PROCEEDINGS, 43rd Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, February 12-14, 2018
SGP-TR-213

Various Geoscientific Investigations of Low-Enthalpy Geothermal Sites in the United Arab Emirates

H. SAIBI[1]

[1]Geology Department, College of Science, United Arab Emirates University, Al-Ain, P.O. Box. 15551, UAE

hakim.saibi@uaeu.ac.ae

Keywords: Geothermal, Remote Sensing, Hydrochemistry, Geothermometry, Magnetic, Inversion, Renewable Energy.

ABSTRACT

Many first geoscientific investigations have been carried out during 2017 at different low-enthalpy geothermal sites in the United Arab Emirates (UAE) country to understand and evaluate the geothermal resources.

Dense magnetic surveys were measured at three main geothermal springs: Green Mubazzarah (GM) and Ain Faidha (AF) in the Abu Dhabi Emirate as well as Ain Khatt (AK) located in the Ras Al Khaimah Emirate. These geophysical surveys indicated that the three hot springs are structurally controlled and a possible deep fractured geothermal system is located beneath these regions.

Hydrochemistry of sampled hot waters estimates the temperature of the geothermal reservoirs to be about 95-130 ^{o}C by using cation geothermometers. The temperature of the springs range from 31 ^{o}C to 50 ^{o}C.

Remote sensing studies estimate the total heat discharge from the three geothermal sites to be about 4530 MW.

All these geoscientific surveys will be used to construct a numerical model of the three sites and then possible future development of the renewable geothermal potential resources in the UAE.

1. INTRODUCTION

Several hot springs occur in and around the city of Al-Ain such as Mubazzarah and Ain Faidha (central-eastern region of the United Arab Emirates) and also in Ain Khatt (Ras El Khaimah Emirate, northeastern region of UAE). While these hot springs are local landmarks and known tourism destinations, no studies have examined their origin or potential for geothermal electricity production potential.

Here, geophysical (magnetic), hydrochemical and remote sensing results are presented for the three geothermal areas of UAE. The collected and interpreted geosciences data are the first-in-depth examination of the geothermal characteristics of the three geothermal areas.

Geologically, Mubazzarah geothermal area is located on the western flank of Hafit mountain, the only geological outcrop in the area. The Hafit mountain is composed of dolomite and limestone rocks. The Ain Faidha geothermal area is located 2 km west of Hafit mountain. Hydrochemical and isotopic studies suggested that the origin of groundwater is from the infiltration of rainwater along the Oman side of the mountain, where high elevated mountains exist. Figure 1 shows the geological map around the two geothermal fields. The geology of the aquifer is mainly carbonates. Mubazzarah and Ain Faidha are within a famous touristic area called Green Mubazzarah Park and Hot Springs.

Ain Khatt hot spring is located adjacent to the Hajar Mountains and the hot spring manifestations are inside the Golden Tulip Khatt Springs & Spa, which is a touristic area where people come for bathing. Figure 2 shows the geological map of Ain Khatt geothermal field. The geology of the aquifer is mainly composed of carbonates.

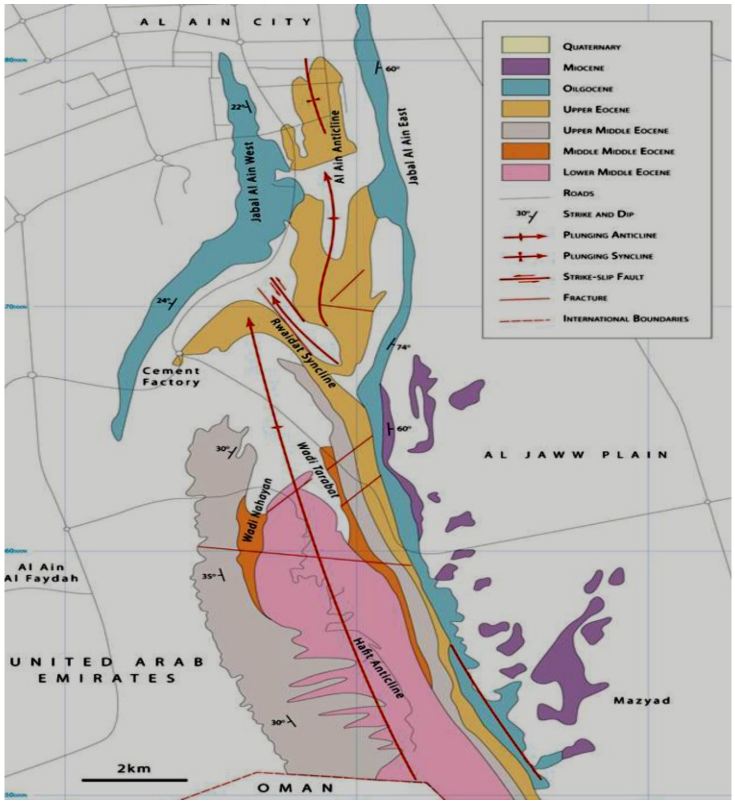

Figure 1: Geological map around Ain Faidha and Mubazzarah hot springs.

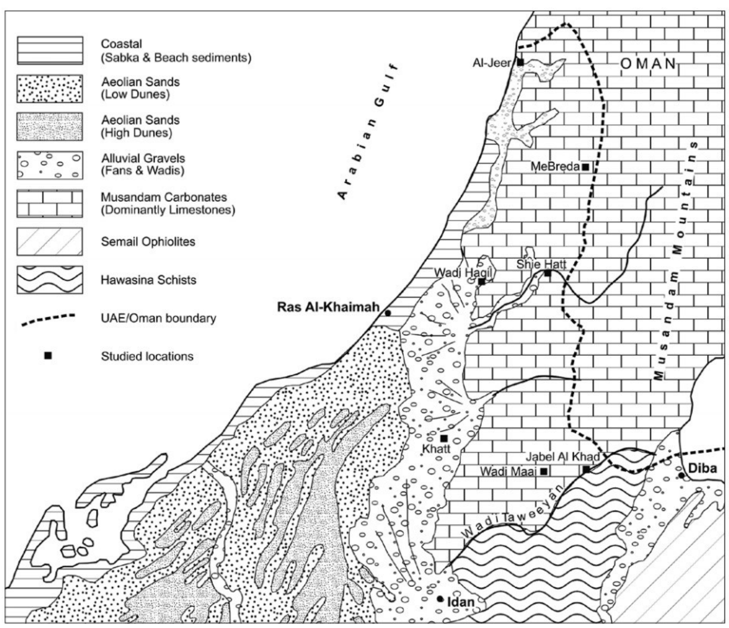

Figure 2: Geological map of Ain Khatt (Al-Farraj et al., 2014, Adopted from The National Atlas of the UAE, 1993).

2. GEOPHYSICAL SURVEYS

During 2017, various geophysical surveys were acquired at studied geothermal springs in United Arab Emirates including gravity, magnetic and magnetotelluric surveys. The corrected magnetic observations is presented here.

The Mubazzarah and Ain Faidha areas were covered by 1008 magnetic stations (D=1.98°, I=38.17°, Elevation=200m) during February and March 2017. The Ain Khatt area is covered by 112 magnetic stations (D=2.05°, I=40.47°, Elevation=630m) in April 2017. An G-856AX magnetometer was used during the magnetic surveys.

The residual magnetic field map (Figures 3, 4) shows that geothermal manifestations are located at boundaries between high and low magnetic fields. This boundary could be explained as a geological contact proving that these hot fluids are controlled mainly by subsurface structures (faults). The three-dimension (3D) inversion of magnetic data (Figures 5, 6 7) was developed by using Geosoft Voxi program and gives another similar observation on the structural control of geothermal fluids flow.

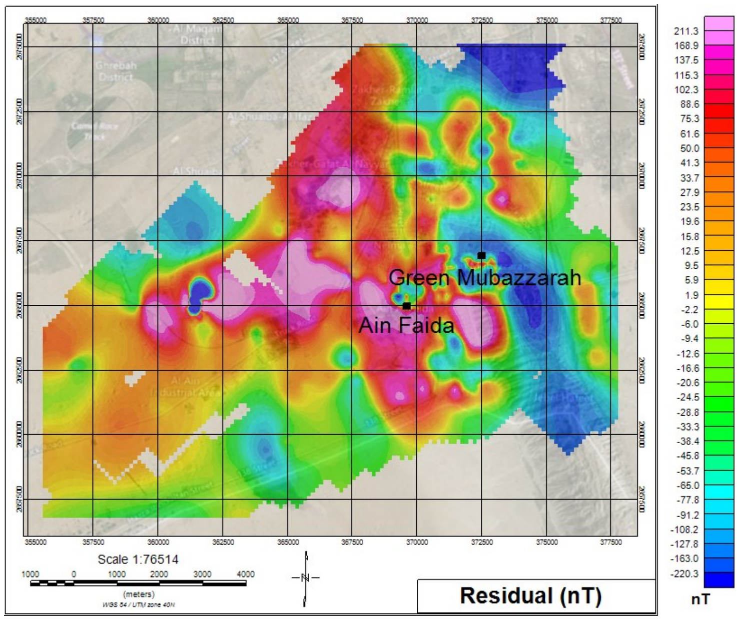

Figure 3: Residual magnetic field map at southern part of Al-Ain region including Mubazzarah and Ain Faidha hot springs.

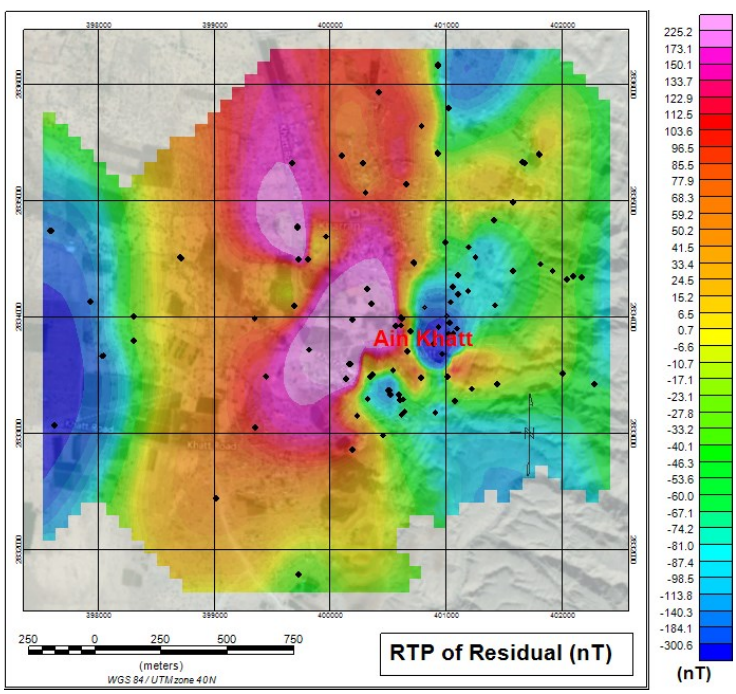

Figure 4: Residual magnetic field map at Ain Khatt hot spring.

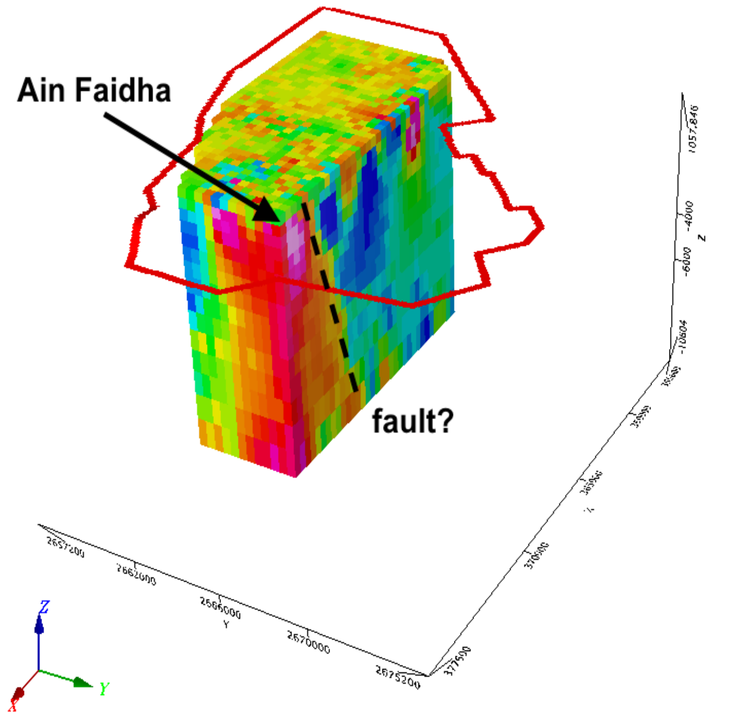

Figure 5: Three-dimension inversion of magnetic data at Ain Faidha hot springs.

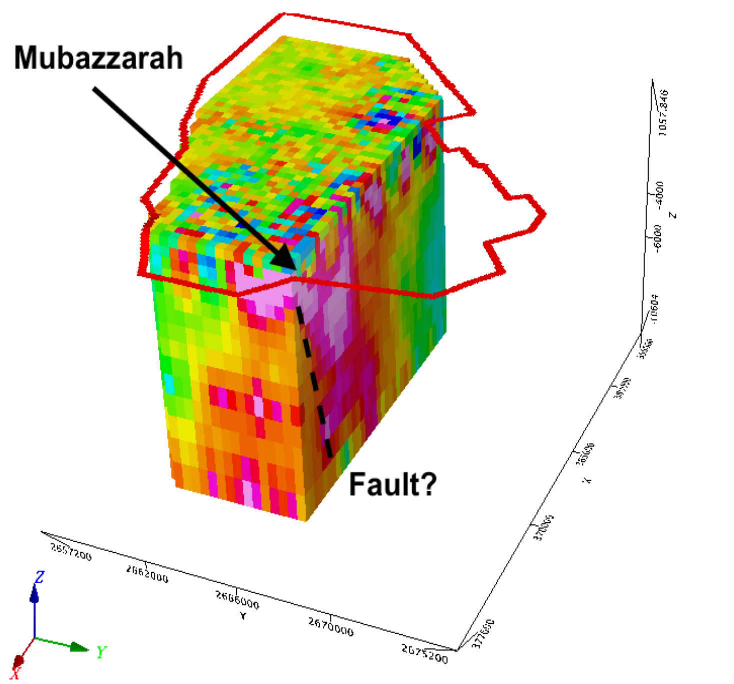

Figure 6: Three-dimension inversion of magnetic data at Mubazzarah hot springs.

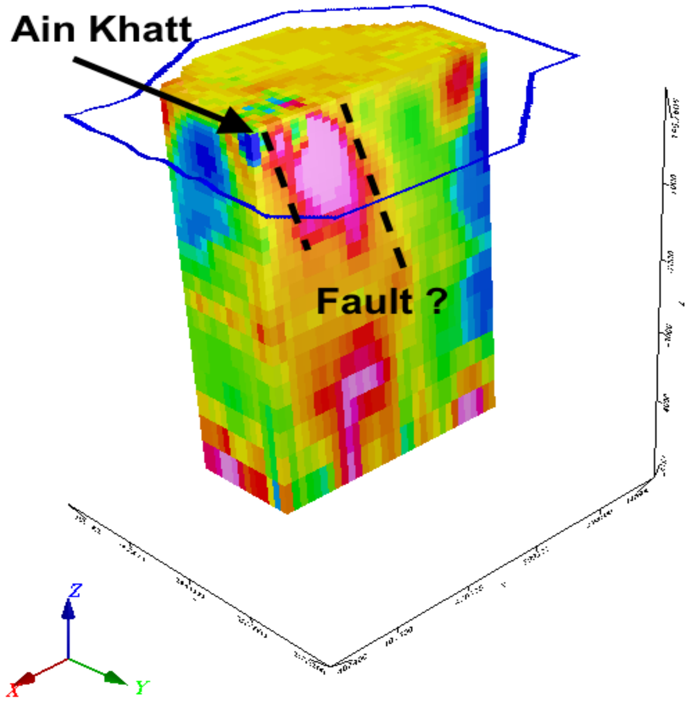

Figure 7: Three-dimension inversion of magnetic data at Ain Khatt hot springs.

3. HYDROCHEMICAL SURVEYS

In general, 19 water samples (cold and hot) were sampled and analyzed at UAEU for major anions and cations (Na, K, Ca, Mg, Cl, SO_4, HCO_3) and other parameters (temperature, pH, Electrical Conductivity) in 2017. The hot waters are from three low-type geothermal manifestations: (1) Ain-Khatt in Ras Al-Kheimah Emirate, (2) Ain Faidha and (3) Mubazzarah from Al-Ain (Abu Dhabi Emirate) in United Arab Emirates. The discharge temperatures ranges from 20.2 to 49.7 ^oC at Mubazzarah area, 32 ^oC at Ain Faidha, and 30.8 ^oC to 39 ^oC at Ain Khatt area. The water type is Na-Cl, Ca-Cl, and Cl-Na-Ca for Mubazzarah, Ain Faidha and Ain Khatt, respectively (Figure 8). The application of cation geothermometers showed that the parent fluid temperature is around 128 ^oC, 131 ^oC, and 94 ^oC for Mubazzarah, Ain Faidha and Ain Khatt, respectively (Na-K-Ca; Na-K-Ca Mg corr; Na/K Fournier, 1979; Na/K Truesdell, 1976; Na/K Giggenbach, 1988; Na/K Tonani, 1980; Na/K Nieva & Nieva, 1987; Na/K Arnorsson, 1983, K/Mg Giggenbach, 1986). The majority of the water geochemistry is located near the Mg corner of the Giggenbach ternary diagram (Figure 9), which suggests the water samples represent a mixture signature of the geothermal fluids with shallow cold groundwaters.

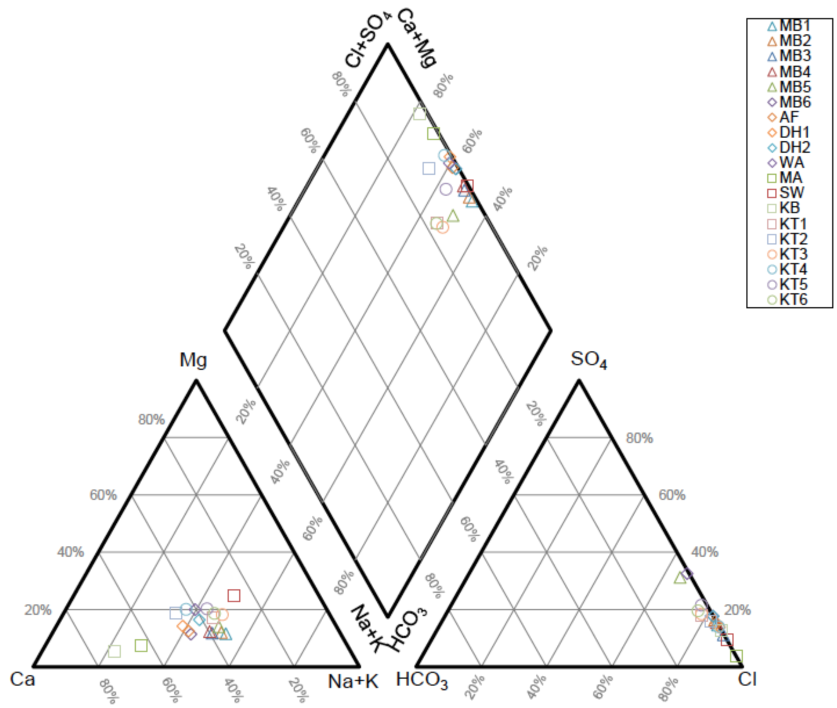

Figure 8: Piper diagram of sampled waters.

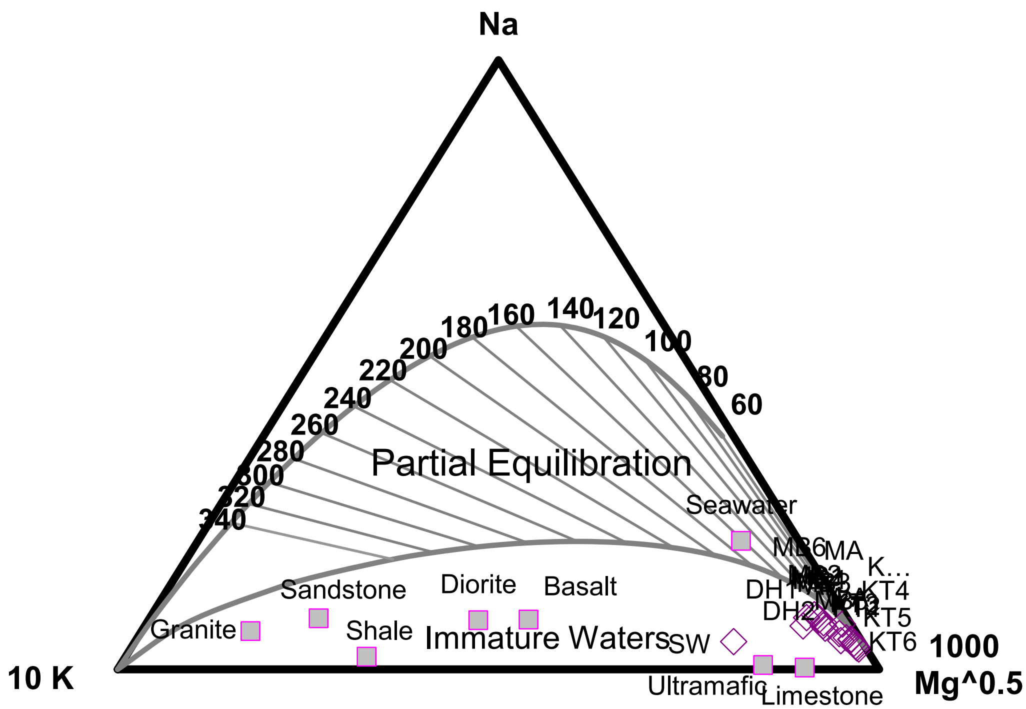

Figure 9: Ternary Na-K-Mg diagram mg/L for sampled waters.

4. REMOTE SENSING SURVEYS

Landsat 8 OLI (Operational Land Imager)/TIRS (thermal Infrared Sensor) image was used to investigate the land use - land cover, emissivity, land surface temperature and radiative heat flux of the three geothermal manifestations (Mubazzarah, Ain Faidha and Ain Khatt) in UAE. Details about methodology and processing are explained in Saibi et al. (2018).

Table 1 shows the calculated emissivity, Land Surface Temperature (LST), Radiative Heat Flux, Total Radiative Heat Loss and Total Heat Discharge Rate. The calculated total radiative heat loss (RHL) was about 1927 MW. The total heat discharge rate after multiplying the total RHL using the relationship coefficient (6.49), was about 12507 MW (Saibi et al., 2018).

Table 1: Remote sensing analyses results.

Geothermal area	Emissivity		Land Surface Temperature (°C)		Radiative Heat Flux (W/m^2)		Total Radiative Heat Loss (MW)	Total Heat Discharge Rate (MW)
	Min	Max	Min	Max	Min	Max		
Mubazzarah	0.98	0.990	26	40.30	-24.30	67.99	156.78	1,012.80
Air Faidha	0.98	0.989	28	42.60	-11.18	83.12	529.95	3,423.48
Ain Khatt	0.98	0.985	21	26.60	-8.60	21.32	14.58	94.1868

5. ENERGETIC ASSESSMENT

A stochastic Monte Carlo simulation was used to estimate the geothermal power energy available for 50 years at low-geothermal fields of UAE using the volumetric method (Pocasangre and Fujimitsu, 2016). The calculation is based on variable reservoir input data such as: reservoir area, thickness of geothermal reservoir, temperature of geothermal reservoir fluid, porosity of geothermal rock, rock specific heat and density, fluid specific heat and density, heat recovery factor, conversion efficiency, power factor and lifespan.

The reservoir temperature is taken from cation geothermometers results (130 °C for Mubazzarah-Ain Faidha (MB-AF) and 95 °C for Ain Khatt (AK).

The results are shown in Figure 10. The most likely power generation is around 11.5 MWe and 216 kWe for Mubazzarah-Ain Faidha and Ain Khatt, respectively.

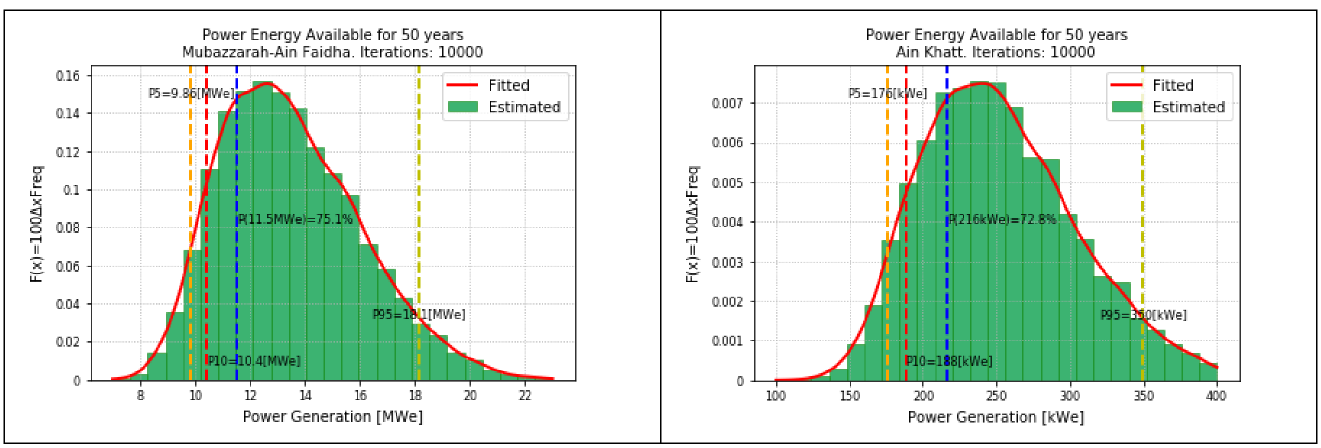

Figure 10: Power energy available for 50 years at Mubazzarah-Ain Faidha (left) and Ain Khatt (right) geothermal fields.

5. DISCUSSIONS AND CONCLUSIONS

This study is showing first results of magnetic surveys at three different geothermal sites in the United Arab Emirates (UAE), including a remote sensing study and a geothermal energetic estimation study for a first investigation of geothermal potentialities in the UAE and possible utilization of such renewable energy in the future, in alignment with the government vision of reducing fossil fuels utilization and diversifying and increasing renewable energies use.

The magnetic surveys showed that the three geothermal springs: Mubazzarah, Ain Faidha, and Ain Khatt are mainly located at magnetic boundaries, which are interpreted as structural-geological boundaries. The construction of three-dimension inversion of magnetic data showed that these hot springs are emerging through fault structures.

Total Heat Discharge Rate was estimated using remote sensing analyses of satellite images at the three hot springs, which is about 4530 MW. The remote sensing is very adequate to explore and monitor the thermal status of such geothermal manifestations with less time and low cost; however, acquiring higher resolution satellite images will improve the results and analyses, along with a combination of ground truth data.

The application of the Stochastic Monte Carlo simulation to estimate the geothermal power that can be produced in the coming 50 years showed results of 11.5 MWe and 216 kWe at Mubazzarah-Ain Faidha and Ain Khatt geothermal fields, respectively.

If we assume that 1 MWe can power around 1000 homes (US standard), the available geothermal power at different hot springs in UAE can power around 11700 homes. The low-enthalpy geothermal potentialities in UAE can also be used for direct use and for Organic Rankine Cycle (ORC) electrical power generation. Future areas of geothermal development also include the abandoned deep oil wells (deeper than 5 km) which may be another source of energy. We can also think about geothermal heat pump application by using the temperature differences between atmospheric temperature and shallow underground temperature, under existence of shallow groundwater aquifer with a good groundwater flow.

Deep well data (temperature data and well logs) is still required for constructing a better conceptual and numerical model to gain a better understanding of the geothermal systems at Mubazzarah and Ain Khatt.

ACKNOWLEDGMENTS

The author acknowledges Pr. A. Murad (Dean of College of Science, UAEU), Dr. K. Al Bloushi (Head of Geology Department, UAEU) and Pr. H. Baker (Geology Department, UAEU) for providing administrative support for achieving the field surveys at studied areas in UAE. The author also thanks Dr. A. Gabr and Dr. S.M. Hussein (Geology Department, UAEU) and undergraduate students of Geology department at UAEU for field survey support. The author thanks Dr. J. Batir for enhancing the paper. The author thanks UAEU for financial support under a research grant: Research Start-up Grant, Fund Number: 31S264.

REFERENCES

Al-Farraj, A., Slabe, T., Knez, M., Gabrovšek, F., Mulec, J., Petrič, M., Zupan Hajna. N.:Karst in Ras Al-Khaimah, Northern United Arab Emirates, *Acta Carsologica*, **43**(1), (2014), 23-41.

Arnórsson, S., Gunnlaugsson, E., and Svavarsson, H.: The chemistry of geothermal waters in Iceland. III. Chemical geothermometry in geothermal investigations, *Geochim. Cosmochim. Acta*, **47**, (1983), 546-566.

Fournier, R.O.: Geochemical and hydrologic considerations and the use of enthalpy–chloride diagrams in the prediction of underground conditions in hot spring systems, *Journal of Volcanology and Geothermal Research*, **5**, (1979), 1–6.

Giggenbach, W.F.: Geothermal solute equilibria. Derivation of Na–K–Mg–Ca geoindicators, *Geochimica et Cosmochimica Acta*, **52**, (1988), 2749–2765.

Giggenbach,W.F.: Graphical techniques for the evaluation of water/rock equilibration conditions by use of Na, K, Mg, and Ca contents of discharge waters. Proceedings, 8th NZ Geothermal Workshop, Auckland (1986).

Muffler, L.P.J.: Assessment of geothermal resources of the United States, U.S. Geological Survey Circular 790, (1979), pp. 163.

Muffler, L.P.J. and R. Cataldi: Methods for regional assessment of geothermal resources, *Geothermics*, (1978), 53-59.

Nieva, D., Nieva, R.: A cationic geothermometer for prospecting of geothermal resources, *Heat Recovery Systems and CHP*, **7** (3), (1987), 243–258.

Pocasangre C., Y. Fujimitsu: Volumetric geothermal resource assessment in El Salvador by using Open-Source Programming Language. Proceedings in: International Symposium on Earth Science and Technology 2016, Kyushu University, Fukuoka, Japan (2016).

Saibi, H., Md. Bodruddoza Mia, K.M.S. Al Bloushi, M. Bierre: Exploration of thermal activity within the three hot springs area in United Arab Emirates using Landsat 8/OLI-TIRS images, Under review at *Sustainable and Renewable Energy Reviews*, (2018).

Tonani, F.: Some remarks on the application of geochmical techniques in geothermal exploration. Proceedings in Adv. Eur. Geoth. Res. 2nd Symp., Strasbourg, (1980), 428-433.

Truesdell, A.H.: Summary of section III - geochemical techniques in exploration. Proceedings of the 2nd U.N. Symposium on the Development and Use of Geothermal Resources, San Francisco, 1, liii- lxxix (1976).