Heat Flow Measurement In Dhamar Prospective Geothermal Field, Yemen

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Keywords: Al-Lisi Geothermal field, temperature heat flow, temperature gradient.

ABSTRACT

This research presents the thermal gradient and heat flow in the Dhamar Quaternary Volcanic Field, where fumaroles, hot springs, as well as hot well waters and domestic wells are distributed, throughout an area exceeding 200km^2. Field data from shallow holes temperatures in the Alisis Field are used to interpret conduction, with the aim of estimating the amount of heat being lost naturally. 1291MWt is lost naturally by conductive heat flow from the field of Al-lisi. Results available from the domestic wells indicate that thermal gradient varies from 41 ºC/km to more than 250 ºC/km.

1. INTRODUCTION

Yemen is located in the Arabian Active Tectonic Plates, on top of the Afar hot mantle plume, faulting results from tectonic activity (Coulié et al., 2003); (Coulié et al., 2003). Field trips were carried out in May 2012, to evaluate the amount of heat being lost naturally from the Al-Lisi prospect field, where the hot rocks were brought close to the surface through the faults that create water channels paths - when water seeps down, is heated at depths and rises due to pressure difference - and heat loss features.

The most promising geothermal area is located in the central part of the Yemen Volcanic Plateau (Yemen Volcanic Plateau =YVP), centred around the city of Dhamar (Minissale et al., 2007). The Dhamar area has evidence of a promising geothermal field for producing electricity, since it was affected by volcanic activity in the 1980's (**Chiesa et al**., **1983).** Geothermal manifestations include fumaroles, hot grounds and hot wells related to the geothermal system below.

The Al-Lisi- Isbil geothermal field study was carried out by YGSMRB-Yemen in 1989. ELC, (1980-1982) **recommended** that, an exploration well for geothermal should be done. Simultaneously, an exploratory well for oil was drilled in 1988 by Exxon (Risabah-1) located 15km north of Dhamar and stopped at 1600m depth, where the temperature is 90 ºC.

2. GEOLOGY AND STRUCTURE OF STUDY AREA

Yemen, being within the area of central-western (about 50,000km^2) contains alkaline basalt trap series of Oligocene-Miocene, Yemen Trap Series (YTS), study area exposed Quaternary volcanic rocks, two recent rhyolitic volcanic cones near the village of Al Lisi. Tectonically, the most active areas in Yemen are located along the Gulf of Aden and the Red Sea (**Ghebreab**, **1998**), where the study area was affected by the main faults with the following direction: NW-SW and E-W fig (1) because of rifting of the Red Sea and the Gulf of Aden.

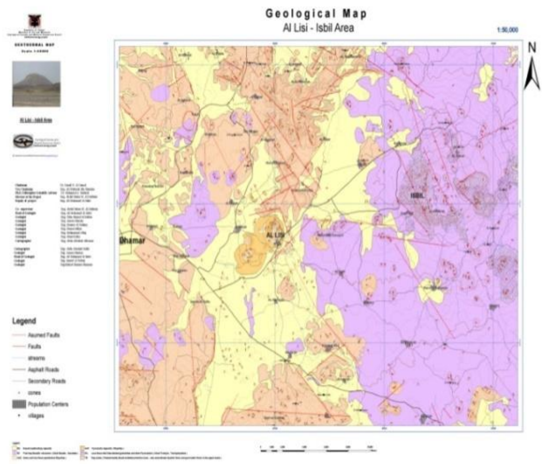


Figure 1: Al-lisi- Isbil Geological Map

3. TOOLS USED FOR HEAT LOSS MEASURMENTS AND METHEDOLOGY

The equipment used in the field include digital thermometer (probe), soil auger, metal rod, a portable Global Positioning System (Gps) and Geothermal Field Map. Heat loss method has used indirectly during surface exploration to evaluate the amount of heat being lost naturally from a prospect area.

Temperature results from 1m shallow holes are directly measured by using digital thermometer. Holes are drilled using 1-inch diameter spike and temperatures measured at the surface, at 50 cm and at 100 cm depths. Location of these is holes read from (GPS). The temperature increases more rapidly with depth, hence, higher heat flow, near to active fumaroles have been founded (Figure 2) on the NE flank and at the top of Al- lisi with temperatures ranging from 82 °C to 86 °C.

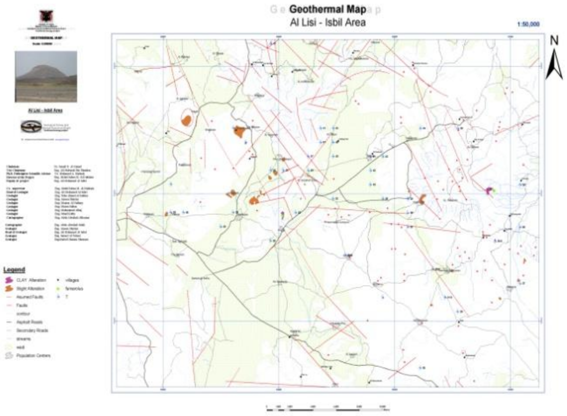


Figure 2: Al-lisi- Isbil Geothermal Field Map

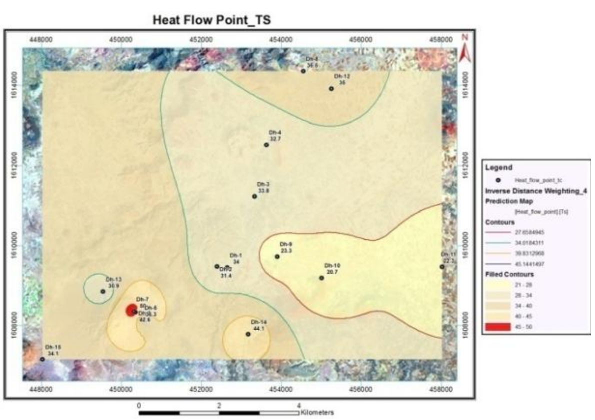
4. RESULTS AND ANALYSIS

Boreholes serve as gradient holes for temperature gradient computation results used to estimate geothermal reservoir temperatures. The prospect area is about 66845m^2. Heat flow measurement carried out in the area of the hot ground in the field of Al-Lisi using the following one dimensional heat conduction equation (1) is used to compute the heat flow of shallow holes, temperature gradients assuming that the soil's thermal conductivity is constant at 2 W/m °Cm. Average temperature gradient is computed and tabulated as shown in Table 1.

$$Q = Ak(dT/dy) \qquad (1)$$

Where Q, *A, k, dT, , dy,* are conductive heat flow (watts) , surface area of hot ground m^2, K (=2) : is thermal conductivity of rock

(W/m °C), and T: is temperature (°C) and y is depth (m).



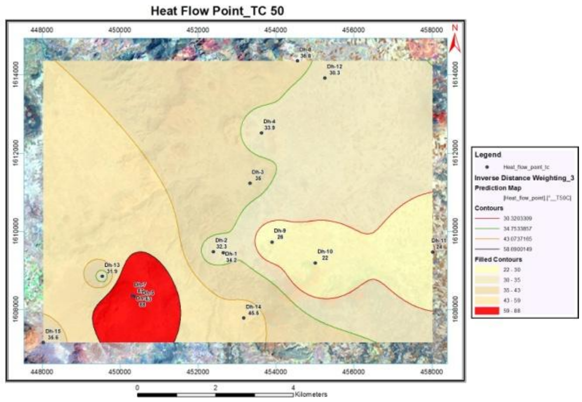
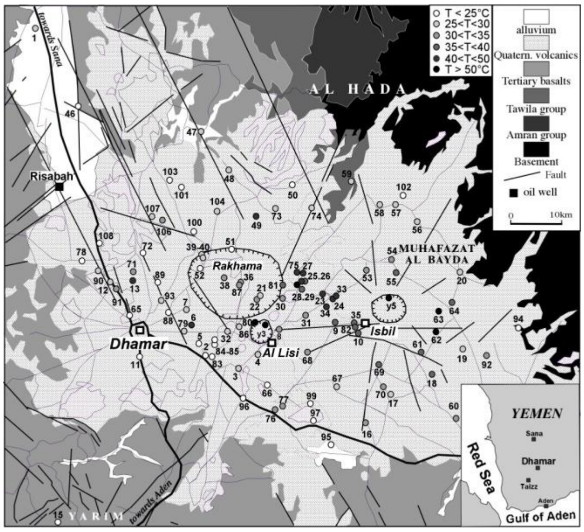


Figure 3: shows heat flow for Al-lisi Prospecting field from shallow holes

Thermally active area is estimated from 40 ºC isotherm at 0.5 m depth. Figure 3 shows borehole locations and mapped ground temperature at surface and 0.5 m depth. The shallow holes were drilled at an interval of 1-5km in the areas. Temperature gradient from shallow boreholes is indicated.

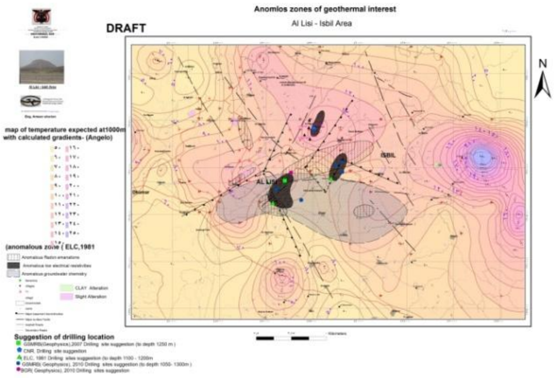
No.	Ts °C	T50 °C	T100 °C	Average (°C/m)
Dh-1	34	34.2	34.5	0.35
Dh- 2	31.4	32.3	33	1.25
Dh -3	33.8	35	35.4	1.4
4 - Dh	32.7	33.9	34.2	1.35
Dh- 5	36.3	63	69.1	29.75
Dh-6	42.6	88	89.2	46
Dh-7	50	87	89.5	38.25
Dh-8	36.5	36.8	37.1	0.45
Dh-9	23.3	26	28	3.7
Dh-10	20.7	22	23	1.8
Dh-11	22.3	24	24.2	1.8
Dh-12	30.9	31.9	32.5	1.3
Dh-13	44.1	45.5		1.75
Dh-14	34.1	35.6	36.2	1.8

Table 1: Sample calculations for Conductive heat transfer



5. BORE HOLE TEMPERATURES & THERMAL GRADIENTS

Boreholes drilled in the prospect area are good gradient holes for heat flow evaluation. In general, temperature increases with well depth. The highest measured temperature was 59 °C in well # 63 (Figure 4) whereas the lowest temperature was 21 °C in several wells (2, 15, 72, 94, 95, 100 and 103). Temperature gradients computed from selected boreholes varied from 41 to 370 °C/km



(Minissale et al.; 2007)

Figure 4: Heat flow for Al-lisi Prospecting field

Mean (°C/m)	Area M2	Heat Flow (MWt)
9.66	66845	1291

Figure 5: Anomalies zones for Al-lisi- Isbil geothermal field from bore hole

Thermal anomalies (Figure 5) calculated from most boreholes that have been drilled by the local people in the geothermal field of Al Lisi and the Isbil volcanoes, got a good agreement with the anomalies of heat flow by conduction.

6. DISCUSSION

Manifestations founded at the Al- Lisi Geothermal Field include hot grounds, altered grounds and fumaroles, which continuously transferred heat from the geothermal system underground to the surface, This heat is caused by conduction. The geothermal reservoirs might be the Jurassic permeable Amran limestone sequence and the overlying Cretaceous Tawila sandstone. Fluids derived from convective hydrothermal systems associated with the Al Lisi, the well-differentiated rhyolitic of most erupted Quaternary pyroclastics and lavas, suggest that the magma chambers might be shallow, that is,5-10km (Bardintzeff and McBirney, 2000). The thermal gradients shown in the heat flow results in A-Lisi geothermal field has a good agreement with the results reported by Angelo 2009 on domestic wells using geochemical thermo metrics equation. Whereas, the thermal anomalies associated with the Quaternary volcanic field were determined, by using the depth and temperature measurement and the samples water that gave reasonable geothermal gradient results, the depth of the wells was declared by the local people, This data wasn't accurate and so was adopted by comparing the average of the well depth and the water table to get reasonable data .

7. CONCLUSIONS

Total heat loss from the prospect area of Al- Lisi is about 1291 MWt. Conductive heat flow is mainly related to the hydrothermal system and is directed by the NW-SE and E-W fault zone as indicated by the heat loss features.

ACKNOWLEDGEMENTS

We would like to thank all the staff of YGP (Yemen Geothermal Project), special thanks goes to Dr. Minissale.

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