PROCEEDINGS, Thirty-Sixth Workshop on Geothermal Reservoir Engineering
Stanford University, Stanford, California, January 31 - February 2, 2011
SGP-TR-191

EXPLORATION OF A POTENTIAL GEOTHERMAL RESOURCE AT WAHAWA PADIYATALWA AREA SRI LANKA

Atula Senaratne and Deepal Chandima

Department of Geology ,University of Peradeniya
Peradeniya ,Sri Lanka
e-mail: atula.senaratne@gmail.com , deepalchandima@gmail.com

ABSTRACT

Geothermal exploration program along two major lithologic units Highland and Vijayan complexes was carried out by Department of Geology , University of Peradeniya ,Sri Lanka in 2009-2010 . Sri Lanka is not an active volcanic region or plate boundary .Geothermal source might be from different source. The source of hot dry rock and geothermal reservoir and flow regimes have not be extensively explored. The Vijayan Complex is considered here as the priority region as it consists youngest intrusions of dolerite dykes with K-Ar age of 150 Ma. The presence of thermal springs in association with a dyke indicates that the thermal component may have been added from relatively young intrusion.

.
Wahawa, Padiyatalawa hot springs field is characterize by NNW-SSE trending dolerite dyke extending 20Km in length. Surface temperature of the springs range 50^0-60^0C.Geology mapping ,structural geological analysis and surface springs temperature analysis and hydrogeologic setting suggest late deformation and deep seated fracture zone in the dyke facilitate thermal water which are circulating through the dyke from Maha Oya catchment ,recharge area in SSW region .

INTRODUCTION

Even though Sri Lanka is not an active volcanic region or situated within proximity to an active plate margin has many geothermal resources having potential for development as a sustainable energy resource. Surface manifestation of thermal springs has been recorded from ancient times and even ruins of a spa (Figure 1) dedicated to Buddhist monks is seen in the vicinity of Wahawa springs. However, no detailed geological exploration has been done until recently. With the objective of getting better scientific understanding of geology, structure, hydrogeology and the thermal system, the Department of Geology of the University of Peradeniya carried out a exploration around Wahawa, Padiyatalawa area during the period of 2009-2010.

This paper summarizes the results of exploration and some previous work related to geology of the study area with special emphasize on the dolerite dike which may have been the source of the heat of the geothermal system.

With the available resources, the study was planned to gather data from literature, aerial photographs, and satellite images and from detailed geological and thermal mapping. Geological structure has been interpreted from satellite images and springs were found falling on a NE trending lineament. Temperature surveys were carried out at all the springs scattered in the area of interest.

Figure 01: Ruins of a Ancient geothermal spa.

The study area is situated about 10 km South–East of Padiyatalwa town (7 21 N 81 18 E) , southern part of the Ampara District, in the eastern province of Sri Lanka (Figure 2) . Wahawa-Padiyatalawa is situated at 100m above MSL. The Maha Oya river is the main surface water source which run through a valley cutting through the dolerite dike formation for a distance of about 12.4Km with a width of about 2 km across the Wahawa area.

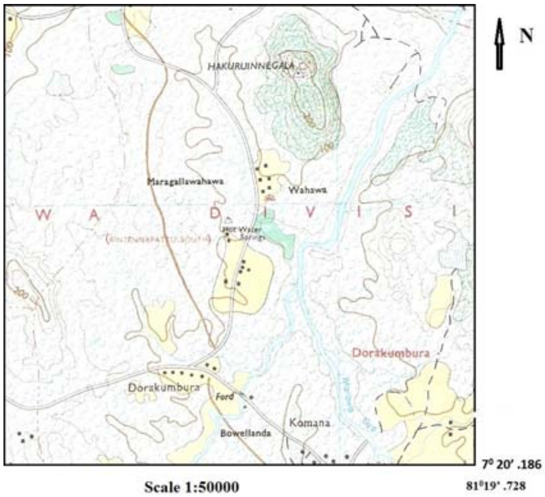

Figure 2: Location map of the study area.

GENERAL GEOLOGY OF SRI LANKA

The Precambrian basement of Sri Lanka is a small fragment of the Godwana super continent and over 90% of the Island is made up of amphibolites to granulite grade metamorphic rocks. The remainder is covered by sedimentary sequences belonging to Jurassic,Miocene and Holocene periods. The Proterozoic crust of Sri Lanka is traditionally divided into three major lithological units on the basis of rock types and metamorphic grades (Cooray,1978;1984).Subsequently Kröner et al.(1991) and Cooray(1994) revised the subdivision of Precambrian Sri Lanka ,based mainly on geochronological ,petrological and geochemical data . Namely Highland Complex, Vijayan Complex and Wanni Complex (Figure 3) .

Figure 3: Geology of Sri Lank (after Cooray ,1984).

STUDY METHODOLOGY

Satellite images from google earth were used to demarcate the structural features of the study area and 1:50000 contour map were aided during the study. Thermal springs temperature measurements and geology and structural features were confirmed during the field excursions. Image map was prepared to using contour data from 1:50,000 map and Surfer 09 demo version to forecast the structural trend of the study area.

GEOLOGY OF THE STUDY AREA

The study area belongs to the Precambrian Vijayan complex geological subdivision of the country. Vijayan complex terrain is underlain by granites, granitic gneisses, quartzites and dolerite bodies (Dahanayake and Jayasena ,1983) Unmetamorphosed dolerite dikes occurs cutting across the granitic gneisses of the Vijayan complex (Coates,1935, Cooray,1978).Their ages are uncertain. Coates (1935) considered these dikes to be of late Proterozoic age .Vitanage (1987) considered these dikes to be Mesozoic, judging from their distribution pattern. Jurrassic-Cretaceous K-Ar ages have been obtained for the dike at Wahawa area. Based on the K-Ar dating of dolerite dike present in the area to be in the age group of Triassic-Cretaceous 152.6+_ 7.6 Ma (Yoshida et al 1988),where as other Vijayan complex rocks of the area have been formed 1150 Ma during Precambrian (Dahanayake and Jayasena 1983). The dolerite dike occurs westward of the thermal springs. The dike is 50m in width and more than 20km in length. Strike of the dike is N 60^0 W.

Lithological Units

Major rock types found in the study area are hornblende biotite gneiss , granites and migmatitic gneiss with occasional pegmatitic bodies. The younger intrusive rock, the dolerite dike was in association with these rocks (Figure 4).

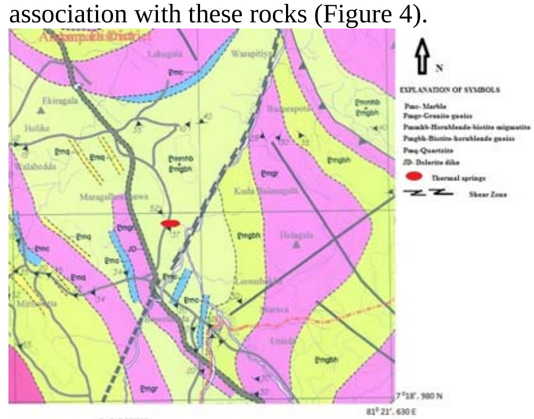

Figure 4: Geology map of the study area.(Source : GSMB 2010).

Structural geology of the Study Area

Eastern contact of Highland and Vijayan Complex is demarcated by shearing at points along the course of Mahaweli river (Vitanage,1972) and this structural feature extends into the northeast towards a deep submarine canyon (Bush et al 1969). The contact zone is characterized by a chain of hot water springs and a series of basic intrusions (Munasinghe and Dissanayake, 1979).

It is evident in the satellite images that the NE trending lineament is represented by the Maha Oya river (Figure 4).

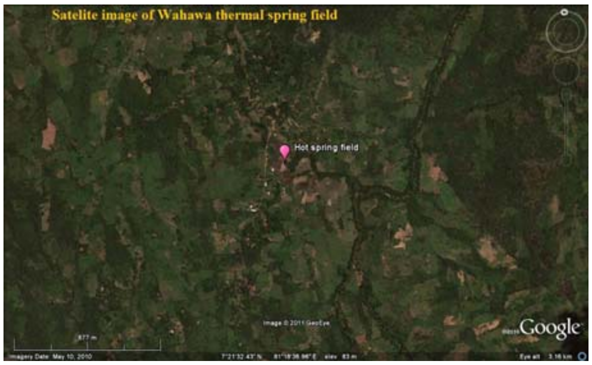

Figure 5: Satellite image of the study area (source ,Google Earth 2010 imagery).

The general lithological trend of the area varying from N-S to NW-SE and is intersected by a NE-SW trending fault structure . This major lineament extends for more than 20 Km across the study area. Maha Oya river flows along this lineament and is clearly visible on satellite images (Figure5).

Study of the satellite images and geological mapping at Wahawa Padiyatalawa area revealed two predominant fracture orientations of NE- SW and NW-SE. The prominent NE fault system likely to accommodate a bulk of the deformation at Wahawa and consequently is probably the primary cause of permeable rock hosting the hydrothermal system. Furthermore, a combination of small pull-apart along the main NE trend, combined with the confluence of the NE and NW trending faults, has created a local zone of dilation and extension, resulting in a region of highly fractured rocks, it is likely that NE faults account for the deep permeability patterns. However, due to the fact that they do exist, are fairly pronounced at the surface, it is probable that the NW faults have a strong influence on shallow permeability patterns.

SURFACE MANIFESTATION OF THE HOT SPRINGS

Geothermal manifestation appear in Wahawa geothermal field as hot springs. Manifestations are spreading around an elongated area trending NW-SE along a 700m long line.

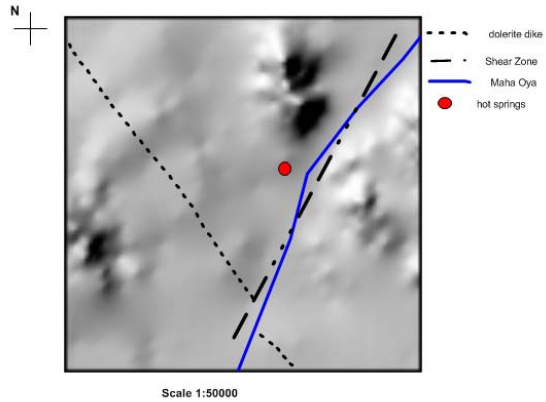

Figure 6: Shaded relief map of the study area.

There are 18 -20 springs ,and the study focused on 4 major springs . Wahawa-1 hot spring has a temperature range of 50 – 52°C with a flow rate of 0.5 L/s. The spring appears in a paddy field along fractures in the granitic gneiss. Physically, the fluids of the hot spring is clear with bubbling sulfurous gas . Wahawa hot spring–2 has measured temperatures between 55 – 60°C with a flow rate of 0.016 L/s, with an area of discharge of about 10x5 m , with sulfurous gas bubbling through mud. Altered minerals are white, black, and brown in color. Wahawa hotspring-3 has a temperature of 51-55°C with a flow rate of 0.017 L/s. The water is muddy with no sulfur scent. Wahawa hot spring- 4 was observed near a fracture in granitic gneiss. It has temperatures between 53 and 55°C with a flow rate of 0.015 L/s. No alteration or sulfur scent was noted in spring no.4.

(a)

(b)

Figure 7: (a) Grayish color of the Wahawa spring 01 (b) view of the Wahawa spring 01.

HYDROGEOLOGY OF THE WAHAWA AREA

Thermal springs are restricted to an area within the valley running in the north-east direction. The water divide of the Maha Oya river basin is at 280 m msl and slope down to below 100m msl where the hot springs emerge. At the point of the thermal springs another valley running in the NW direction intersect the NE trending river valley .

The thermal springs are at the margin of NE trending valley , a short distance upstream of the valley wall towards the NW direction from the confluence of the NE trending major valley and NW trending minor valley .

The tube well drilled down to about 20m depth, yields about 125 liters/minute. It is hypothesized that the distribution of shallow fracture zones is directly linked to the deep seated shear zones. However, there are not enough data to predict the spatial distribution of voids within the zone. The connection between the deeper and shallower void zones is uncertain. In groundwater exploration, it is a common practice to drill through increasingly competent metasedimentary bedrock until the primary reservoir is reached.

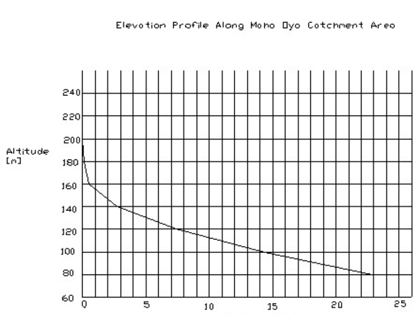

Figure 8: Elevation profile along the Maha Oya catchment which runs through the major NE trending valley.

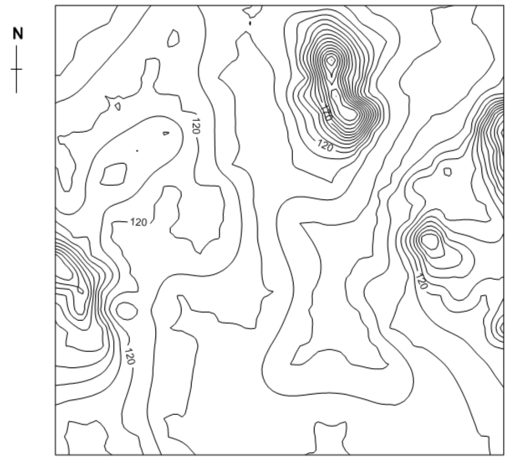

Figure 9: Contour map showing the major valleys of the study area.

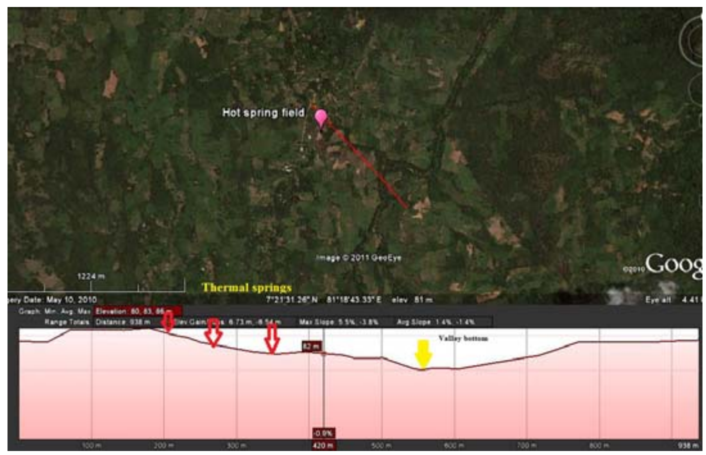

Figure 10: satellite image and elevation profile showing the NE trending Maha Oya stream valley bottom and relative occurrence of thermal springs .

CONCEPTUAL MODEL OF THE THERMAL SPRINGS

The requirements for a geothermal system to exist are (1) a large source of heat, (2) a reservoir to accumulate the heat, and (3) a barrier to hold the accumulated heat . In the Wahawa geothermal area the dolerite dike is considered as the heat source which belong to a relatively younger age group of Triassic-Cretaceous 152.6+ 7.6 Ma (Yoshida et al 1988). A variety of rocks have been found to constitute good reservoirs. At Larderello (Italy) it is fractured limestone and dolomite at the Geysers (U.S.A) it is fissured greywacke; at Wairakei (New zealand) it is pumiceous breccias and tuff; and at Cerro Prieto (Mexico) it is deltaic sands.Good reservoirs could also be formed at geological unconformities and formation boundaries, provided that they are permeable and have good hydraulic continuity and water supply. Geothermal reservoir at Wahawa is associated with highly porous and permeable deep seated fractured granitic gneiss. Meteoric water percolate from Maha Oya river upper catchment area through the upper fractures of the shear zone to deep seated fracture zone provides continuous flow of water to the system. Less fractured impermeable cap rock with low permeability, overlying the reservoir, prevents the escape of hot reservoir fluids through convection in the Wahawa geothermal field.

As illustrated in figure 11, hot water plume rises up through the mixing zone where cool groundwater flux from Marawa oya stream lowers the temperature toa range between 50 and 60 Celsius.

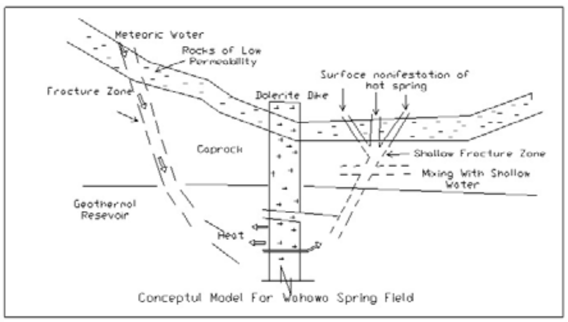

Figure 11: Conceptual model of the Wahawa spring field.

REFERENCES:

Bush, S.A., Bush, P.A. (1969), "Trincomalee and Associated Canyons," Deep Sea research, **16**, 655-660.

Coates,J.S.(1935) “The Geology of Ceylon”. Ceylon Journal of Science (B), **19,** 101-187.

Cooray,P.G.(1978) “Geology of Sri Lanka” .Proc.3rd Regional Conference on Geology and Mineral Resources of SE Asia,Bangkok,Thailand,14-18, 701-710.

Cooray,P.G.(1984) “An Introduction to the geology of Sri Lanka (Ceylon)” ,2nd revised ed. Colombo: National Museums Department ,340.

Cooray ,P.G. (1994) “The Precambrian of Sri Lanka: a historical review”, Precambrian Res., **66**, 3-18.

Dahanayake,K , Jayasena,H.A.H (1983) “Textural Studies of some Granites and Gneisses from the Precambrian Vijayan Complex of Sri Lanka”. National Science Council of Sri Lanka **11**(1), 77-86.

Geology map of Padiyatalawa area 1:100000 Provisional map series (2010) ,Geological Survey and mines Bureau of Sri Lanka.

Kröner,A.,Cooray,P.G,Vitanage,P.W.(1991) “Lithotectonic subdivision of the Precambrian basement in Sri Lanka.” In: Kröner,A.(ed.),The crystalline crust of Sri Lanka.Part 1: Summery of Research of the German-Sri Lanka consortium, Geological. Survey Department of Sri Lanka Prof. Paper **5**, 5-21.

Munasinghe,T, Dissanayake,C.B.(1979). “Is the Highland –eastern Vijayan boundary in Sri Lanka a possible mineralized belt?” Econ.Geol**.74,** 1495-1496.

Vitanage ,P.W.(1972). “Post Precambrian uplifts and regional neotectonic movements in Ceylon” 24th Intern.Geol.congr.Sec**. 3**, 642-654.

Vitanage ,P.W .(1987) “Precambrian and later lineament tectonic event in Sri Lanka”. Geological Survey Department Spec.publ.Geological Survey Department of Sri Lanka,Colombo. IGCP **236**, 33.

Yoshida,M, Funakai,M and Vitanage,P.W. (1989). “Jurassic-Cretaceous dolerite dike from Sri Lanka”. Journal Geological Society of India, **33,** 71-75.