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Feasibility of Finding Geothermal Sources in Sri Lanka with Reference to the Hot Spring Series and the Dolarite Dykes

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ABSTRACT

Sri Lanka is situated far away from an active plate boundary and there is no volcanic region at close proximity to the Sri Lankan land mass. The story of geothermal potential in Sri Lanka mainly depends on the Highland Vijayan boundary, Dolarite dyke intrusions and the related hot spring series. Most of the studies conducted to find possible geothermal sources were mainly focused at the source of hot spring series. Although it was suggested that the Highland Vijayan boundary is the source of the hot springs, there is a huge distance between the hot springs and the boundary, and also recent MT (Magneto Telluric) studies implied that there is no direct relationship between the boundary and the hot springs. Most of the research conducted along the hot spring series interpreted that there is no possible heat source at depth exactly beneath the hot springs. This study was mainly focused on finding the possibility of an existence of a relationship between the hot springs and the Dolarite dyke and thereby identifying the dyke as a source of the hot springs and a source for geothermal power generation. Magnetic surveys, resistivity surveys and geological mapping were conducted in the study area related to the hot springs and the Dolarite dykes. The result implied that there is some relationship between the hot springs and the dykes. Most of the times a dyke could be seen at close proximity to the hot springs and they are interconnected by deep fractures. Sri Lanka has high temperature hot springs, the highest with a mean of 70ºC at Kapurulla. A schematic diagram for a feasible geothermal model was developed by using the above results and it gives a proper path for deep exploration for a possible geothermal source in Sri Lanka. This study gives a better idea about the related interconnecting paths of channeling hot springs.

1. INTRODUCTION

Sri Lanka is an island in the Indian ocean, near the equator, between 5º55’ N to 9º55’ N and 79º42’ E to 81º52’ E. The geographical location of Sri Lanka is relatively far away from the tectonic plate boundary (Figure 01).

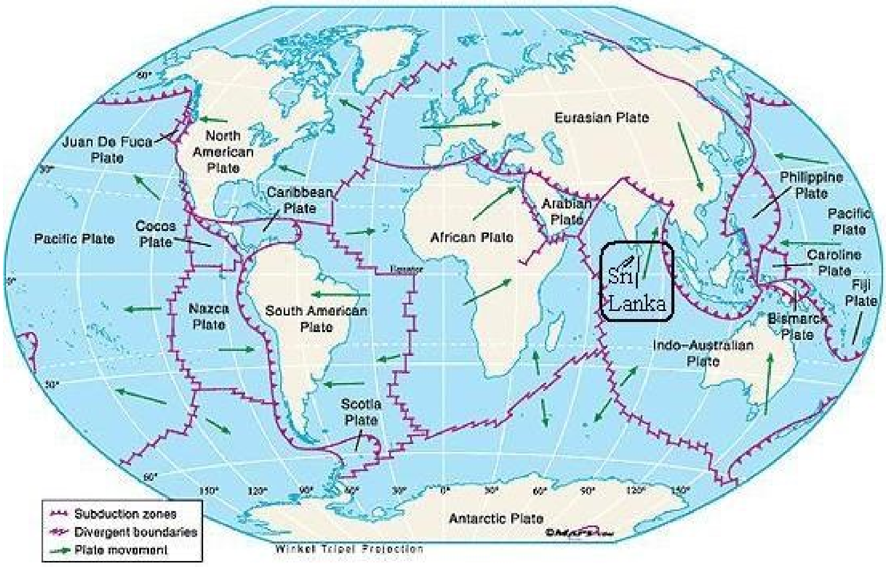

Figure 01: Plate boundaries and direction of movement (http://www.maps.com)

Over 90% of Sri Lanka is composed of high grade metamorphic rocks of granulate and amphibolites facies metamorphism. Three major distinct lithotectonic complexes have been identified though the exact boundaries between the complexes and are not well defined. The boundary between those lithotectonic complexes is called the highland Vijayan boundary (H/V boundary) (Dissanayake, C.B., et al., 1999). A series of hot springs with geothermal activity, a belt of mineral occurrences and a chain of igneous looking rocks heighten the interest of this boundary (Geology Survey and Mines Bureau, Sri Lanka, 2011; Geology Survey and Mines Bureau, Sri Lanka, 2008). Figure 02 shows the H/V boundary and the Dolarite dykes in Sri lanka.

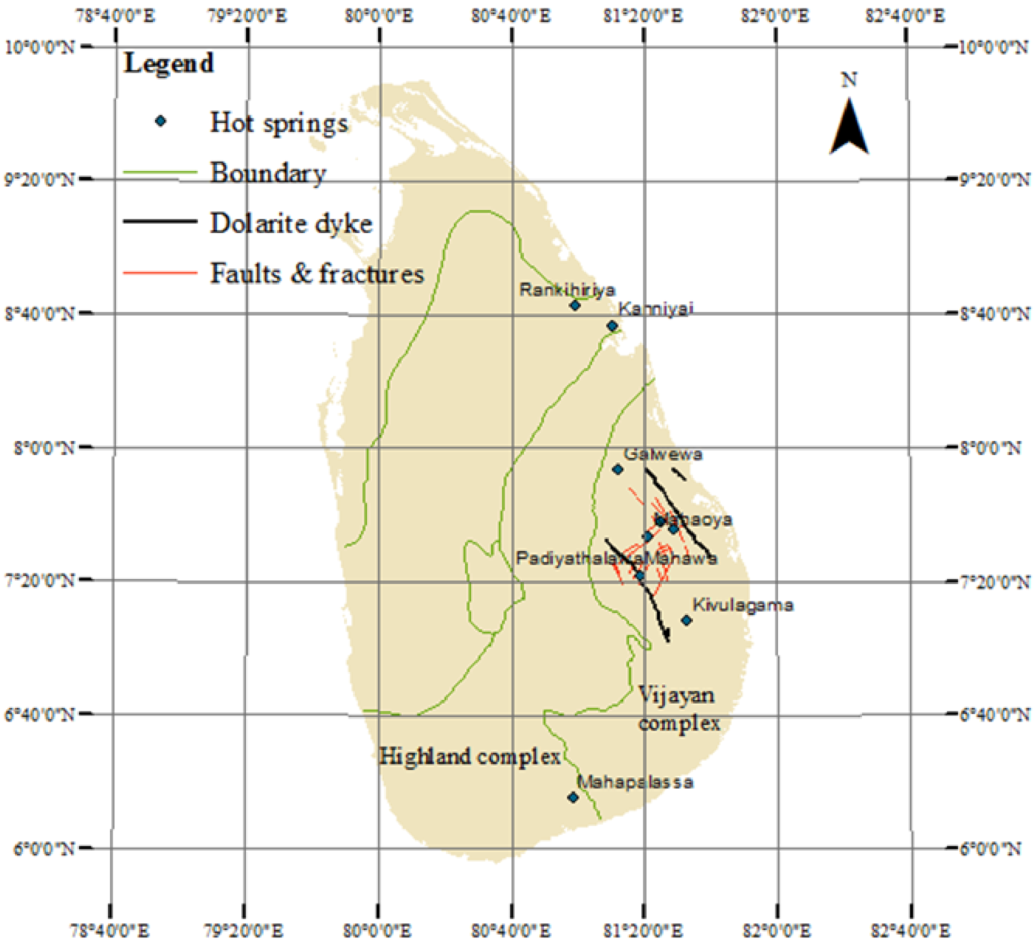

Figure 02: H/V boundary and the Dolarite dyke extension in Sri Lanka

The hot spring series in Sri Lanka can be clearly identified with the deviation of the location of the H/V boundary. The actual source of the hot springs is still not confirmed. The temperatures of those springs are in the range of 40ºC to 70ºC. Kapurulla hot spring recorded the highest surface temperature with a mean of 70ºC. Therefore these springs are in the suitable temperature range for research to find the feasibility of geothermal resource in Sri Lanka.

The following initial studies were conducted at the hot spring related areas: a. Geological studies, b. Geochemical studies, c. Geophysical studies

a. Geological studies

Geological studies identified a linear fracture pattern in this area. They were always inter-connected and have driven through the hot springs. The hot springs were identified as hot water coming out of the field and it was suggested that the channeling of the water from source to surface is done via fractures (Geology Survey and Mines Bureau, Sri Lanka, 2011; Geology Survey and Mines Bureau, Sri Lanka, 2008).

b. Geochemical studies

Hydro geochemical and isotopic characters of hot spring water and the related normal spring water confirmed that both have the same source and have less interaction with the rock-water and the limited depth penetration. Those studies revealed that the type of water in the hot spring is meteoric and similar to the type of normal water springs. From the type of the water, it was obvious that the precipitated water driven through the deep circulation not up to the crust comes to the surface as hot springs whereas the other normal water springs have shallow water circulation. This study gives a clue for the geothermal source which is not in a very deep environment.

c. Geophysical studies

The deep geophysical survey conducted in these areas suggested that there is no geothermal water flowing path at the bottom of the hot springs and hence should be away from the survey lines (Hobbs, B.A., et al, 2013).

Although it is conventionally believed that the source of the hot spring is the H/V boundary, it is really unlikely, since some of the geothermal fields were far away from the H/V boundary. Another idea for the origin of the hot springs is that they come from the

Dolarite dykes (Senaratne, A. et al, 2011). Dolarite dykes are young intrusions dated after the main Gondwana break-up and can be seen close to most of the hot springs.

1.1 Scope

The scope of this study was to identify the Dolarite dykes with its special relation to the hot springs.

2. RESULTS AND DISCUSSION

2.1 Geological setting of the Dolarite dyke and the hot springs

There are two major Dolarite dykes found in Sri Lanka. Other than these two major Dolarite dykes there are some short extended Dolarite dykes as well. Figure 02 shows the Dolarite dyke extension in Sri Lanka. It clearly shows that the fractures connect the dykes and the hot springs.

2.2 Sub-surface characters of the hot springs in Sri Lanka

The MT surveys were conducted through the hot springs and the related areas (Hobbs, B.A., et al, 2013). Figure 03 shows the 2D resistivity profile obtained from the MT survey results for two different areas.

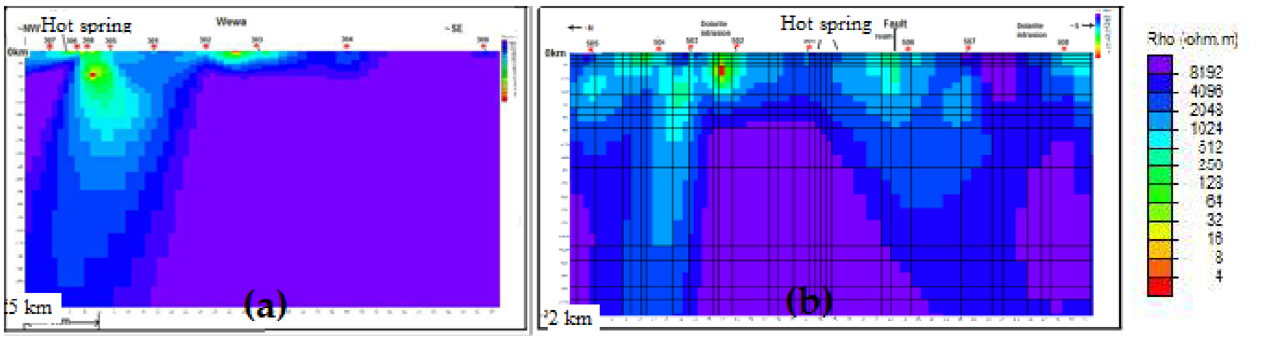

Figure 03: (a) 5 Km extended MT profile from Kapurulla hot spring, (b) 2 Km extended MT profile from Padiyathalawa hot spring (Hobbs, B.A., et al, 2013)

In Figure 03 (a,b) low resistivity zones are found at very shallow depths just beneath the hot spring. Those figures also clearly imply that either the path from the source to the hot spring might be very thin or not present beneath the hot spring (Kearey, P., et al., 2002).

A 2D resistivity survey was conducted near the hot spring in Padiyathalawa to verify the nonexistence or a thin low resistivity path at shallow depth just beneath the hot spring.

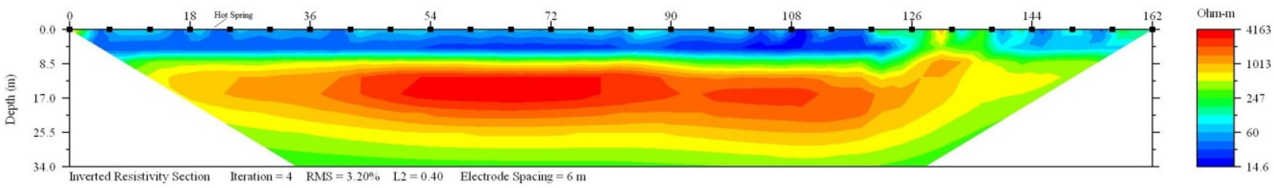

Figure 04: 2D profile near Padiyathalawa hot spring

The Figure 04 clearly implies that the source is not exactly beneath the hot spring, since there is no thin low-resistivity path at shallow depth.

2.3 Surface and sub-surface characters of Dolarite dykes in Sri Lanka

Dolarite dykes of Sri Lanka are composed of fine grained ferro-magnesium mineral assemblages. The general width of exposed dykes is in the range of 5-10 m, with sporadic bulky occurrences along the extension of the dykes having a width over 40 m. Two major Dolarite dykes were identified and mapped with an extension of more than 50 km. This is shown in the Figure 02 (Geology Survey and Mines Bureau, Sri Lanka, 2011; Geology Survey and Mines Bureau, Sri Lanka, 2008).

Apart from the two main dykes, Dolarite dykes appear as short extensions and in many instances follow the same direction as the two major dykes, predominantly in NNW-SSE direction.

Chronological analysis confirms that Dolarite as late intrusions to the old-cold Precambrian shielded rocks of Sri Lanka during the 160 – 170 Ma time period (Yoshida, M. et al., 1989; Funaki, M. et al., 1989; Emmel, B. et al., 2012; Yoshida, M. et al., 1992). Considered with the age of two major lithotectonic complexes of Sri Lanka: Highland and Vijayan, Dolarite dykes are late intrusions and the cross cutting nature of the country rock is prominent (Geology Survey and Mines Bureau, Sri Lanka, 2011; Geology Survey and Mines Bureau, Sri Lanka, 2008). However, the dykes dominate in the Vijayan Complex and almost terminate at the Highland complex margin. This suggests that the extensional forces acted upon the two complexes during the formation of dykes were different; the Vijayan crust probably thinner than that of the Highland crust where intrusions easily penetrated to the surface (Geology Survey and Mines Bureau, Sri Lanka, 2011; Geology Survey and Mines Bureau, Sri Lanka, 2008).

The average magnetic susceptibility value of Dolarite was 40 x 10^{-3} (SI units). This is well over the susceptibility values of the country rocks suggesting a strong remnant magnetization for Dolarite dykes. Strong unique magnetic signals specifically for Sri Lanka are shown in Figure 05.

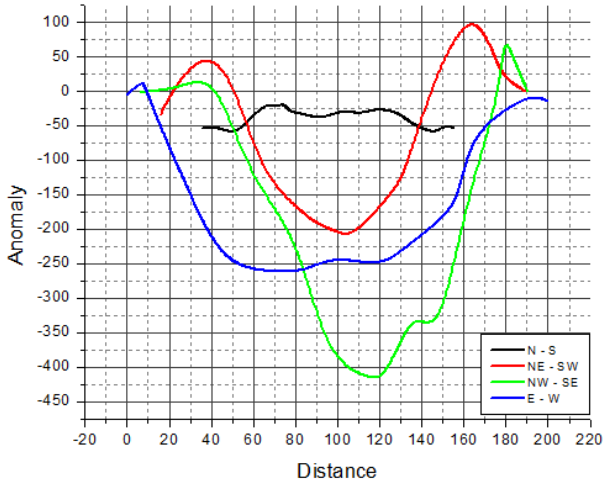

Figure 05: Common pattern of magnetic signature of Dolarite dyke observed in Sri Lanka

2.4 Dolarite and the geothermal source

The Dolarite dyke is the youngest intrusion in Sri Lanka and made of igneous material. Therefore it is suggested that heat existed in these dykes at a certain depth.

To assess the relationship between Dolarite dykes and the hot spring, the fracture pattern of the related sites were deeply studied. Kapurulla and the Padiyathalawa were selected as our current study sites.

2.4.1 Kapurulla hot spring field

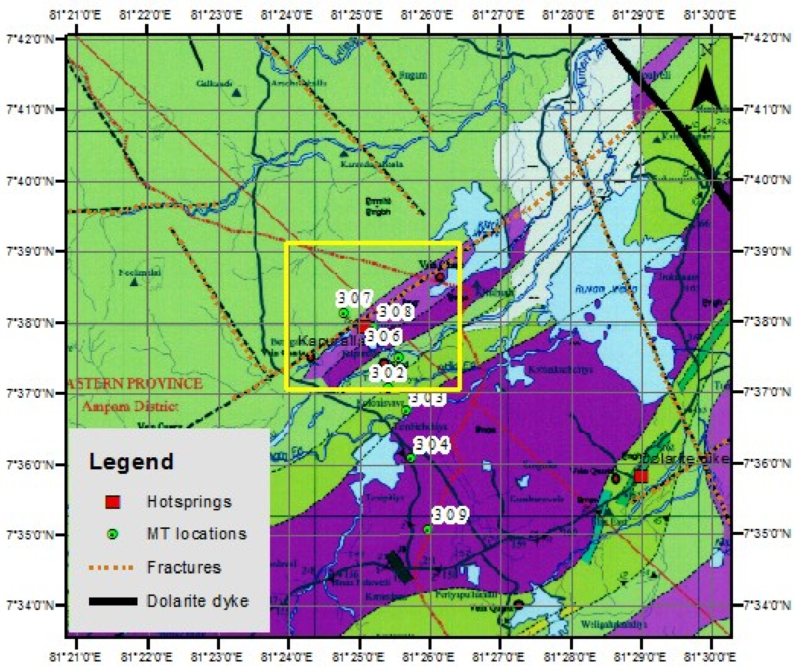

Figure 06: Fracture pattern, Dolarite dyke extension and the hot springs in the Kapurulla area

Figure 06 shows the fracture pattern, Dolarite dyke extension and the hot springs in the Kapurulla area. There is a major fracture driven through the hot spring series and connected to the Dolarite dyke. A ground magnetic study (Gobashy, M.M, et al, 2008) was conducted in this area to identify the fracture direction near the hot springs (Figure 07).

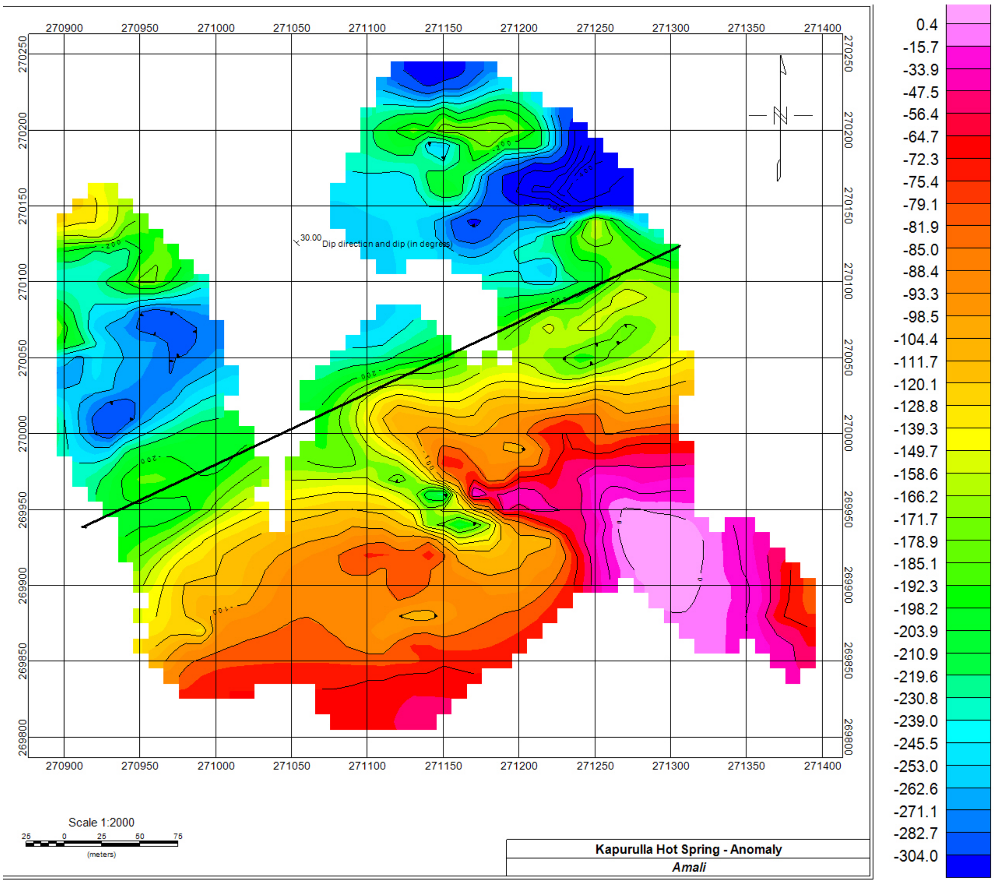

Figure 07: Magnetic anomaly of the fracture near to the Kapurulla hot spring

The magnetic anomaly distribution (Figure 07) clearly shows the fracture extending in the South-west to North-East direction. Upward continuation depicts that it extends to the depth itself.

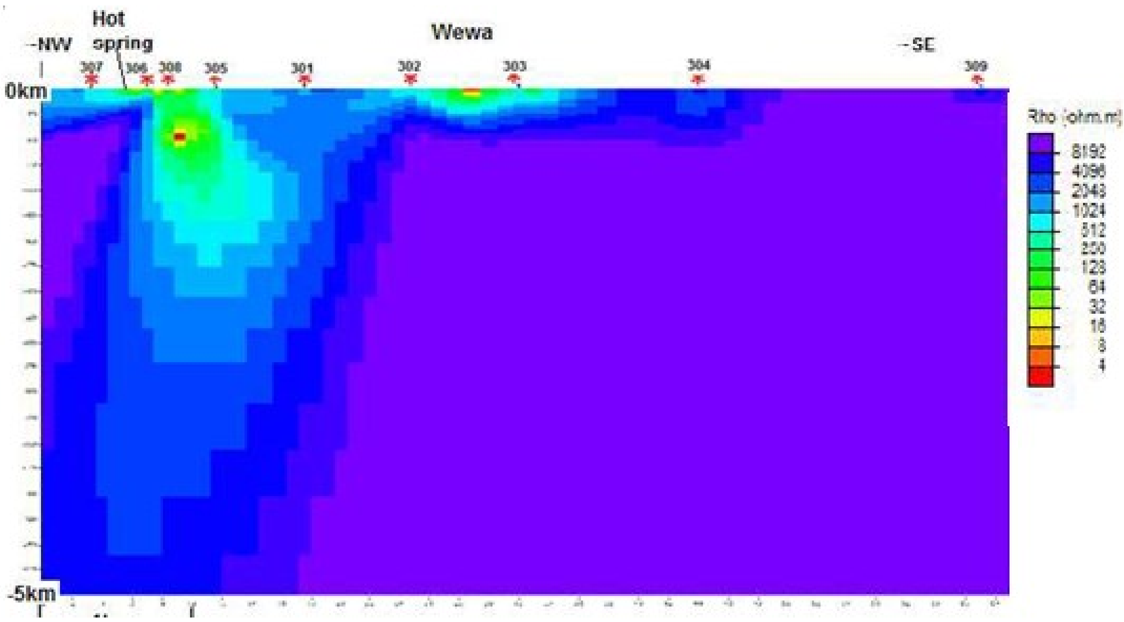

Figure 08: 5 Km extended MT profile from Kapurulla hot spring field

Figure 08 shows the MT profile from Kapurulla conducted by Hobbs, B.A., et al, 2013. There are 9 MT sites and they are aligned with the hot spring and the Rugam tank (Wewa) itself. Same figure shows that the low resistivity zone extends to the N-W direction, site 305 to 307.

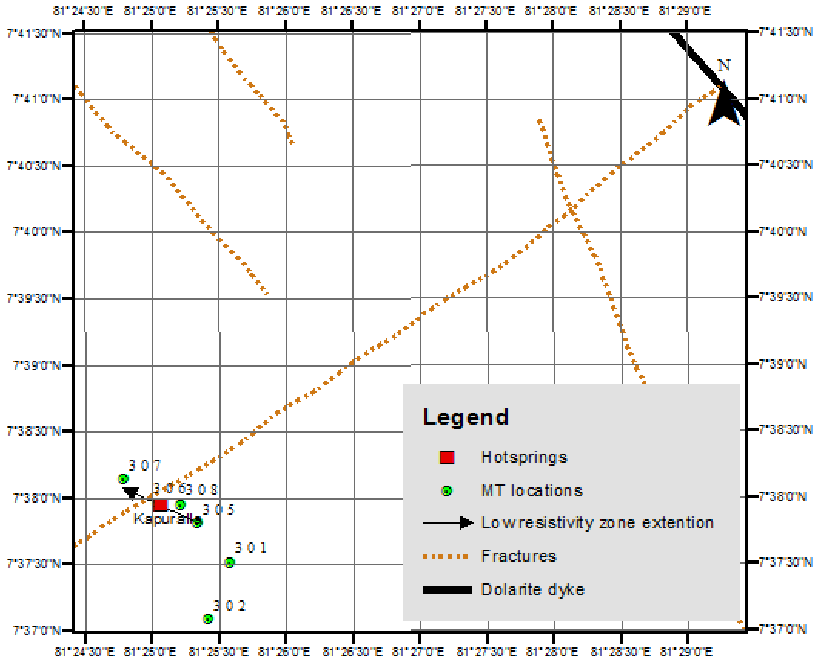

Figure 09: Low resistivity zone extension of the Kapurulla hot spring field

Figure 09 shows the low resistivity zone extension direction and the fracture pattern. It is clearly seen that the low resistivity zone extends to the fracture and that the fracture cross cuts the Dolarite dyke. This pattern is common and can be easily observed in most of the hot springs in Sri Lanka.

2.4.2 Padiyathalawa hot spring field

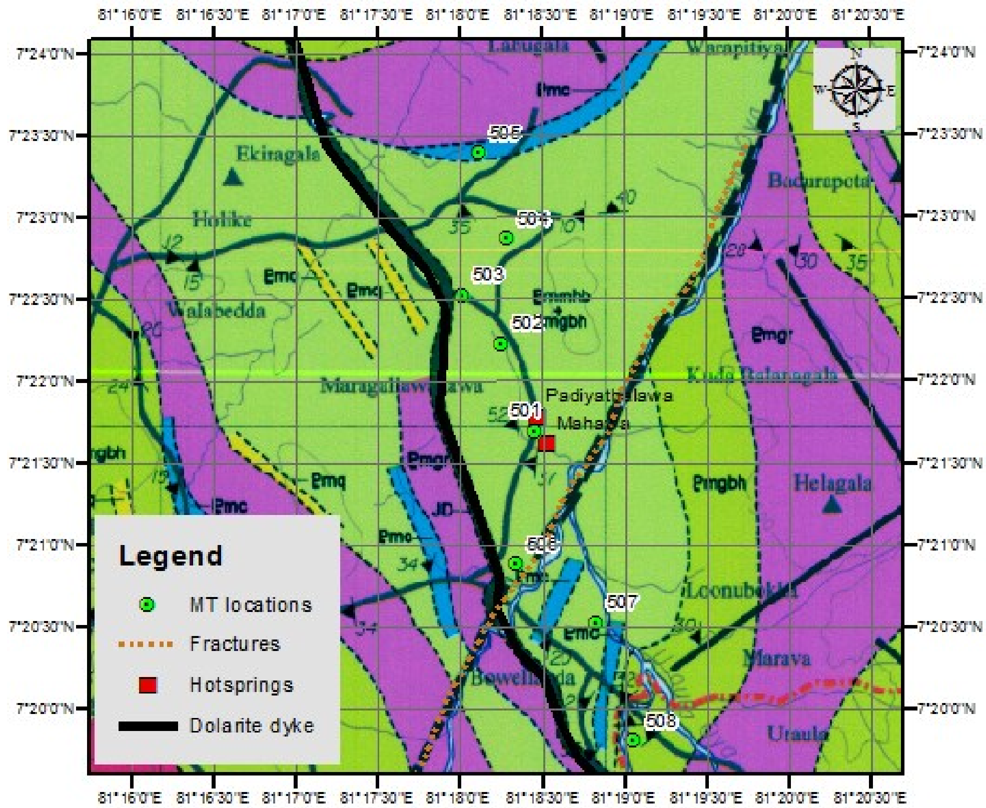

Figure 10: Fracture pattern, Dolarite dyke extension and the hot springs in the Padiyathalawa area

Figure 10 shows the fracture pattern, Dolarite dyke extension and the hot springs in the Padiyathalawa area. MT survey location 503 stays very close to the Dolarite dyke.

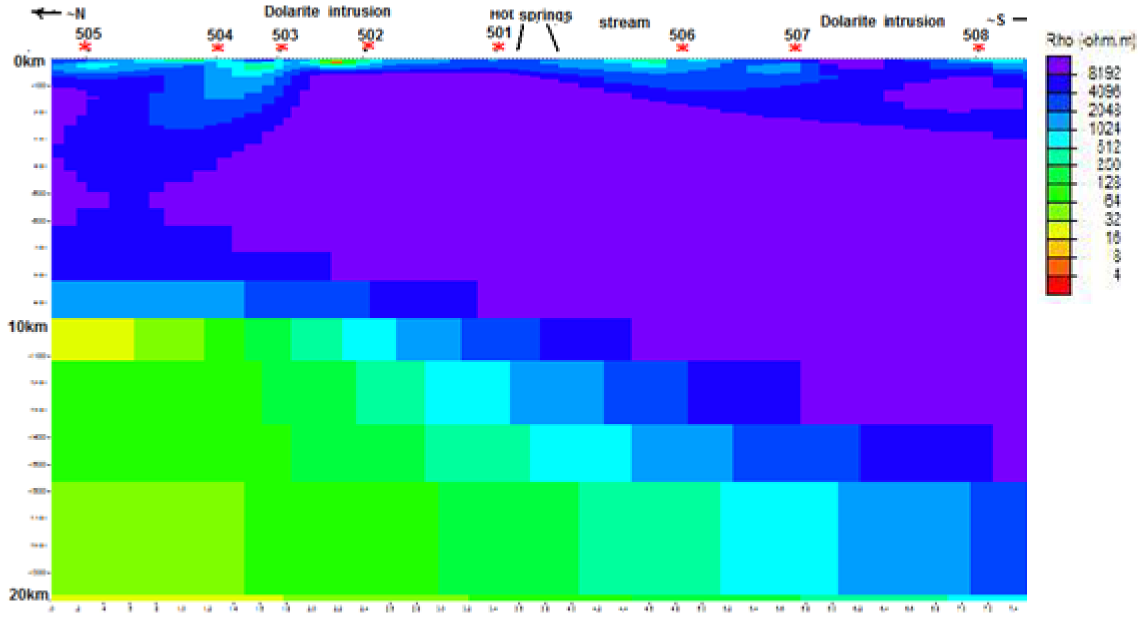

Figure 11: 20 Km extended MT profile from Padiyatalawa hot spring field (Hobbs, B.A., et al, 2013)

Figure 11 shows the low resistivity zone, just 10 km beneath the Dolarite dyke. It is connected to the surface with a very thin fracture.

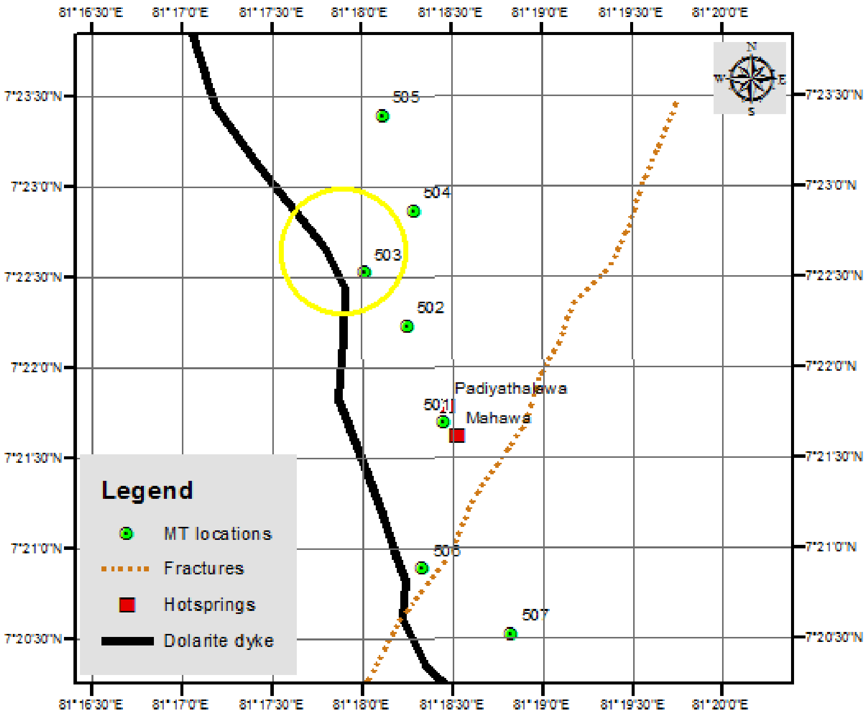

Figure 12: Low resistivity zone extension of the Padiyathalawa hot spring field

The Figure 12 interprets the fracture pattern, the Dolarite dyke and the MT survey locations. The yellow colour circle shows the area containing the low resistivity zone. It is visible from the figure that the low resistivity zone comes near to the Dolarite dyke.

3. CONCLUSION

It is not possible to find the geothermal source exactly beneath the hot spring. Most of the time the hot water comes through the fracture connected to the deep driven fracture and it is always connected to the Dolarite dyke. In some cases the root of the hot spring directly links to the Dolarite dyke. It is advisable to find the source closer to the Dolarite dyke than to the hot spring. The

Dolarite dyke plays a huge role in the geothermal potential in Sri Lanka. The schematic diagram of the proposed model can be seen in Figure 13.

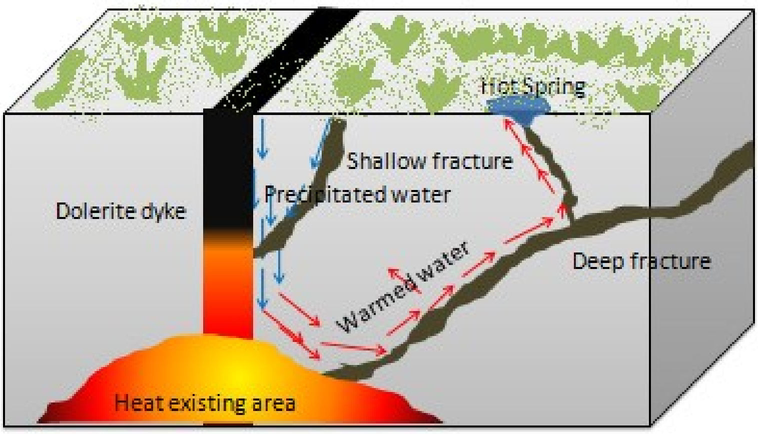

Figure 13: Schematic diagram of the proposed model

FUTURE STUDIES

It is more effective to take ideas from thermal flow of the ground and the actual source by conducting MT surveys through the Dolarite dyke and the related fractures. It will be important to conduct detailed magnetic surveys from the Dolarite dyke to identify the source depth and compare it with the MT results.

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