ISSN 2348 – 7968

TEMPERATURE CHARACTERISTICS OF BOREHOLES IN UMULOKPA AND ENVIRONS, ENUGU STATE, SOUTHEASTERN NIGERIA.

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Abstract

The study area is the only source of geothermal water in the southeastern Nigeria. The aim of the study was to determine the temperature characteristics of the surrounding rocks using bottom hole temperature logs obtained for boreholes.

A total of nine (9) existing boreholes were evaluated. The results show that discharge temperatures range from 29^0C to 49^0C while bottom hole temperatures vary from 29^0C to 32^0C in non-artesian wells and from 29^0C to 116.2^0C in artesian wells. Bottom hole temperatures tend to vary with depth. The highest bottom hole temperatures are in Umulokpa where there are geothermal springs and increase from east to west of the study area.

The elevated groundwater is as a result of heat transfer by rising artesian water due to great burial depth of the aquifer.

Keywords: *Geothermal water; Umulokpa; bottom hole temperature; artesian and aquifer*.

1. Introduction:

The energy needs of Nigeria were recently estimated to be about 14MWof electricity. This is to be generated mainly from gas turbines and hydroelectric dams but presently, the level of power generated is still below 5MW. According to Kurowska and Schoenich (2010) estimated that only about 40% of Nigerians can access electricity. This means that about 60% of the populations have to seek for alternatives to meet their energy need. In recent times, solar and wind energy alternatives have been considered but cost and logistic considerations have limited their widespread use.

Geothermal energy is an option or alternative but is not well understood since the scientific community in the country is yet to study it in detail. It is generally believed that there are very few manifestations of geothermal energy in Nigeria and this may be responsible for the low level of interest. The most well known hot or warm spring in Nigeria is the Ikogosi springs in Ekiti which has temperatures that range from 34^0C to 38^0C. One other spring is known from the Yankari Games reserve in Bauchi State, Nigeria. There is also a warm spring near in Jos, Plateau State, Nigeria. The existence of these warm springs indicates that there must be some geothermal energy in the country. Mapping of geothermal conditions in the subsurface requires knowledge of geothermal gradients. Detailed estimation of heat flow characteristics for the different lithological provinces of Nigeria has never been carried out but good pioneering works by Verheijen and Aja- Kaiye (1979) gave an account of the Younger Granites of Jos while Nwachukwu (1976) and Onuoha and Ekine (1999) worked on heat flow of the Anambra basin or Southern Benue Trough. In all the studies carried out, the authors usually argue that the primary source of the heat in the subsurface is due to decay of radiogenic materials.

In southeastern Nigeria, Mmirioku (Hot water) “spring” in Umulokpa is a geothermal manifestation that has received little or no attention. Though the locals call it a spring, it was later found out that this was an artesian well drilled over 40 years earlier. Over the years, the artesian head has reduced so much till it is issuing from the ground surface as if it was a spring. The temperature range at the discharge point is between 39-49^0C but no attempt has been made to determine the source of the heat before now.

The aim of this investigation is to find out the temperature characteristics of boreholes in the area by estimating bottom hole temperatures. This would provide a clear picture about the geothermal gradients in the area and hence contribute information about the source of the heat in the groundwater.

2. The Study Area:

Figure 1 shows the geologic map of the study area. Umulokpa and environs is bounded by latitudes 6^0 23^l N and 6^0 35^l N and longitudes 7^0 04^l E and 7^0 26^l E with an extent of 624.22sqkm. The study area encompasses Umulokpa, Amandim Olo, Ibite-Olo, Oguluogu Iwollo-Oghe, Eke and Ninth mile. Umulokpa is an important rural community in Uzo-Uwani local government area of Enugu state, Nigeria with a population of about 95, 200 people. It is bordered by Umumbo in the north, Umerum in the west, Adaba in the east and Iwollo Oghe in the south. Umulokpa is the headquarter of Uzo-uwani Local Government Area.

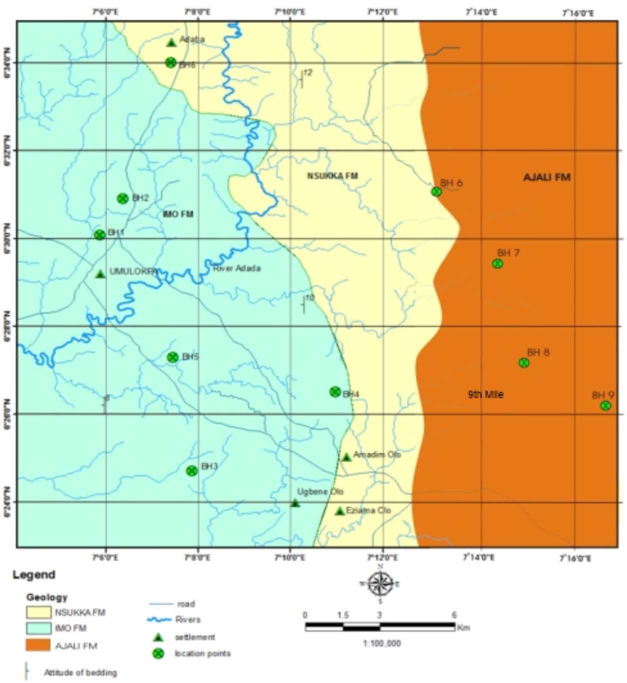

Figure 1; The geologic map of the study area.

(i.) Topography and Drainage:

Figure 2 shows the physiographic provinces of Nsukka. The area has two major types of landforms which consists of a high relief of central zone with undulating hills and ridges (Nsukka plateau) and lowland area (Anambra plains) according to Ofomata (1978). The high relief zone is geologically associated with the outcrops of Ajali and Nsukka Formations while the western lowland zone is associated with the outcrops of Imo Formation. The area is drained by Duu River popularly known as Adada River and its tributaries. The Adada River is a major tributary of River Niger.

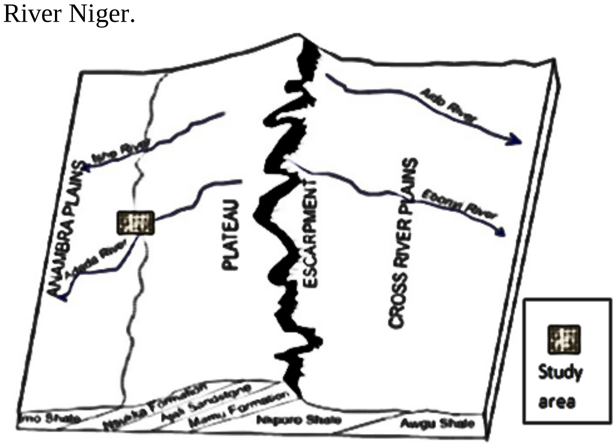

Figure 2; The physiographic provinces of Nsukka (adapted from Ofomata, 1978 and Ozoko, 2015).

(ii.) Climate and vegetation:

The study area has two distinct seasons every year. The rainy season runs from April to October. These months have an average of about 8-21% of the total annual rainfall in a year per month. The rest of the months in the year were classified as dry season months because the average rainfalls of each of months have less than 6% of the annual rainfall. It has 28^0C as average temperature. Therefore, the region is characterized as humid tropical climate and part of the tropical rainforest/Guinea Savannah belt of Nigeria (Iloeje, 1995).

(iii.) Geology:

The study area is underlain by three geologic formations, from the oldest; Ajali, Nsukka and Imo Formations. All the three formations are part of the Anambra sedimentary basin. The Anambra basin developed during cretaceous times at the southeastern extreme of the Benue trough. Its west is bounded by the Precambrian basement rocks of western Nigeria while its eastern boundary was the Abakaliki Anticlinorium. Onuoha (1986) and Onuoha and Ekine (1999) worked on the thermal history of this basin but no specific work on Umulokpa.

Lithologically, the oldest formation in the study area is the Ajali Formation (maastrichtian) which consists of medium to coarse grained sandstones, lenticular shales, beds of grits and pebbles. It dips 3^0-6^0 NW in the study area. It is comformably overlain by Nsukka Formation which is Danian in age, and consists of an alternating succession of sandstones, dark shales and sandy- shales. In the study area, it dips 4^0-8^0 in the NW direction. It is overlain by Imo Formation which is paleocene in age. The formation lacks good exposures in the study area but limited exposures were found at the bank of Adogwu stream. The unit consists of basal shales that grade into mudstone upwards and thick bands of ironstone lodes. It dips 3^0-5^0 NW direction

3. Methodology

Temperature readings of the various boreholes were taken with the aid of an alcohol thermometer. The thermometer was inserted at the point of discharge and the readings were designated as discharge temperatures. Borehole logs were used to determine the depth profiles of the boreholes. The average annual surface temperature was taken from previous works in the region. The type of flow (whether artesian or not) in each boreholes was noted. The equation of Husson et al (2008) was used to estimate temperature gradients and botton hole temperatures. All the data were then used to estimate geothermal gradients in the area.

The thermal regime in Umulokpa and environs was characterized using the true estimates of static formation temperatures derived from bottom hole temperature data. The bottom hole temperatures were sourced from logs of CSDP and ADB assisted boreholes at Olo/Umulokpa Water Scheme. Bottom hole temperatures were used to

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 2, February 2016.
www.ijiset.com
ISSN 2348 – 7968

estimate formation temperatures because none of the boreholes had continues temperature logs. The equation of Husson et al (2008) was the used to calculate the temperature change for the area. This is given by equation 1.

$$\Delta T = T_{bht} - T_{dt} \qquad (1)$$

Where ΔT = Temperature change in ^{0}C
T = Bottom hole temperature in ^{0}C
TDT = Discharge temperature in ^{0}C

Table 1. Temperature characteristics of the boreholes

S/N	Locations Name	GPS Locations	$\Delta T = T_b - T_s$ (^{0}C)	10%,ΔT (^{o}C)	Discharge Temp. (^{0}C)	BHT (^{0}C)	Depth (M)	Type of Flow
1.	Unity Pri. Sch Akiyi Borehole	$N6^{0}30^{1}05.5^{11}$ $E7^{0}05^{1}54.6^{11}$	21	2.1	49	116.2	289.57	Artesian
2.	Mmirioku Akiyi Umulokpa	$N6^{0}30^{1}66.6^{11}$ $E7^{0}06^{1}50.8^{11}$	17	1.7	45	96	274.32	Artesian
3.	Mmirioku at Oguluogu	$N6^{0}24^{1}97.1^{11}$ $E7^{0}08^{1}86.1^{11}$	19	1.9	47	98.3	252.984	Artesian
4.	Olo/Umulokp a Water scheme	$N6^{0}26^{1}86.1^{11}$ $E7^{0}10^{1}70.6^{11}$	-2	0.2	26	30.8	234.939	Non Artesian
5.	Ibite-Olo water Scheme	$N6^{0}27^{1}13.3^{11}$ $E7^{0}07^{1}49.2^{11}$	-3	0.3	25	32	213.36	Non Artesian
6.	Borehole at Afor Iwollo Oghe	$N6^{0}26^{1}34.2^{11}$ $E7^{0}18^{1}14.1^{11}$	-3	0.3	25	32	213.36	Non Artesian
7.	Borehole at Eke Junction	$N6^{0}26^{1}42.1^{11}$ $E7^{0}22^{1}06.4^{11}$	-3	0.3	25	30.5	167.64	Non Artesian
8.	Borehole at Abbor in Udi	$N6^{0}25^{1}58.6^{11}$ $E7^{0}24^{1}22.7^{11}$	-3	0.3	25	29.99	152.4	Non Artesian
9.	Abba father at 9^{th} Mile	$N6^{0}25^{1}52.3^{11}$ $E7^{0}25^{1}10.3^{11}$	-3	0.3	25	29	121.92	Non Artesian

4. Results and discussion

Table 1. above shows the temperature characteristics of the boreholes in the study area. Temperature change, ΔT varies from -3^{0}C to 21^{0}C while the discharge temperatures (i.e temperature at the point of water issuance at the boreholes) range from 25^{0}C to 49^{0}C. Bottom hole temperatures (BHT) go from 29^{0}C to 116.2^{0}C. Elevated bottom hole temperatures occur in the artesian wells while “normal” BHT values range from 29^{0}C to 32^{0}C in non-artesian wells. The depth of the boreholes range from 121.921 to 289 meters. Artesian conditions occur in boreholes that are quite deep (from 252.984 to 289.57meters deep). Figure 3 and 4 gives the vertical temperature distributions within each of the boreholes. The temperature intensity is depicted in the form and number of pointed arrows. Borehole 1-3 indicates maximum temperature intensities meaning high bottom hole temperatures. Some of the boreholes show very normal temperature distribution.

IJISET - International Journal of Innovative Science, Engineering & Technology, Vol. 3 Issue 2, February 2016.
www.ijiset.com
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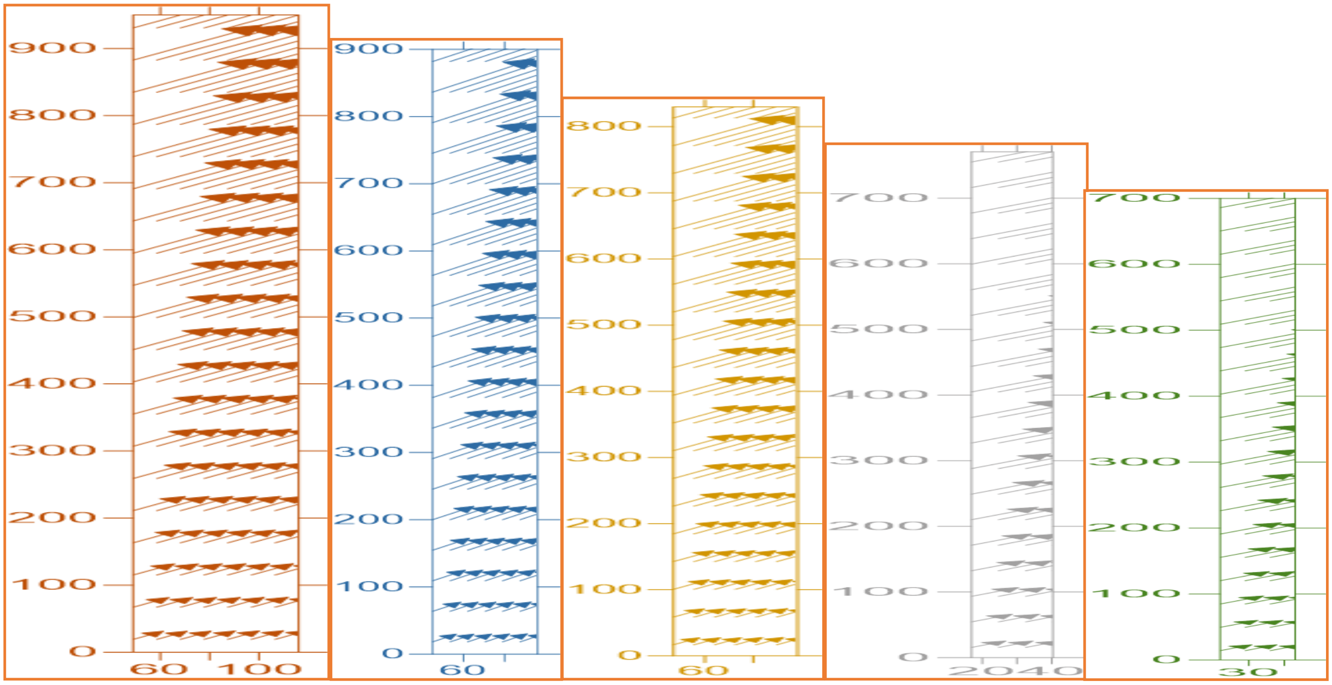
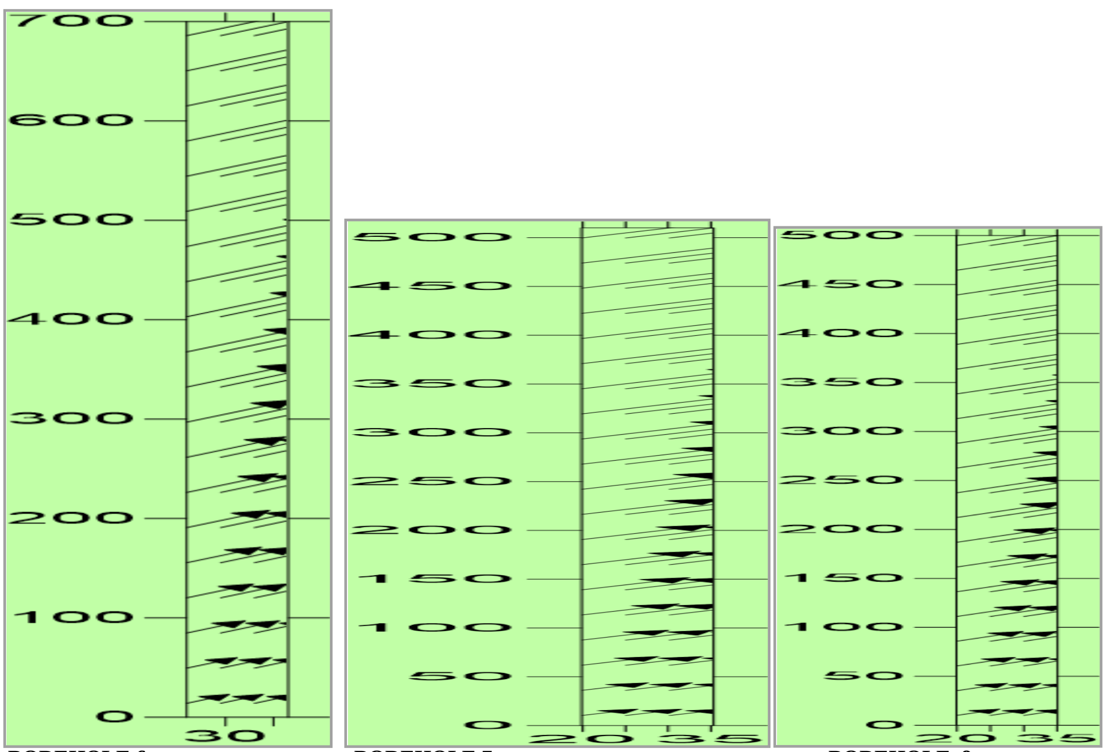


BOREHOLE. 1 BOREHOLE. 2 BOREHOLE. 3 BOREHOLE. 4 BOREHOLE. 5

Figure 3. Vertical temperature profile of the boreholes in the Umulokpa area.



BOREHOLE.6 BOREHOLE 7 BOREHOLE. 8

Figure 4. Vertical temperature profile of the boreholes around 9th mile rea.

Figure 5 is a plot of temperature versus depth. The temperature versus depth plots generally shows that the bottom hole temperature varies with depth. Increases in bottom temperature were observed at borehole 1-3 where

ISSN 2348 – 7968

the temperature ranges from 96^0C to 116.2^0C at Oguluogu and Umulokpa within the section of Imo shale. From Ibite-Olo, Amadim Olo, Iwollo-Oghe, Eke and Ninth Mile Corner the range is 25^0C to 32^0C. This indicates that the Umulokpa area has higher bottom hole temperature (BHT) than the Ninth mile area.

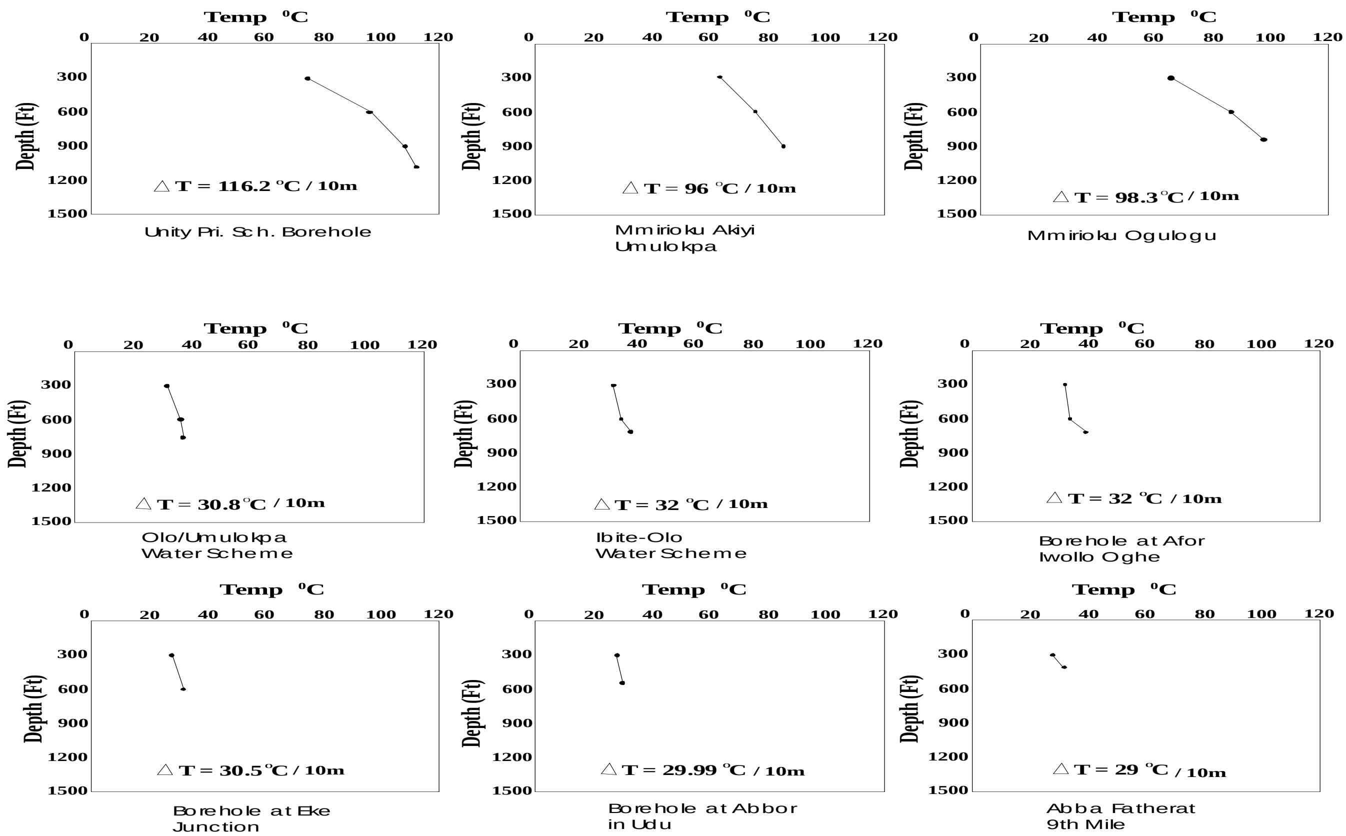


Figure 5. Temperature – depth plot for the boreholes.

A careful examination of the results obtained from this study indicate that elevated bottom hole temperatures seem to increase from east to west in the area. The highest values coincide with zones of artesian groundwater flow where the aquifers are capped by thick members of Imo Formation.

According to Habermehl and Pestov (2002), the high groundwater temperatures (30^0C to 100^0C) in the Great Artesian Basin of Australia is caused by the heat flow arising from the burial depth of aquifers decaying uranium and thorium, and vertical groundwater flow along geological faults. There were no known sources of geothermal energy in the study area.

Erkan et al (2007) found that hot springs in the Alaska geothermal system of North America are meteoric in origin but developed high temperature due to its depth of circulation and contact with high background soil temperature at depth.

It is the opinion of the authors of this paper that the high groundwater temperatures in the study area are due to the great depth of the burial aquifers at Umulokpa. Onuoha and Ekine (1999) showed that the study area has high geothermal gradients. The implication is that the elevated groundwater temperatures occurs as the rising artesian water transfers heat from the high bottom hole temperature zones to the surface. It should be noted that the elevated temperatures occur mainly where there are artesian wells or springs. This conclusion is similar to the findings of Habermehl and Pestov (2002) and Erkan et al (2007).

5. Conclusion

The elevated groundwater temperatures at Umulokpa in Enugu State, Southeastern Nigeria is unique. This is the only known location in southeastern Nigeria with such temperatures. It was found that the temperature increase goes from east to west in the study area and coincides with great burial depth of the aquifers, high geothermal gradient and artesian conditions. The area does not have any evidence of past or present volcanic activities thus ruling out any deep-seated magmatic geothermal sources. The geology consists of shales and medium to coarse grained sandstones. The elevated groundwater temperatures is caused by heat transfer by deep artesian groundwaters receiving heat to the high geothermal gradients in the subsurface.

ISSN 2348 – 7968

It will be necessary to extensively sample the hot water in order to establish their geochemical characteristics and possibly use geothermometer for further characterize the heat flow in the region.

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