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Geothermal power potential at the western coastal part of Saudi Arabia ☆

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ABSTRACT

Saudi Arabia is enriched by many geothermal resources that are located along the western coastal part of the Red Sea, in the form of a number of hot springs and many volcanic eruptions. Wadi Al-Lith is considered one of the most promising geothermal targets that encounter many hot springs with a good surface temperature upto 95 °C. This paper aims mainly to evaluate the geothermal potential of the main hot spring at Wadi Al-Lith area (Ain Al Harrah). The available remote sensing images are analyzed and a number of 2D electric resistivity profiles are interpreted to delineate the surface geological lineaments and the subsurface structural elements that control the movement of the thermal water. It is found that the main surface lineaments are structurally oriented along NNE–SSW and NE–SW directions with a frequency percentage of 52% and an average lineament length of 835 m. Furthermore the subsurface structural elements, as inferred from the interpretation of the geophysical 2D electric profiles, have assumed the same directions beside the NW–SE direction.

The characteristics of thermal water of the hot spring are indicated through analyzing the major and minor elements of some collected water samples. Geo-thermometers are applied to estimate, subsurface temperature, heat flow and discharge enthalpy. These parameters are found to be 136 °C, 183 mW/M^2 and 219 kJ/kg, respectively. An estimate of the geothermal reserve using the volumetric method, gave total stored heat energy of 1.713×10^{17} J (rock and fluid) and a geothermal reserve potential of 26.99 MWt.

It appears from our research that the estimated energy is quite enough for operating a medium scale power plant that utilizes low boiling point fluid (Kalina Cycle) for limited electricity production, beside other low-temperature applications (district heating, green houses and medical therapy).

Contents

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1. Introduction

Geothermal power is among the renewable energy sources which come from natural resources such as sunlight, wind, rain, tides, and biomass which are renewable. About 16% of global final energy consumption comes from renewables, with 10% coming from traditional biomass, which is mainly used for heating, and 3.4% from hydroelectricity. New renewables (small hydro, modern biomass, wind, solar, geothermal, and biofuels) accounted for another 3% and are growing very rapidly. The share of renewables in electricity generation is around 19%, with 16% of global electricity coming from hydroelectricity and 3% from new renewables [1,2].

The most critical factor for the classification of geothermal energy as a renewable energy scale is the rate of energy recharge. In the exploitation of natural geothermal systems, energy recharge takes place by advection of thermal water on the same time scale as production from the resource. This justifies our classification of geothermal energy as a renewable energy resource. In the case of hot, dry rocks, and some of the hot water aquifers in sedimentary basins, energy recharge is only by thermal conduction; due to the slow rate of the latter process, however, hot dry rocks and some sedimentary reservoirs should be considered as finite energy resources [3].

Geothermal power is cost effective, reliable, sustainable, and environmentally friendly, but has historically been limited to areas near tectonic plate boundaries. Recent technological advances have dramatically expanded the range and size of viable resources, especially for applications such as home heating, opening a potential for widespread exploitation. Geothermal wells release greenhouse gases trapped deep within the earth, but these emissions are much lower per energy unit than those of fossil fuels. The International Geothermal Association (IGA) has reported that 10,715 MW of the online geothermal power in 24 countries, are generating 67,246 GWh of electricity in 2010. This represented a 20% increase in geothermal power online capacity since 2005. IGA expects that this will grow to 18,500 MW by 2015, due to the large number of projects presently under consideration, often in areas previously assumed to have little exploitable resource [4,5].

In Saudi Arabia there is a big gap of knowledge and information concerning the potential of geothermal resources. A more detailed and much more comprehensive work is needed to study the geothermal resources in Saudi Arabia, especially those encountered in Southwestern parts, from one hand, and to evaluate their economic reserves for possible energy production and domestic application, from the other hand. Large number of exploration methods and technologies should be initiated in order to reach these objectives. Many of these methods are in current use and have already been widely experimented in other sectors of research [6].

The geothermal recourses of Saudi Arabia can be categorized as the following:

1. *Low enthalpy resources (sedimentary aquifers)*: represented by deep-seated aquifers encountered in thick sedimentary basins in the eastern part of the Kingdom. These resources are confined and geothermal potential is represented by the normal geothermal gradient. It can be accessed only by deep drilled wells (i.e. oil wells).
2. *Medium enthalpy resources (hot springs)*: encountered along the western and southwestern coastal parts and represented by the shallow hot springs of hot surface water. These resources are unconfined targets with direct accesses to the subsurface hot anomalies through an open network of active faults and fractures (structure control).
3. *High enthalpy resources (basaltic lavas, Harrats)*: Saudi Arabia has approximately 80,000 km² of lava fields, known as Harrats. They are represented by volcanic eruptions, mainly basaltic in composition, that extend along the coastal part of the Red Sea at the western of Saudi Arabia. Harrats of Khaybar and Rahat are believed to be the best in terms of high heat flow and enthalpy [6].

The first geothermal work done at Saudi Arabia was that of El Dayel, 1988 [7]. He focused mainly on studying the hydro-chemical characteristics of the hot springs at Jizan and Al-Lith areas. Some water samples from the hot springs were analyzed. Other interested work regarding the petrography, petrochemical composition and mineralogy of the basaltic volcanic eruptions, was done by Roobol et al. and Pint et al. in the period from 1992 to 2007. A more detailed and recent work is done by Lashin and Al Arifi, 2012 [8]. They focused on giving a preliminary investigation of the geothermal resources encountered in the southwestern parts of the Saudi Arabia (Jizan area), based on the interpretations of the Landsat images and chemical analyses.

In general, a few studies have presented the characteristics and the potentiality of the geothermal resources and its utility for some locations along the western coastal area of Red Sea of Saudi Arabia [8–14]. This work presents an initial evaluation of the geothermal energy potential of Wadi Al-Lith area, and provides a basis for a preliminary assessment of geothermal resources in the whole region.

2. Geologic setting

2.1. Rock units

Wadi Al-Lith is represented by a catchment area that is considered an integral part of the Arabian Shield. It extends from the western coast of the Red Sea to high Mountains in the east. The area is mainly covered by metavolcanic rocks, metasediments and late Proterozoic plutonic rocks (Fig. 1). Four major rock units are found covering about 91% of Wadi Al-Lith catchment area. These rock units are summarized, from youngest to oldest, as follows:

1- *Quaternary, sand, gravel and silt*: This unit represents 18% of the total catchment area of Wadi Al-Lith. Eolian sand-dune fields,