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Geothermal energy resources of wadi Al-Lith, Saudi Arabia

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ABSTRACT

The entire western Arabian shield is the domain of both hydrothermal and enhanced geothermal systems associated with volcanic centres (*Harrats*) and high heat generating granites. The most prominent sites of hydrothermal systems are located around Al-Lith and Jizan. The hydrothermal system in Al Lith is controlled by high heat generating (~11 μW/m^3) post orogenic granites. The high heat flow value of >80 mW/m^2 across Al-Lith coast is due to such granite intrusives, presence of dike swarms that intrude into the granites as well as position of Moho at shallow level. Although the thermal waters are chloride rich, Red Sea involvement is not observed. Long residence time and water rock interaction with granites are the main processes responsible for chloride enrichment in the thermal waters. Oxygen isotope shift indicates presence of high temperature geothermal system in the area. The tritium values indicate that the circulating waters are >75 years old.

1. Introduction

Saudi Arabia has the richest oil and gas reserves and the largest oil and gas producing country in the world. The country's revenue and GDP depends on 90% export of oil and oil related products. As on date the country has reached its production target of 12 million barrels per day of oil (OPEC, 2012). Nearly 60% of electricity is being generated from oil based power plants and the rest is generated from gas based power plants. In the recent years, due to concerns related to climate change and CO_2 emission from oil and gas fired power plants, and due to CO_2 emission cap imposed by UNFCCC, renewable energy sources are being considered as a viable option for clean development mechanism to mitigate climate change and to reduce CO_2 emission. ARAMCO, the Saudi Arabia's major oil exploration and production company, has realised the importance of renewable energy and is recommending that the domestic users may switch to renewable energy based electricity and increase the country's GDP by exporting the domestic consumption of 3 million barrels of oil. Although the country has considerable promising geothermal resources, it has not drawn the attention it should have from the policy makers due to prevailing feel-good factor from oil and gas reserves. The entire western Arabian shield region is the domain of both hydrothermal and enhanced geothermal systems (EGS) associated with volcanic centres (*Harrats*) and high heat generating granites. The most prominent sites of hydrothermal systems are located around Al-Lith and Jizan (Fig. 1). Although considerable geological, geophysical and geochemical investigations have been carried out, the data has remained in the academic reports and not accessible to investors. In the light of this, geological and geochemical investigations on the thermal springs occurring in Al-Lith geothermal site are presented here with an emphasis to commercialise this resource for power generation and to reduce CO_2 emission.

2. Geology and structure of wadi Al-Lith

The western continental margin of Saudi Arabian broadly consists of two groups of rocks: the mafic and the felsic rocks. The mafic group includes the volcanic flows and dikes around the volcanic centres (also so known as "*Harrats*") and the felsic group includes Precambrian Formations (the basement rocks) and post orogenic granites and its equivalent of different ages (Fig. 1). The volcanic centres occupy 45 % of the western Arabian shield while 55% is occupied by the post orogenic granites and its equivalents

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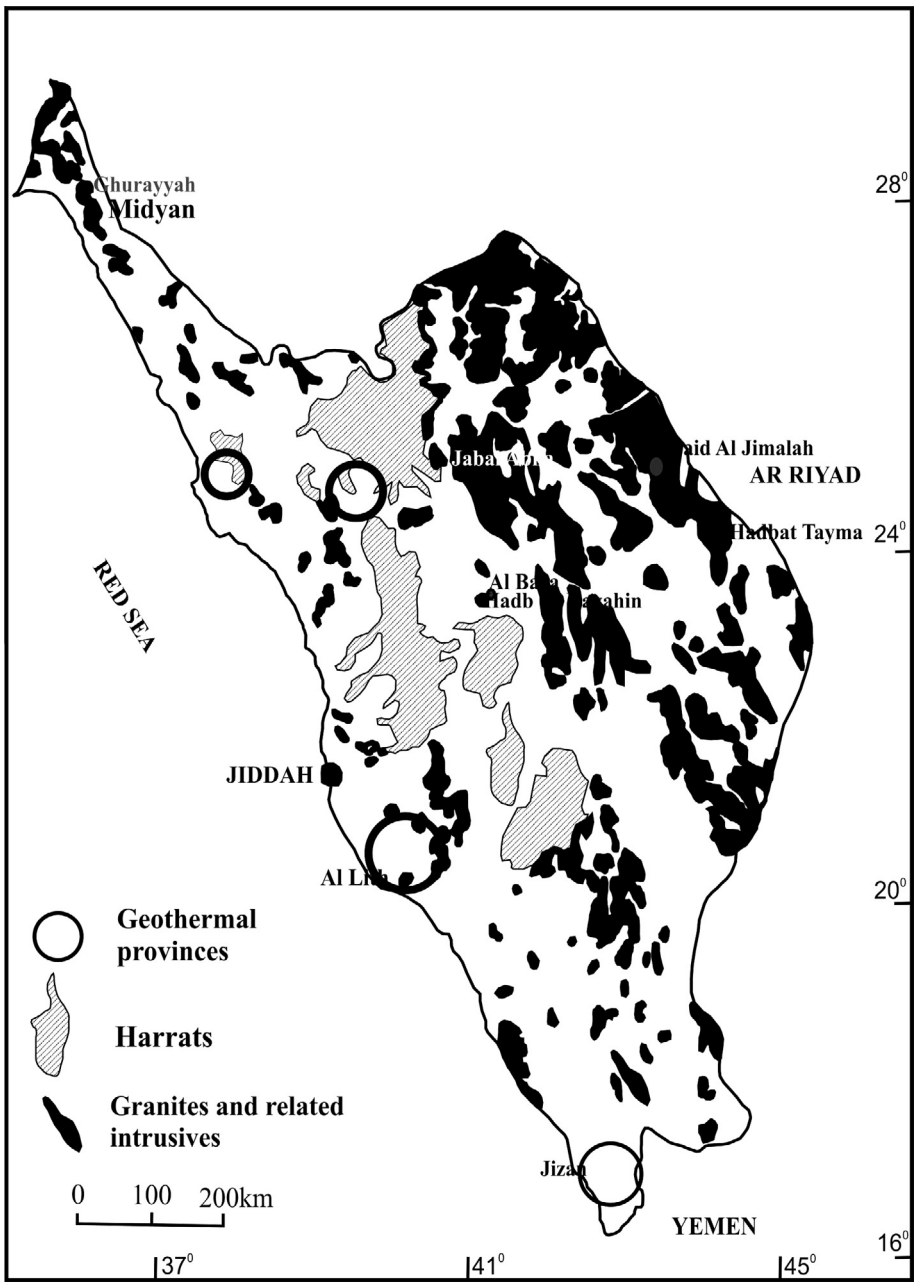

Fig. 1. Western Arabian shield showing the location of distinct geothermal provinces. Only Al-Lith geothermal province is discussed in the text. The black areas mark the exposure of rocks of granitic composition and the grey areas represent Harrats.

(Stoeser, 1986). The area under the present investigation (Fig. 2) is covered by Precambrian rocks, post orogenic granites and its equivalents and basic dikes. The Al-Lith basin is flanked by Jabal Afaf basin on the east and Wadi Sadiyah on the north. The area occupied by granitic and intermediate rocks in Asir terrane (Fig. 3) where the study area falls, is given in Table 1.

2.1. Precambrian

These rocks are represented by the Baish group of volcanic sequence represented by flows of basaltic, andesitic and rhyolitic composition (Fig. 2). The rocks have undergone greenschist metamorphism and at some places exhibit their original structure and texture (Hadley and Fleck, 1979; Pallister, 1986a; Carter and Jonson, 1987). The basaltic flows contain glomerophyric clots of plagioclase feldspars and vugs filled with secondary minerals like quartz, chlorite, zeolite and calcite. The Rb–Sr age of these rocks is 1165 Ma with an initial $^{87}Sr/^{86}Sr$ ratio of 0.7028 indicating their primitive nature. These flows appear to be related to the volcanism associated with initial phase of Red Sea rifting. These rocks are overlain by volcanic tuff and pyroclasts of rhyolitic composition. The Baish group is intruded by a variety of rocks that are classified as Ablah intrusive, exposed towards the southern part of the basin (Fig. 2). They are represented by quartz diorite, gabbro, tonalite, granodiorite and monzodiorite. The basic variety is enriched with hornblende while the felsic members are rich in biotite and potash feldspars and large crystals of pyrite (Hadley and Fleck, 1979). The diorites enclose large mafic xenoliths. These intrusives are dated at 895 Ma and have $^{87}Sr/^{86}Sr$ ratio of 0.7025 indicating their parentage from basaltic magma. The Late Precambrian