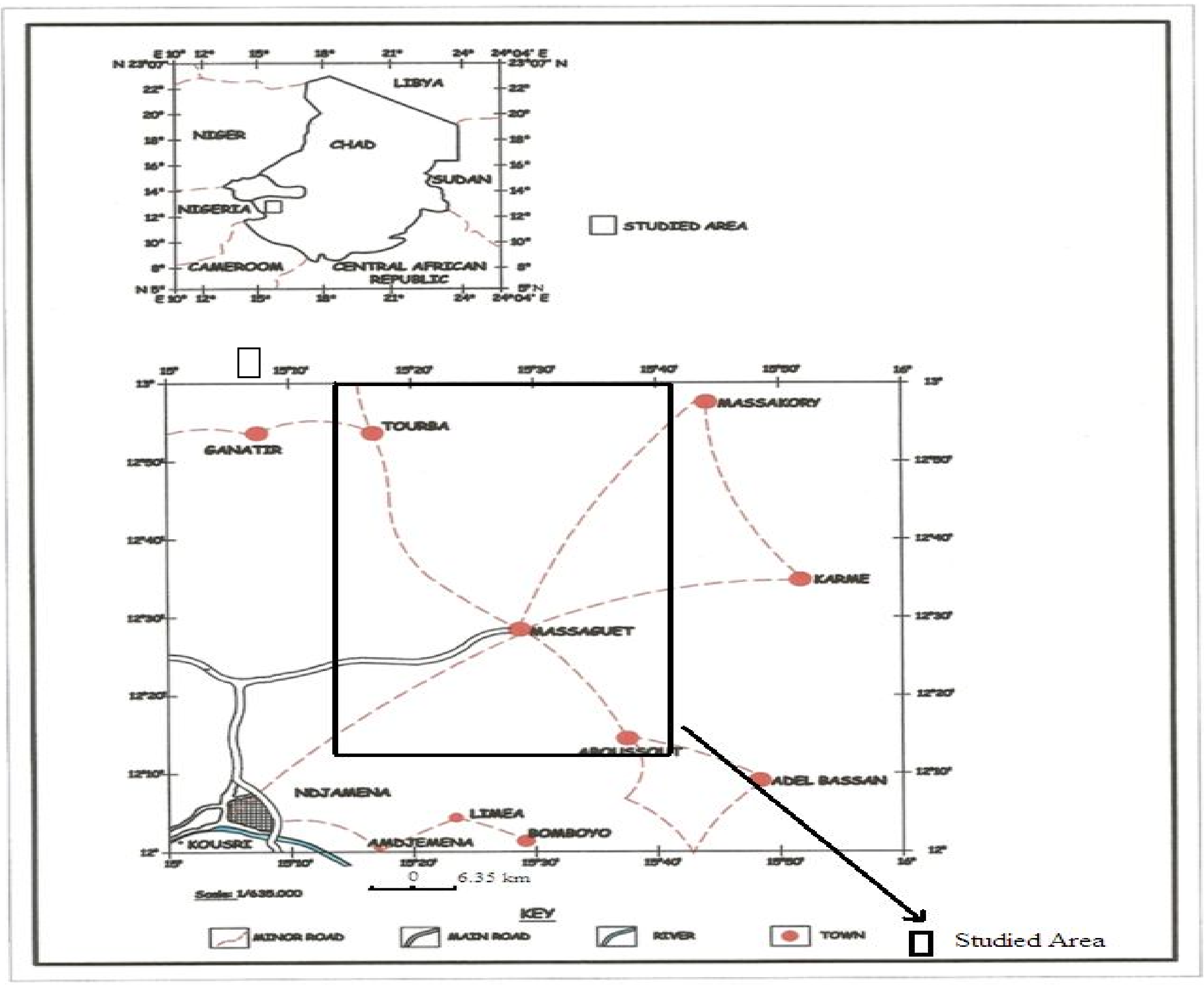

Figure: 1 Location Map

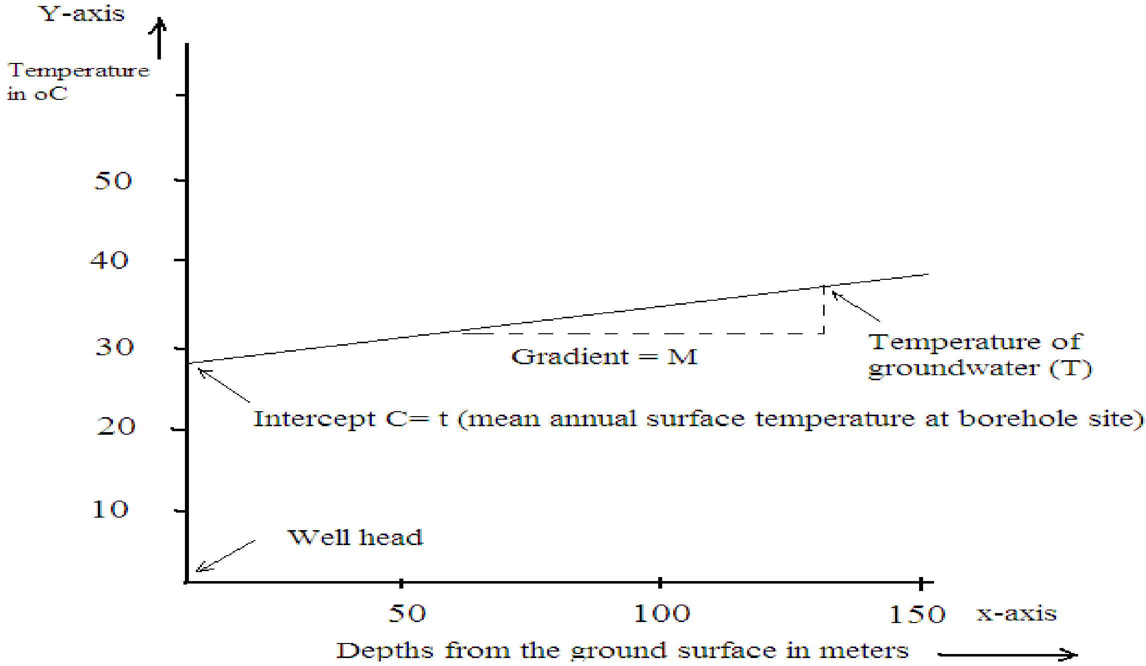

Figure 2: A graph of temperature against depth showing the geothermal gradient profile with intercept on the Y-axis.

Temperature

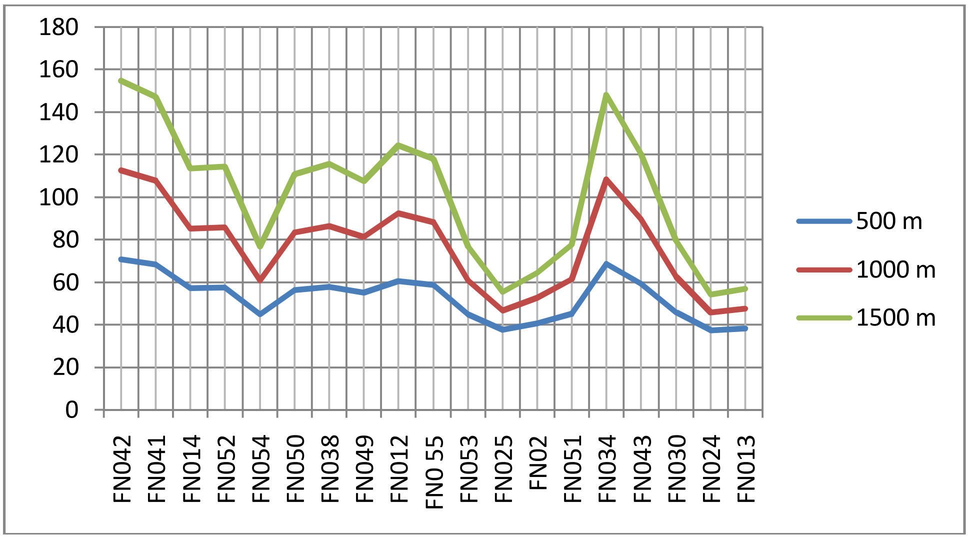

Figure 3: Temperature at 500 m1000 m and 1500 m below ground surface

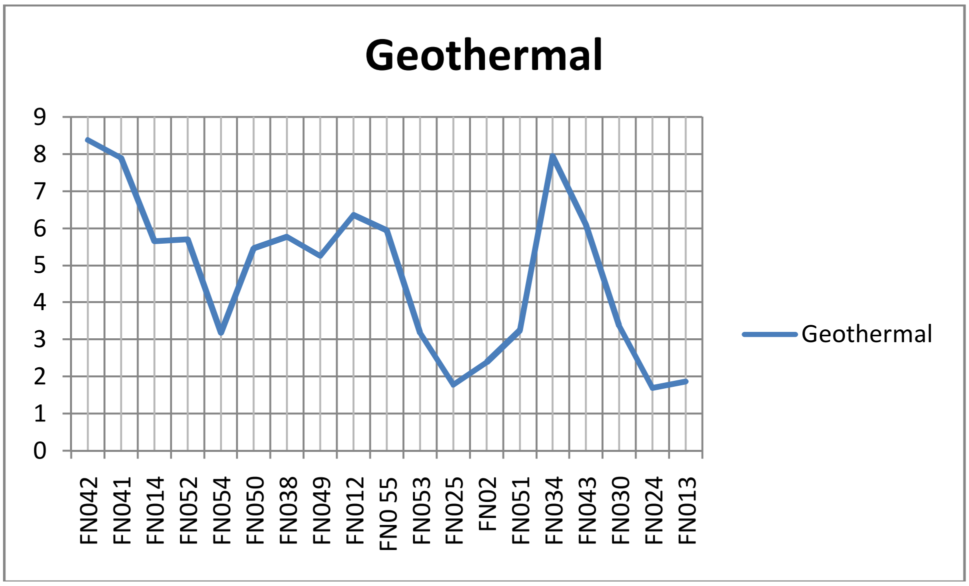

Figure 4: Geothermal gradient

Conclusion

Summing up, there is much need for the country to assess and evaluate all its energy resources potentialities so that an economically harnessable one can be selected.

The geothermal gradient values computed in this study vary from well to well; and a regional range of 1.6929^{0}C/100 m to 8.3817^{0}C/100 m. Due to the fact that oil or gas is yet to be found in commercial quantity in the Chadian sector of the Chad Basin do not rule out the possibility of having oil or gas reservoirs in this basin (Nwankno et al, 2009). No doubt the Chadian basins as a whole have been highly under explored probably because of the poor knowledge of their geology.

For effective planning, harnessing and management of the thermal resources of groundwater in the basin, it is necessary therefore to study the relationship between subsurface temperatures, borehole yield and spacing to ascertain the amount of water that can be safely drawn from a borehole or set of boreholes in the basin, to maintain a constant thermal water temperature for a long exploration period.

In terms of geothermal resource potential, the area may be considered as containing hot water deposits mostly along the anomalous zones. However, the high cost of deep drilling and the low cost of energy handicap its exploitation at least for now. Nevertheless, the existing temperatures could support other uses with low temperature requirements such as recreational field, domestic hot water support for towns and low temperature refrigeration.

ACKNOLEDGEMENT

We wish to thank Mr. Doudarial Moussa, coordinator of European Fun, in cooperation with the ministry of water and Environment as well as the Director of the Ministry without forgetting to appreciate the assistance of the staffs during this work.

REFERENCES

Bardeau, J. (1956) .Notice explicative sur la feuille de Fort- Lamy. Carte géologique des reconnaissances à l'échelle de 1/1000.000DMG AEF, Paris.

Burgassi, P.D., Carol, R. Ferrara, and Toro, B.(1970). Geothermal gradient and Heat flow in the Radicofart Region (East of monte Amiata Italy) Geothermic, secial Issue 2, v.2.Pt.1pp. 443-449.

Combs, J. and Rex, R.W. (1971). Geothermal investigation in the Imperial Valley of callifornia (abc). Geol. Surv.of Nigeria Bull. No 36

Gerard,G.(1958) Notice explicative de la carte géologique de l'A.E.P au 1/2000.000^{e} Paris Imp Topographique d'édition, 201p

Jones, B. (1948). Sedimentary Rocks of Sokoto Province. Bull. 18 Geol. Surv. Of Nigeria Kaduna 79pp.

Kusnir, I. (1993). Géologie, Ressources Minérales et Ressources en eau du Tchad. Travaux et document scientifiques du Tchad série connaissance du Tchad 1100p

Lovering, T.S. and Geode, H.D. (1963) Measuring geothermal Gradient in Drill holes less than 60 Feet Deep, East tintic District, Utah.US Geol.Surv.Bull. 1172, 48pp

Nwankwo, Cyril N; Ekin, Anthony s ; Nwosu, leonard I (2009) Estimation of heat flow variation in Chad Basin Nigeria. Journal of Applied sciences and environmental management, vol 13, no.1 March, 2009 PP73-80.

Schoeneich and Askia (1987). Geothermal outline of the Nigerian Part of the Lack Chad Basin Paper presented at the international Seminar on Water Resources of the Lake Chad Basin Management and convention in Chad Republic from 3nd to 8th june 1987

Schoeneich,K (1973).Hot groundwater in Poland nafta.v.XXI. No 8.pp301-358 (in Polish, English summary)