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Geological setting and origin of hot springs in West Malaysia

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Although mMore than sixty hot spring areas have been discovered in the Malaysian Peninsula, the origin and source of hot water in these hot springs are still questionable. The location and geological settings of these hot springs indicates the geographical courseoccurrence of these hot spring areas towardsin two trends. The WWest-EEast trend extends from Langkawi in the WWest to Kelantan and and then toward one site in Terengganu to the EEast. The North- South trend extends from the Thai-Kedah border in the NNorth to two springs in SingaporeJohor in the extreme SSouth. The major common features of these hot springs pearl rope phenomena are their location of these hot springs on or close to granite intrusions and at major fault zones. The recent remote sensing map of some of these hot springs shows their location also on small fractures and/or faults.

These observations are suggestive for a model that combines the cooling magma and the thermal gradient models. The granitic intrusion represents the cooling magma that can increase the temperature of all rocks in the area. These granites bodies have also become embedded in the earth crust continuinge to dispersegive off heat after solidification as a result of the thermal gradient. The sSource of water derivesincludes either from the surface water which enters the underground passages and circulates to great depths and attains the high temperature or it stems from the "old" water in the aquifers. The hot, "lighter," water begins to rise again toward the ground surface, pushed upward by the colder, "heavier," near-surface water. The fault zones also offer rapid penetration of ground or meteoric water to depths where the rocks are hot enough to generate a convective up-flow of hot water. The low SO_4 content in the Malaysian hot springs and absence of volcanic activities near the hot springs in Malaysia decline the possible volcanic origin of the hot waters in these springs and rather is supportive of the theory of a mixed coaling magma and geothermal gradient model. The contaminations of some of these hot springs are most probably due to the near surface mixing with the ocean water or the soil cover. Out of the 61 so far detected areas, in anticipation of a publication in the near future where all areas are considered, this article will focus on three only to show the similarities and differences

Keywords: Hot springs, Malaysia, Geology, Origin

Introduction

Hot spring is a spring that is produced by the emergence of geothermally heated groundwater from the Earth's crust. The hot spring appears as opening on the surface of the ground but the source of water, source of heating as well as possible contamination of this water are hidden beneath the surface of the earth.

It is known that an area may have a geothermal power deposition only if the following four main factors occur at the same place simultaneously (Özgüler, 1984).

1. A source of natural heat of great output,
2. An adequate water supply,
3. An «aquifer» or permeable reservoir,
4. An impermeable cap rock.
5. Fractures/fault along which water descends to the surface.

Three major sources can be postulated for the natural heat in a hot spring site including the volcanic, cooling magma, and thermal gradient. In the volcanic model (e.g. Lui, et al., 2011), water from rain and snow (meteoric water) falls on the highlands of volcanic area. Once deep underground, the water is heated by a body of hot or molten rock beneath the hydrothermal system. The deeper part of the system, where hot water saturates the rock, is called the liquid-dominated zone. At shallower depths, lower pressure allows rising hot water to boil. The subsurface area in which steam and gas prevail in open fractures is called the vapor-dominated zone. Although most of the steam condenses near the surface, some reaches the surface through conduits to form fumaroles (steam and volcanic-gas vents). Additionally, beneath the surface, gas-depleted hot water flows away from the liquid-dominated zone and reaches the surface south of the area to form hot springs. According to the cooling magma model (e.g. Arehart, et al., 2003), a body of buried molten rock takes a long time to cool. During cooling, tremendous quantities of heat are transmitted by conduction into the solid rocks surrounding the magma chamber. Eventually the whole region becomes hot. This heat is enough to melt 0.5-1 tons of ice per second. According to this explanation, the surface water enters underground passages (fractures and faults) and circulates to great depths-as much as 5,000-10,000 feet in some areas there to become heated far above its surface boiling point. The increase in temperature with depth causes a corresponding decrease in the weight (density) of the water. Because of this, the hot, "lighter," water begins to raise again toward the ground surface, pushed upward by the colder, "heavier," near-surface water which sinks to keep the water channels filled. Thus is set into motion a giant convection current which operates continuously to supply very hot water to the thermal areas. In the thermal gradient model (Blackwell et al., 1999), rock temperatures increase about 1°F per 100 feet of depth in the earth's crust. The rain water falling on adjacent hills infiltrates the geological formations and flows to great depths (few kilometers) where it obtains its heat. It then rises up through fractures to the surface as hot water. The aquifer of hot water can be porous and permeable sandstone and/or fractured and dissolved limestone.

Although, more than sixty hot springs have been discovered in the Malay Peninsula of variable water characteristics (e.g. Ho, 1979; Samsudin et al., 1997; Chow et al, 2010), the setting, origin, and origin of hot waters in these hot springs are still questionable since most of these studies focused more about the characteristics, temperature and potentiality of these hot springs as a possible source of geothermal energy and tourism activities. This article, therefore, tries to shed more light on the general geological settings of the hot springs in Malaysia with detailed examples to examine the possible source and origin of these springs and how much these hot spring are matching with the models of hot springs origin.

Geological setting of hot springs in west Malaysia

Samsudin et al. (1997) reported 40 hot springs in West Malaysia. The current study reported and visited another 20 hot springs. Some of these 20 springs were not reported before. The location and geological setting of these hot springs indicates the occurrence of these hot springs in two trends. The Wwest-Eeast trend extends from the Ayer Hangat hot springs at Langkawi Island in the west to the Kg. Labok hot spring, Machang, Kelantan and Kg. La hot spring, Hulu Besut, Terengganu to the east. The North-South trend extends from the Kg. Legong hot spring, Baling, Kedah in the north to the Parit Gerisik hot spring, Batu Pahat, Johor in the extreme south (Fig. 1). The major common features of these hot springs are the location of these hot springs on or close to granite intrusions (e.g. Samsudin et al., 1997) and a major fault zones (Harun, 1992). The recent remote sensing map of some of these hot springs shows their location on small fractures (Wagner et al., 2014, submitted). Following are some examples of the geological settings of the hot springs in West Malaysia to clarify these features.

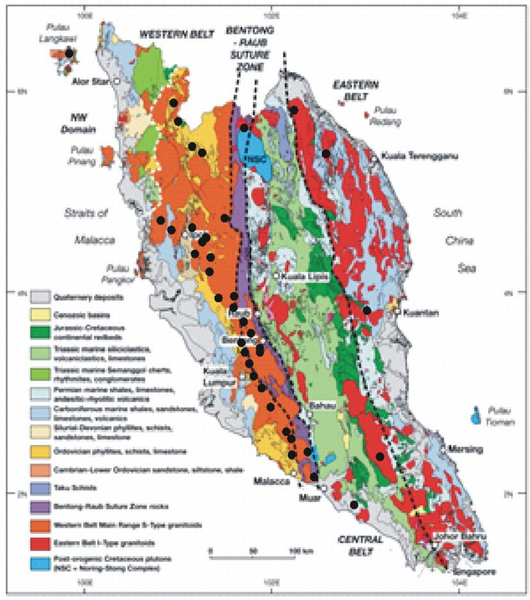

Fig. 1: Geologic map of Wwest Malaysia shows the locations of then 39 hot springs (modified from Samsudin(, (1997)).

Out of the 61 so far detected areas, in anticipation of a publication in the near future where all areas are considered, throughout the next pages we will focus on three only to show the similarities and differences.

Ayer Hangat hot spring

Two main hot springs occur at the Ayer Hangat area that are assigned in the layout map of the so-called "well" eastward and "spring" westward (Fig. 2). With a distance between the two springs of approximately 200 m, the water of both springs is slightly yellowish apart from a suspension of green algae showing little signs of motion. In addition, other two smaller hot springs, called the small and original hot springs, are located between these two main hot springs (Fig. 2). The water in allthe four outcropshot springs is salty and, depending on shade and daytime, the surface temperatures was measured rangeding between 39.4°C and 43.1°C. The Ayer Hangat hot springs are located on alluvium sediments of Recent to Pleistocene age, which is composed of unconsolidated marine mud and sands forming the coastal plains and smaller areas of raised clays, sands and occasional gravels of terrestrial origin inland. The granite appears as a rocky mountain ridges wwest to the Ayer Hangat hot springs. It is an acid, leucocratic, medium to coarse-grained rock (Jones, 1978). It is grayish or slightly greenish in color. The hot springs at Ayer Hangat area areis located more or less on thea NW-SE Kisap thrust (Fig. 2).

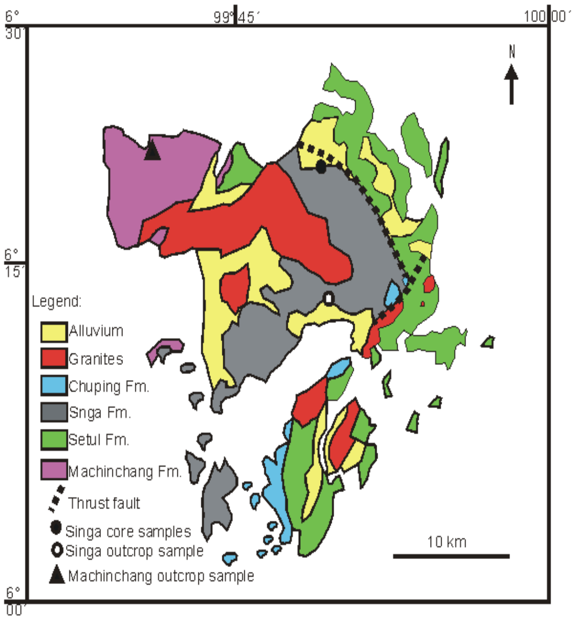

Fig. 2: Geologic map of Langkawi Island shows the locations of the hot springs at Ayer Hangat.

Fig. 3: Field photo of Ayer Hangat hot springs.

Ulu Slim hot springs

Four hot springs were reported at the Ulu Slim area. It is a small town in Perak about 100 km from Kuala Lumpur. The springs with the highest temperature (104°C) of any surface findings throughout the peninsula is~~It is~~ situated in the southern part of Perak, ~~and is~~ 20 km north of Tanjung Malim and about 100 km ~~(driving time 1hour)~~ from Ipoh. It ~~it'~~s determine~~confin~~ed at~~to~~ latitude 3°54' to 3°58' north and longitude 101°30'to 101°34' E~~e~~ast. The area is dominated by granitic rocks with minor metamorphic rocks to the S~~s~~outhwest of the area. Two sets of faults are detected in the area, of N-E and NE-SW trends. The hot springs are located on the granite intrusions along the faults (Fig. 3).

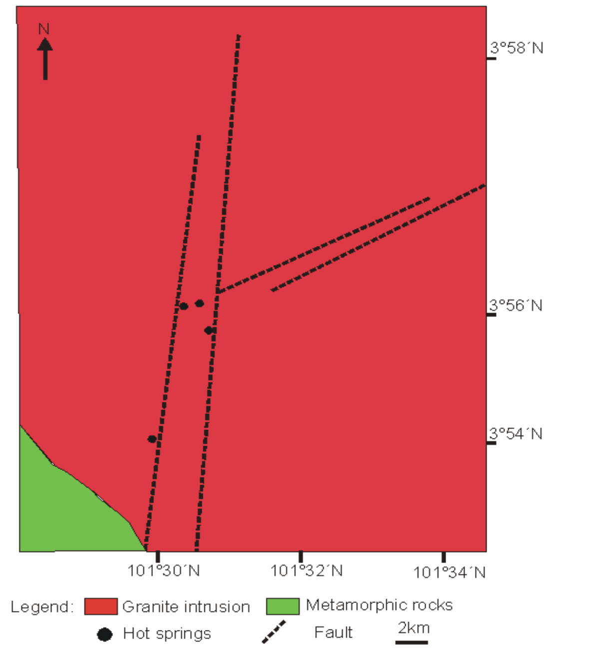

Fig. 4: Geologic map of the Ulu Slim area shows the locations of hot springs.

Fig. 5: Field photo of Ulu Slim hot spring.

Lojing hot springs

Lojing hot springs are located at the northeast area of Cameron Highland and southwest of Gua Musang. The site~~I~~ ~~it'~~s ~~confine~~located ~~ond to~~ latitude 4°39' to 4°45' N~~n~~orth and longitude 101°32'to 101°39' E~~e~~ast. The area is divided into two main lithological types of igneous and metamorphic rocks, which are respectively the Triassic-Jurassic age and Ordovician-Silurian, respectively (e.g. Ismil et al., 2002; Mohamed et al., 2001). The ~~All~~ hot springs found in Lojing area are concentrated along the main granite Great Range. It also exists in the direction of alignment of the northeast-southwest trend representings~~s~~ a major tectonic peninsula and the main focus is the hot locality canggan tectonics (Fig. 4).

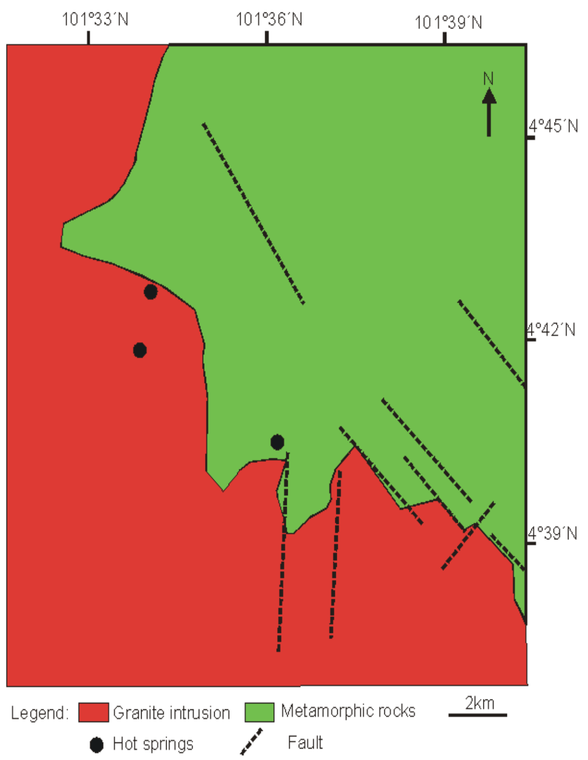

Fig. 6: Geologic map of the Lojing area shows the locations of hot springs.

Fig. 7: Field photo of Lojing hot spring.

Discussion

The geological studies indicated that the occurrence of thermal springs in both Peninsular case studies show~~s~~ a distinct pattern that is considered to be structurally controlled and probably genetically related to granite intrusive and post magmatic activities (Bach, 1991). It is observed that most of the hot springs is located either in or close to granitic masses or along the major fault or shear zones. Other thermal springs occur at the granitic-sedimentary contacts or within sedimentary rocks near the granite contacts.

These observations are suggestive for a model that combines the cooling magma model and the thermal gradient model (Fig. 5). The granitic intrusion represents the cooling magma that can increase the temperature of all rocks in the area. Their residual heat is probably in the order of 700 - 1200°C (Samsudin et al., 1997). These granites bodies have also become embedded in the earth crust continuinge to give off heat after solidification as a result of the thermal gradient. Source of water includes either the surface water enterings underground passages (fractures and faults) and circulatinges to great depths ~~and~~ attainings the high temperature or the "old" water in the aquifers. The hot, "lighter," water begins to rise again toward the ground surface, pushed upward by the colder, "heavier," near-surface. The geographic distribution of the hot springs as illustrated by the map appears to follow a NNW-SSE alignment which represents the main tectonic trend of the Malay Peninsula. A greater concentration of the springs is noted at localities of major fault zones (Harun, 1992). These permeable zones offer rapid penetration of ground or meteoric water to depths where the rocks are hot enough to generate a convective up flow of hot water.

The chemical composition ~~of~~of the Ulu Slim's hot springs water in the volcanic model is~~are~~ generally characterized by relatively high SO4 concentrations (e.g. Homma and Tsukahara, 2008; Yoshike, 2003). Generally speaking, t~~T~~he low SO4 contents in the Malaysian hot springs (e.g. Ho, 1979; Samsudin et al., 1997) is supportive of the mixed coaling magma and geothermal gradient model that has been postulated for the origin of the hot springs in Malaysia. The exceptional high content~~s~~ of SO4 in the hot spring water at the Ayer Hangat area is ~~are~~ related to the contamination of this aquifer~~water~~ by the saline water from the ocean via the Kisap thrust fault that connects the hot spring with the ocean. The high Na, Cl and Mg, as well as the saline taste of the water supports this interpretation. The high clay and iron oxides contents in other places like~~the~~ Pengkalan Hulu (Kedah) or Baranang (Selangor) hot springs is most probably due to the near surface mixing with the soil cover.

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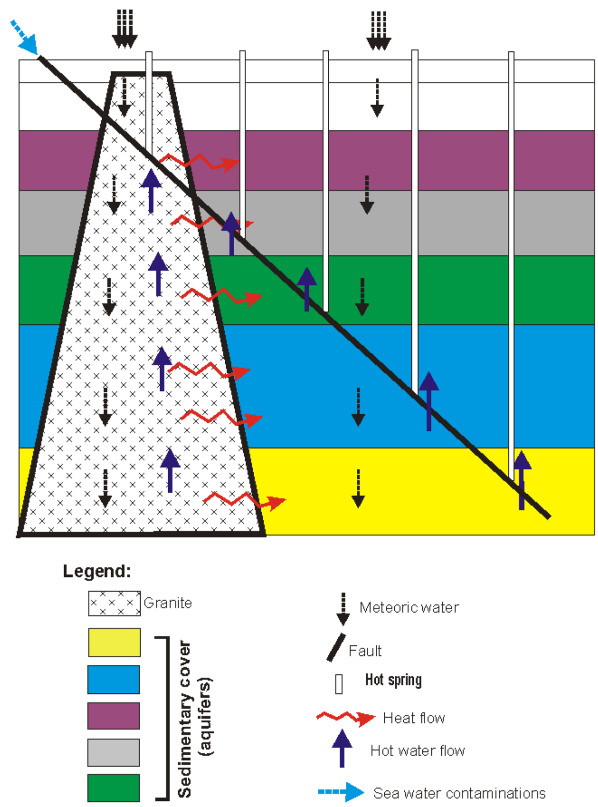

Fig. 8: Geologic map of the Lojing area shows the locations of hot springs.

Conclusions

More than sixty hot spring areas have been reported in West Malaysia. The location of these hot springs on or close to granite intrusions and a major fault zones as well as the general low SO4 contents suggested a combinatione model between the cooling magma and the thermal gradient models. The granitic intrusion represents the cooling magma that can increase the temperature of all rocks in the area, while faults represent the permeable zones, which offer rapid penetration of ground or meteoric water to depths where the rocks are hot enough to generate a convective up flow of hot water. The contaminations of some of these hot springs are most probably due to the near surface mixing with the ocean water or the soil cover.

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