Initial subsurface model for the Kanniya hotspring field by using magnetic and DC resistivity techniques

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1. ABSTRACT

Constructing subsurface models for geothermal fields is required to develop geothermal energy utilization plan. In this context, demarcating the resource periphery and origin of the geothermal system of Sri Lankan geothermal fields were hardly studied. Therefore, this study is focused to develop an initial subsurface model to Kanniya hotspring field via geophysical studies. The outcome of this study reveals that there is a heated water influx to the Kanniya hotsprings from northeast direction. This observation is contradicting the widely-accepted idea of Highland/Vijayan boundary as the source of heat, since the boundary itself is further to southeast direction from the Kanniya hotsprings.

2. INTRODUCTION

Characters of global geothermal fields can be explained mainly in terms of origin, temperature and geology. There are several countries which are gifted with geothermal prospects and act as sources for energy generation. Conventionally, magmatic geological settings are favourable for geothermal field occurrences, yet Sri Lanka is having over 09 hotspring sites scattered in metamorphic geological settings (Samaranayake et al., 2015). Senevirathna and Balendran (1968) conducted the first scientific study on hotsprings in Sri Lanka, which provided an overview of locations, geological conditions and physical and chemical characteristics of water from individual hotsprings. Dissanayake and Jayasena (1988) proposed a model for the origin of hotsprings in Sri Lanka and suggested that water derived from meteoric sources is associated with an underground temperature of approximately 140 °C. Chandrajith et al. (2013) suggested that hotsprings in Sri Lanka were due to percolation of water through faults and fractures, and heating them at higher depths due to steeper-than-normal geothermal gradient. It is significant character that almost all Sri Lanka hotsprings are located close to regional fault or fracture zones. Therefore, deep percolation of meteoric water and heating-up subsequently, is possible and this model (Chandrajith et al., 2013) partially explains the mechanism for the origin of hotsprings. The most popular hypothesis suggests that the hotsprings in Sri Lanka originate beneath the Highland-Vijayan (H/V) boundary, which constitutes an inactive mini-plate boundary traversing the landmass of Sri Lanka (Samaranayake et al., 2022). However, in pertain to the source; this model possesses its own drawbacks as Sri Lankan crust has been identified as thick old/cold shielded fragment. This study was focused to assess subsurface behaviour of the Kanniya hotspring field via geophysical techniques.

Kanniya hotsprings are located about 1 km west of Trincomalee-Anuradhapura main road. The distance to hotspring is about 10 km from Trincomalee town towards northwest direction. Seven hot wells, within slightly varying temperatures, are scattered with an aerial extent of 200 m^2 at the Kanniya hotspring site.

2.1 Geology of the study area

Kanniya is one of the few hotsprings in the Highland complex, and the most are in the Vijayan Complex (Figure 01). According to the figure, hotspring field is at the foot of a massive quartzite band with a synform structure. Charnokite rocks can be identified as the background rock type of the study-area.

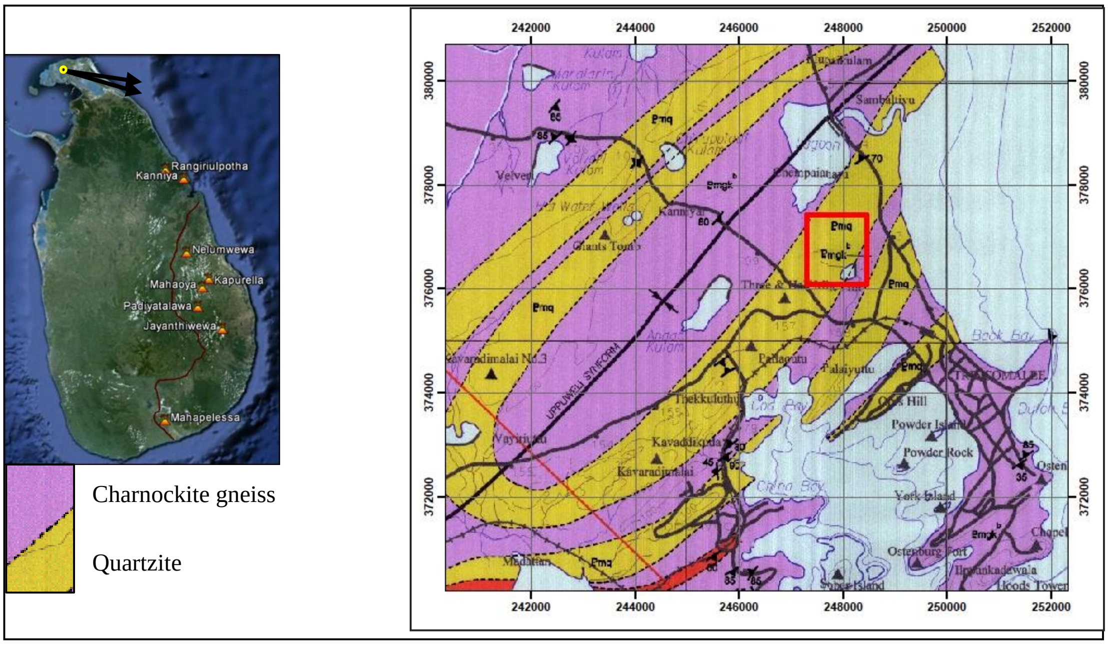

Figure 1: Geology of the Kanniya hotspring field (Geological Survey and Mines Bureau, 2011)

Both magnetic and resistivity surveys were conducted in the area of interest to identify subsurface characters of the hotsping site and its surroundings. Magnetic survey was conducted to demarcate hidden geological features and a resistivity survey was performed to map near-surface water flow pattern.

Magnetic method

The magnetic method is used to investigate the subsurface geology using the anomalies in the Earth's magnetic field resulting from the magnetic properties of the underlying rocks. In general, the magnetic susceptibility of rocks is variable, which depends on the type of rock and mainly the magnetic mineral content of the whole rock. Common structural causes for magnetic anomalies are dykes, faults, and lava flows. In a geothermal environment, decreasing susceptibility values are observed with increasing temperatures (Mariita, 2007). Magnetic minerals can also be weathered or leached from rocks and re-deposited in other locations, such as faults, changing magnetic characters. In a geothermal environment, this is a very useful feature as it may indicate the presence of faults, probably the pathways for hot-water transfer. Ground magnetic surveys were conducted in the area enabling to correlate with geology.

Resistivity method

Resistivity values of the subsurface depict different geological layers, which can be measured remotely. The input current flows along the equi-potential surfaces and as of the resistivity of subsurface layers, response is registered. Two-dimensional (2-D) resistivity technique enables to assess resistivity contrast both in vertical and horizontal directions (Telford et al., 1990). In many situations, particularly for surveys on elongated geological bodies, it is assumed that the resistivity changes along the strike direction are constant. (Dahlin, 1996). Schlumberger electrode array was employed for this survey due to its relatively high depth penetration ability. The maximum electrode spread for this survey was maintained at 270 m with 60 m depth detection limits. Figure 02 shows the 2D array setup in Kanniya hotspring field.

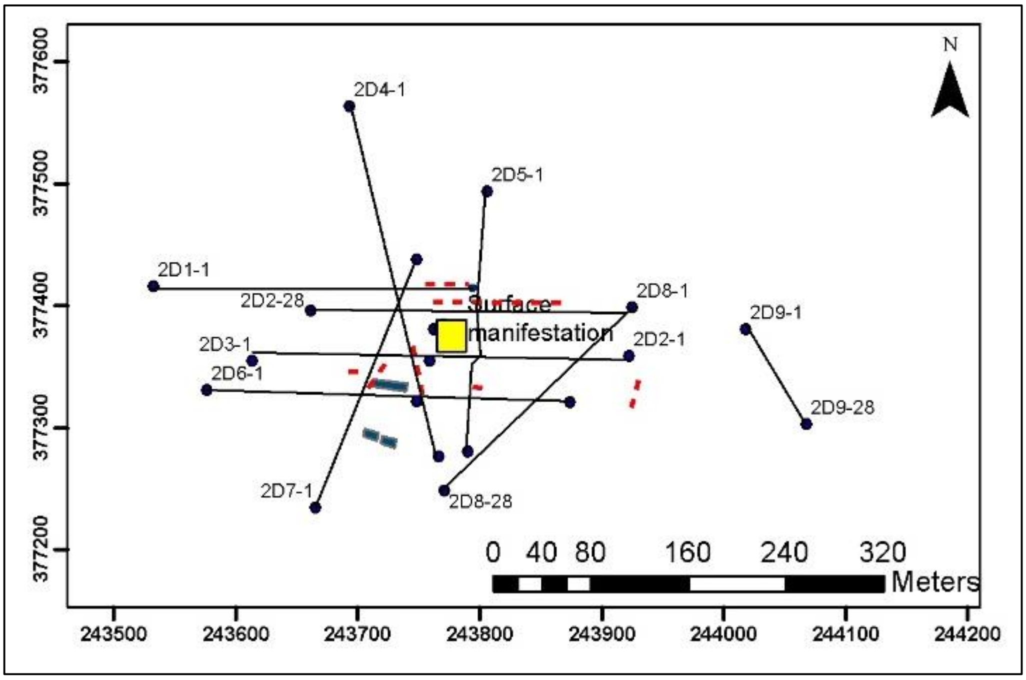

Figure 2: 2D array setup in Kanniya hotspring field.

3. RESULTS AND DISCUSSION

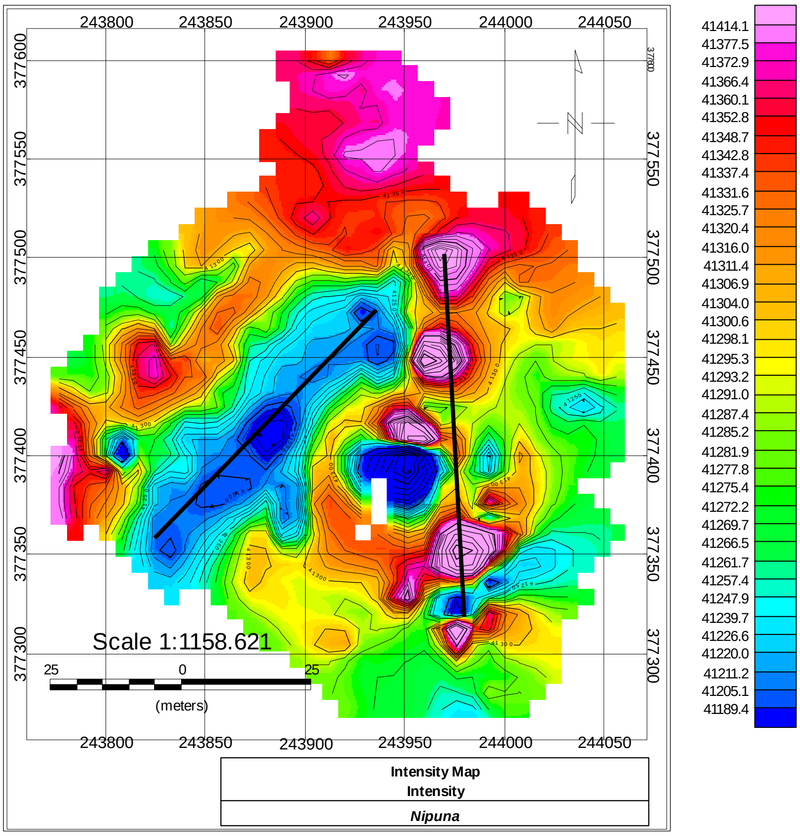

Figure 3: (a) Total magnetic intensity map of the study site;

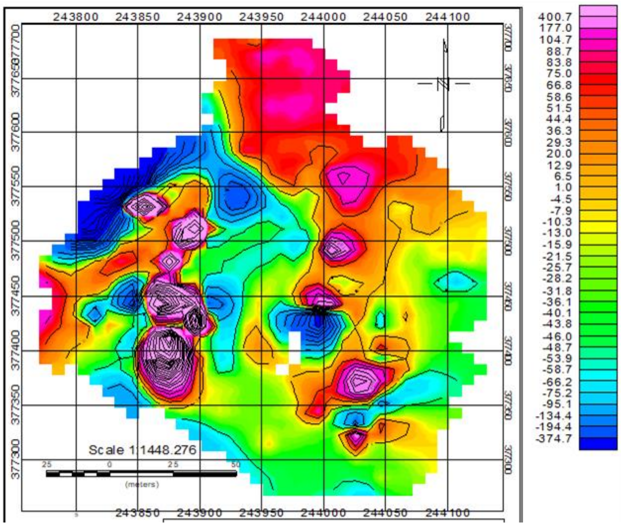

Figure 3:(b) Magnetic anomaly map. Geological structures in the area were shown in black.

Figure 3 (a) shows the total magnetic intensity map of the study site. Magnetic anomaly map shown in figure 3 (b) was produced to understand the perturbation of the magnetic intensity values with the background magnetic field. Base magnetometer was used to measure the time varying magnetic field that is required for data reduction. Results indicated that the major structural features of the study area with NE-SW directional trend.

A 2D resistivity survey was carried out following the guidelines outlined in a magnetic survey to discern near subsurface structure of Kanniya hotspring field. 2D resistivity profiles are shown in figure 4. Unlikely the other hotsprings found in Sri Lanka very high resistivity values recorded in close proximity to the hotspring could be a result of its location just on top of the quartz band. Circled areas in the figures show the low resistivity pockets beneath the surface which could be confined aquifers which is a very common feature for quartzite rocks. Marked line features shown in the figure represent the fracture zone and rectangular cages show the near surface weak zone demarcated in the 2D resistivity arrays.

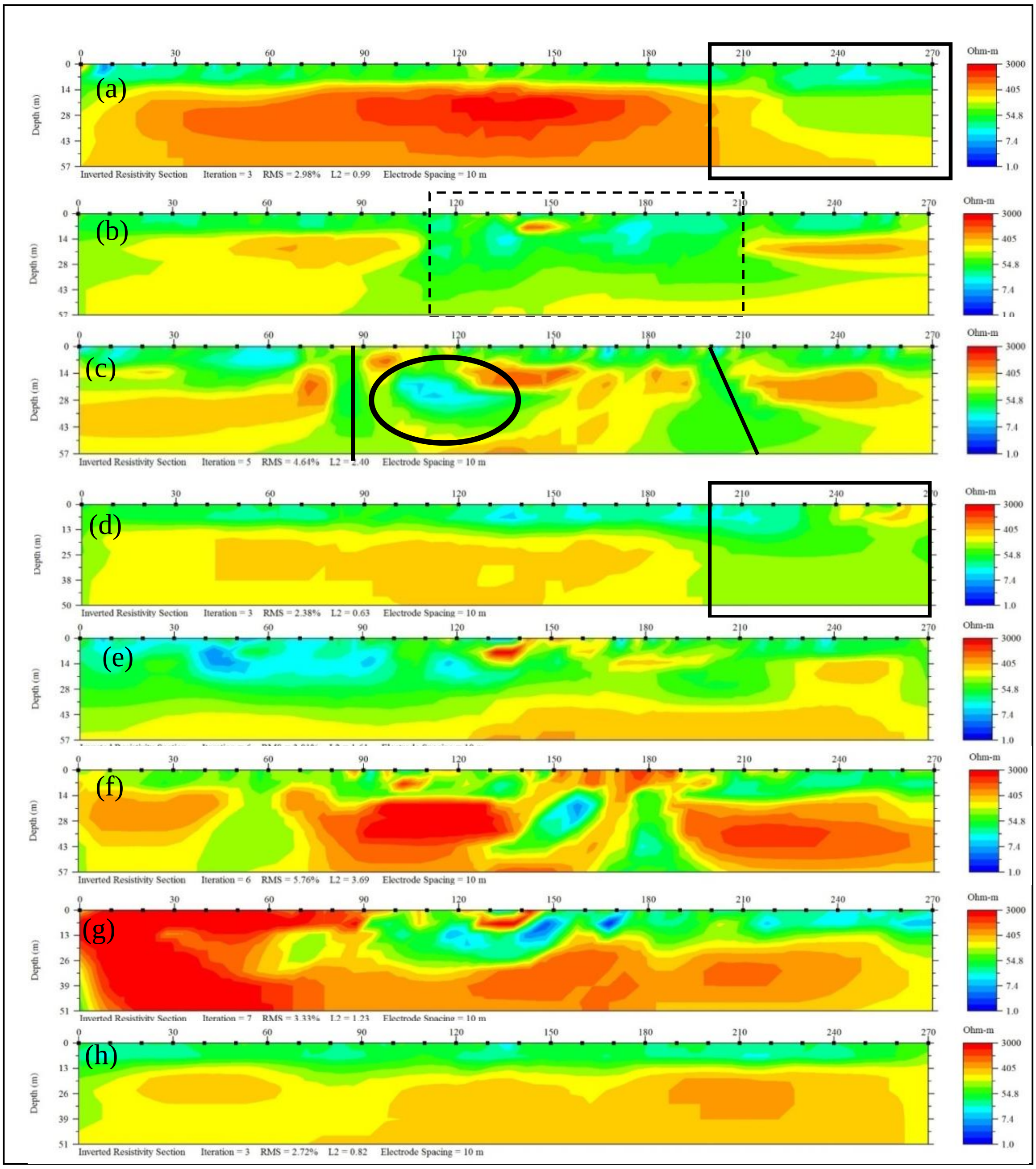

Figure 4: 2D resistivity profiles. Circled areas show the low resistivity pockets beneath the surface, Marked line features represent the fracture zone and rectangular cages show the near surface weak zone.

The Figure 4 shows the flow path of water towards Kanniya hotspring field from NW – SE direction. Depth and the dip angle of the fractures are very much important to define a geothermal field. Therefore, depth wise resistivity analyses were conducted to identify the subsurface behaviour.

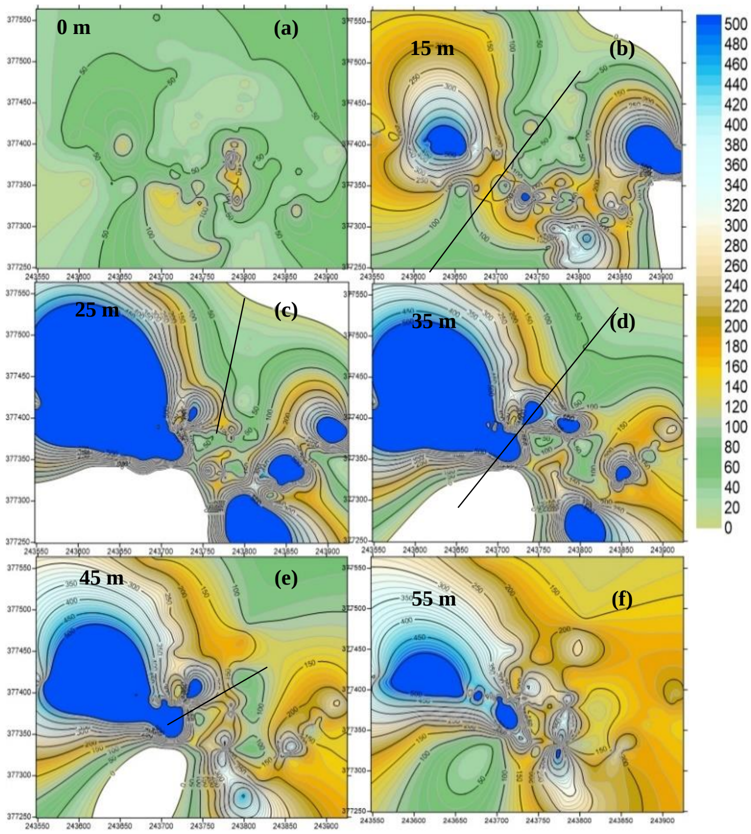

Figure 5: Depth wise resistivity analyses;(a) 0 m; (b) 15 m; (c) 25 m; (d) 35 m; (e) 45 m; (f) 55 m.

Figure 5 clearly shows that fracture continuation started with 15 m to 45 m. This fracture bound with the high resistive cap may possibly be a quartzite band.

4. CONCLUSION

The Kanniya geothermal field is surrounded by a quartzite rock formation and channels hot water through deep fractures originating from the northeast. Resistivity analyses have confirmed that the water movement occurs within the fractures within the quartzite layer, directing it towards the Kanniya hotspring site. This investigation undermines the longstanding assumption linking Sri Lanka's hotsprings to the H/V boundary, as the water flow towards Kanniya originates from the opposite direction of the H/V boundary, situated in the southeast.

5. REFERENCES

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