RE-EXPLORING THE GEOTHERMAL POTENTIAL OF WEST MALAYSIA

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ABSTRACT

Unlike adjacent countries as Indonesia or the Philippines that cover 27% of its electricity supply, the assessment and later utilisation of renewable geothermal resources in Malaysia remains still a hidden treasure. In order to assist the Malaysian government on striving to reduce 40% of CO_2 until 2020 by considering geothermal energy, our first surface-near reconnaissance study sets the initial milestone outlining its potential for Peninsula Malaysia. A geothermal map indicating the existence of two potential fault lineaments (NNW-SSE and E-W) is devised. This map is shaped by 57 mostly lined-up hot spring areas which are explored in detail. The temperature of the aquifers (sub-surface temperature) in at least 13 hot springs areas is measured to be at least 100 ºC which is a prerequisite for viable clean electricity production based on novel ORC- or Kalina Cycles. In at least 7 most promising cases, resistivity survey results can tell if the depth of the necessary rigs to be drilled might be less than 100 m which translates into cost-effectiveness. Even if it turns out that the geothermal potential of Peninsula Malaysia can nowhere be used for renewable energy, it can be reconsidered for tourism, green district cooling and aquaculture.

Keywords

Geothermal Energy, Reconnaissance Study, Electricity Generation, Enthalpy, Geothermal Gradient, Viability Study.

ABSTRAK

Tidak seperti negara-negara jiran yang bersebelahan seperti Indonesia atau Filipina yang meliputi 27 % daripada bekalan elektrik, penilaian dan penggunaan sumber geotermal bumi yang boleh diperbaharui di Malaysia masih tersembunyi dan belum diterokai. Dalam usaha untuk membantu kerajaan Malaysia dalam usaha untuk mengurangkan 40% daripada CO2 sehingga 2020 dengan mempertimbangkan tenaga geotermal, kajian pertama kami di sub permukaan menjadi perintis yang akan menggariskan potensinya untuk Semenanjung Malaysia. Peta geotermal menunjukkan kewujudan dua potensi lineament sesar utama (NNW - SSE dan EW) adalah dirancang. Peta ini dibentuk oleh 57 kawasan air panas yang menbentuk satu garisan yang kemudian diterokai secara terperinci. Suhu akuifer (suhu sub-permukaan) dalam 13 punca air panas di kawasan yang diukur adalah sekurang-kurangnya 100 º C yang merupakan prasyarat untuk pengeluaran tenaga elektrik yang bersih yang berdaya maju berdasarkan novel ORC atau Kalina Kitaran. Dalam sekurang-kurangnya 7 kes yang berpontensi, hasil daripada tinjauan profil kerintangan boleh menentukan jika kedalaman pelantar yang perlu digerudi mungkin kurang daripada 100 m yang boleh menjiamtkan kos. Walaupun ternyata bahawa potensi geoterma Semenanjung Malaysia tidak boleh digunakan untuk tenaga boleh diperbaharui, ia boleh dipertimbangkan semula untuk pelancongan, penyejukan dan akuakultur.

1. INTRODUCTION

West Malaysia is located in the centre of the East Asian ring of fire within a geothermal zone of high enthalpy (Sanner, 2005). If an abundance of surface-near hot water can be allocated, enthalpy implies economic viability utilising the heat for recreation, hot water supply, aquiculture and perhaps electricity production. Unlike geological depictions, only the map of Major Tectonic Plates of the Earth shows that West Malaysia along with Indonesia, the Philippines and Japan is located in the same centre of two subducting boundaries hachures on upper plates (vulcan.wr.usgs.gov).

Looking further to a global scale, there are some resemblances to the fracture-zone centered Grand Basin area located between California, Utah and Nevada which is widely utilised for geothermal purposes. The global volcano maps demonstrate, however, that the image of the geothermal potential of West Malaysia totally differs from most global enthalpy areas as no eruptive areas had been reported at all. That led to the obvious neglection compared to the neighbouring countries Philippines and Indonesia which pose no. 2 and 3 on the hit list of geothermal power producers (http://www.geo-energy.org/geo_basics_plant_cost.aspx). In West Malaysia, except a cold mini volcano and one magma stream detected during the following study, thermal springs are the only witnesses of the earth's local hotness (Fouladinejad and Fouladinejad, 2009). Altogether, seventy nine (79) reported localities were reported, but remain undisclosed at the Ministry of Natural Resources and Environment's (NRE) website (http://www.nre.gov.my/english/Pages/Home.aspx). To our knowledge gained through the following reconnaissance study, the geographical locations of hot springs in West Malaysia might pose an unknown phenomenon as only some hot areas are scattered. We will explore whether most follow one or even two previously invisible clear lineaments which are not fully foot-printed by traceable fracture zones.

The objective of this paper is to initially test the theory of two underlying main hot springs fault lines in Malaysia being surface-near envoys of mother earth's hotness with altogether fourty seven (47) locations (out of 57). Furthermore, to attain information how to utilize West Malaysia's detected surface-near geothermal potential for electricity production, hot water supply, district cooling and recreation business. As a side effect, to provide information for touristic developed and underdeveloped sites to create or improve their services and/or to consult them with reengineering. At a later stage and with help of research grants to initiate the development of the first 70-100 kW surface-near geothermal prototype electricity plant based on a low-temperature binary plant strategy on one of seven prioritized hot springs locations.

1. METHODOLOGY- RECONNAISSANCE STUDY

This reconnaissance study is a journey into the known geological set-up of Peninsula Malaysia from a different perspective. This reconnaissance study remains on the ground, as it just changes the perspective away from the known geological map to scrutinize the courses of emerging surface-near water tables. At first, they are entities of mere face-validity. Because of their frequent occurrence rendering their line shape, the question arises what geological structure might lie below. So far, the geological map Malaysia did not include hot springs with any geographical image about these witnesses of the earth’s hotness and underlying faults. Hence, this reconnaissance study started from layman’s scratch to retrieve and gather general first-hand information. Prior to in-depth researches, resistivity survey and research drills, a comprising scientific reconnaissance study was conducted to find out any information about the hot springs. Respectively, to assist in reconsidering the geothermal potential of Peninsula Malaysia in terms of surface and sub-surface aquifer temperatures, flow rates, and a geochemical analysis.

Therefore, this reconnaissance study can be conceived as a “phase 0” prior to any viability consideration to utilise geothermal as renewable energy, as it assists to provide general information for the country about its overall potential. This is the process with our geophysical reconnaissance assessment method. In detail, for desk exploration the following sources were utilized.

1. **Internet-sources**:

To gain as comprising information as possible, content analysis visible for the public was performed looking into local tourist and international websites.

- http://www.malaysia-trulyasia.com/mta/hotsprings.htm. (-> 6 hot springs)
- http://www.travelguide.com.my/hot-springs.htm (-> 11 hot springs)
- http://www.virtualmalaysia.com/destination/Hot%20springs-cat.html (-> 12 hot springs)
- http://www.youtube.com/watch?v=91KWTfrjwow (-> 61 hot springs?).
- http://en.wikipedia.org/wiki/List_of_hot_springs (-> 19 hot springs).

Apart from visual tourist information, the first picture of the number could be gained. It shows that six most common areas are to be found in every of the quoted websites, and, as the sixty one (61) websites of youtube or not disclosed, nineteen (19) prime-site locations could be confirmed. Hence, as a chain reaction, geological archives and journals were allocated where hot springs are listed which enabled this research to browse those locations and dig deeper.

2. **Archives and Journals:**

Bott (1890) reportedly carried out the first documented investigations on thermal hot springs in Selangor and Malacca, almost simultaneously accompanied by the inception of the first spa in Jasin, Malacca (1884). Bott gave an account of the then known occurrences, chemical composition of the hot water and gaseous discharges from these hot springs. In the past recent thirty three years, four kinds of research were conducted, each with a completely different focus, but with lots of synergies:

a. **Mineral water production**: Abdul Rashid (1990) followed by Chow et al. (2010) carried out a regional investigation of fourty five (45) hot springs in the Malaysian Peninsula in order to gage their potential for mineral water production. Field measurements on the temperature, flow rate, conductivity and pH of water from these hot springs were conducted. Their chemical and physical properties were compared with the quality of some commercial mineral water from France, Indonesia, Scotland and Malaysia with the aim of determining whether or not the water from the hot springs could be commercially used as mineral water (Abdul Rashid, 1990). Only two hot springs in Perak in Sungai Siput Selatan met all the requirements for drinking and mineral water, and three or four more can be developed, but with a very low flow rate of on average 2.03 lt/second (Chow et al., 2010).

b. **Tourism**: Abd. Rahim Samsudin et al. (1994, 1996, 1997) studied fourty hot springs of Peninsula Malaysia to gather information on their associated geology, temperature, flow rate and water quality as well as to assess their potential development for tourism industry. These studies which focus only on existing sites, but not hidden potentials in a small distance from the publically accessible main source "identified nine hot springs having a big potential for development, fourteen having medium potential and the remaining seventeen having low or least potential for development. Around that time, most of at least twenty six hot springs spas were incepted. In 2012, according to this reconnaissance study, only eleven can be considered as well maintained and attractive for a commercial number of visitors.

c. **Geothermal Electricity Generation**: Ho (1979) acted as the only pioneer trying to find the geothermal potential for electricity generation in the Northern Peninsula states of Perak and Kedah. Almost a century after Bott, he conducted an exploration of sixteen then known hot springs in Kedah and Perak (nowadays, the count is twenty). Ho (1979) measured the subsurface temperature using the still valid chemical geothermometric tool called SiO_2-test. In parallel in 2011 when the research had been initiated, the research unit of the public electricity provider TNB stated in an article the existence of fourty undisclosed hot springs areas in Malaysia with four of them being proposed for an onwards power generation utilisation in 2016 (Star Online 11/05/2011, Amir Hisham Hashim, 2011).

d. **Geothermal Mappings**: every author mentioned above came up with an own map: Abdul Rashid (1990) with fourty five (45), Abdul Rahim Samsudin (1997) with fourty (40), ASEAN (2005) with fifty one (51) and the former Ministry of Natural Resources and Environment's (NRE) website 2009 with senenty nine (79) (http://www.nre.gov.my/english/Pages/Home.aspx). However, the indication of the locations whereabouts was removed.

3. The **word of mouth** opened the door to further places so that in March 2012 . Fifty seven (57) hot springs above 40 C could be confirmed and explored further (Three locations with 29 ºC are not considered). Mapping the sites led to a ten days expedition tour visiting 27 places in

December 2011 to conduct interviews with stake-holders. In a nutshell, out of a battery of thirty two (32) questions, these are the main items of the word-of-mouth survey conducted with owners, guests and local authorities:

1. Location and connectivity to possible unregistered sites nearby.
2. Accessibility for geophysical resistivity and Transient Electro Magnetic (TEM) surveys
3. Infrastructure database for power supply

4. With the Remote Satellite Sensing we strived to gain a Reconnaissance Map which can witness the morphology and structural elements with spring temperature and thermobarometry for the geothermal potential. As part of the pre-assessment in West Malaysia of a selected area in a pilot run we continued the focus of Ho (1991) looking at Perak (with twenty hot springs having the highest potential throughout the country) and the neighbouring state Kedah.

After visiting libraries, archives and the web to perform basic content analyses, a 10 days exploration tour through the hot springs of the whole Peninsula was performed as the first necessary step to map and stock-take the country's geothermal potential. These onsite visits of twenty seven selected sites, attending to those which are not situated in the jungle or too far away from human settlements. During the visit of twenty seven sites, a list of fifty hot springs areas could be allocated and it was completed in March 2012 with other findings totaling in fifty seven areas.

2. RESULTS AND DISCUSSION

a. Updated Geothermal Map West Malaysia

Asking people on the street in a pilot study about how many hot springs are located in West Malaysia, the awareness is low. On average, the pilot study has proven that even graduates can name 1-2 areas with a high probability at the same time having remembered one or two of the six most well-known sites. None of those who knew about hot spring areas connected them to geothermal energy. The above quoted geothermal studies have gathered vital information, but they claim to be at a premature stage for renewable energy production with the latest results still remaining undisclosed (Star Online, 2011).

As elaborated below, thirty nine (39) out of those fifty seven (57) hot springs this research was able to allocate from the various resources mentioned in the methodology and twenty seven own visits, these are mainly found along the eastern part of the Malaysian Main Range batholith. The geographic distribution of the hot springs as illustrated by Figure 2 appears to follow a clear NNW-SSE alignment which represents the main tectonic trend of the Malayan Peninsula at localities of major fault zones (Zaiton, 1992).

In order to gain a comprising picture, the reconnaissance study yielded the following main result: As the desk exploration (internet, geophysical archives) and the word of mouth as laid out above led to the reconfirmation of fifty one (51) relevant hot springs areas compiled as a comprising map by ASEAN in 2005 and 6 found furthermore. As mentioned, thirty nine (39) of them are following an evident NNW-SSE –Line beyond the geological map, and eight seem to be found on an EW-Line which was never focused on earlier. Previous geological studies only indicated that most of the hot springs are located within or close to the granite rock and associated with fault zones, but not the overall tendency. Therefore, using the ASEAN (2005) map, in Figure 2 six further sites marked with yellow stars are included 2012 as well as the two lineaments:

1. North-South (NNW-SSE)- Line, as described for Kedah and Perak and then further south all the way from Bentong / beyond the Thai border to Sembawang in Singapore with altogether thirty nine (39) locations.

2. East-West (ES-WS) Line starting from the island of Langkawi, reaching over Baling (Kedah), Jeli and south of Kuala Krai (Kelantan) up to La Hot Springs, Besut (Terengganu).

The questionnaire used during the onsite tour comprised of 32 questions remeasuring and revalidating the results of the former studies yielded the following results. As we were not content with revisiting well-mapped locations, but asked systematically for further springs around the area, we discovered further and hotter activities which had never been registered before at six visited locations. In three cases, the measured surface temperatures and flow rates widely exceed what has been recorded in by former researches. In another case, a previous TEM shows a magnificent water table in a surface-near depth of maximum 30 m. All these information render the sites more stretched out in terms of diameter and interesting to search for geothermal potential. In addition, recent pictures ere taken and drew charts of every location, for the very first time estimating the magnitude of every side in terms of estimated length and breadth, the vicinity of hillsides and rivers respectively their temperature as an indicator of any subterraneous connectivity.

b. Satellite Remote Sensing: After the allocation by GPS during the onsite tour, as a pretest Remote Sensing (by the interpretation of satellite images and aero-photographs) that was conducted so far for the both preselected Northern states, Kedah and Perak, checked whether the geology can trace the fractured zones. It shows that the overall line pattern hypothesised here is invisible on the existing morphological structure on the geological map of West Malaysia. The satellite view remote sensing confirmed the following picture:

From the onsite tour, based on the findings by Ho (1979), Abdul Rashid (1990) and Samsudin (1997), a comprising geochemical analysis of the water was conducted. The geothermal potential gaged hereupon indicates that all of the hot spring waters are relatively low in dissolved salts and metals. The surface-near SiO_2 test was singled out for the water samples of the states of Perak and Kedah. Out of eighteen (18), at least thirteen (13) locations in both states were promising in terms of hotness and prospective water tables above 100 ºC - 166 ºC. The electricity study looks into the distance to the grid then found out whether or not the sites are interesting for electricity production or other geothermal usages. To narrow down the scope of viable hot springs candidates, it determined if a site is in an economic reachability of a power line. Only if the site is or can be made available for surface-near accessibility study (pre-drilling assessment) and the permission for pre-drilling assessment by the respective owner can be gained, further explorations can be considered. Otherwise, out of the remaining hot springs which cannot be considered for geothermal energy production, some are probably interesting for other geothermal usages. In this case, the research team liaises and passes on the information to respective stakeholders.

The result of the reconnaissance study ends up with scoring and portfolio analysis. The proposal of pre-drilling assessment of selected sites can be presented in a portfolio matrix showing lower or higher geothermal and economic potential, setting priorities and providing recommendations. At first, out of the database of fiftey seven (57) locations, a score is being calculated and recalculated in a matrix indicating the hot springs' viability by the following three preliminary information each with rank 1-10.

a. Accessibility for any further step, starting from reachability and access road and possibility of pre-drilling assessment filter the existing 57 to 20 hot springs (prerequisite to be considered in the portfolio matrix).

b. Portfolio dimension 1: Economic Viability (power demand in the respective area and vicinity of grid)

c. Portfolio dimension 2: Anticipated Geothermal Value (e.g. besides the water temperature individual flow rate between 2 to 6 litres/second averaging at 2.03 lt./s up to 27.0 lt./s in a singular case).

This is how the portfolio matrix with the still undisclosed seven most promising sites looks like:

Along with the geochemical analysis of the water samples, this contribution as Reconnaissance Report is able to provide the answers for the research questions pertaining 32 types of information for the already selected twenty seven (27) of the fifty seven (57) West Malaysian hot springs preliminary exploration. Before the overall project enters another stage of geothermal development as derived in the way forward (pre-drilling assessment and further steps), this undisclosed information tells neutrally which are the best locations to consider.

3. CONCLUSION

Apart from an extension of this reconnaissance study to onsite tours targeting the remaining 30 hot spring sites, these are the recommended actions emerging from the initial study above:

a) Geothermal exploration for electricity production step 1-4 is the first option after a promising step which is the reconnaissance study. It can be distinguished in 4 phases (Di Pippo, 2008, Galenka, 2009), with the economic go-/no-go-decision in terms of viability between phase 2 and 3:

1. Reservoir Tapping / Predrilling Assessment (Resistivity Profile, Remote Sensing, surface-near Transient ElectroMagnetic inclusive of Helicopter Remote TEM-Sensing (SkyTEM).and, if required, deep and highly expensive Magnetotelluric Profile),

2. If authorities give necessary permission, Test Drill into the Reservoir / Research Drill

3. If 2 successful, shareholders can be found 2nd (Confirmation) Drill with Pressurised Casing

4. Prior to commercialization, preparation to develop a mini show case Geothermal Plant based on Organic Rankine Cycle (ORC)- or Kalina Cycle Technology.

The flow rate between 2 to 6 liters/second averaging at 2.03 litres/second found by previous researchers is not encouraging, except for the 27 lt./ second at Tambun hot springs which is already fully utilised as a 5*-resort and cannot be disturbed. However, going deeper if there is any indication of an ample water table like in one already assessed area, Arthesian wells can be considered to harvest any lame hot water by pumping it to the surface. The geothermal gradient of one hot spring which was listed with only 45 ºC has already 92 ºC in a rig at 30m depth.

b) Extension to colder areas**:** The researchers found warmer water instead at a depth of up to 80 m at 3 locations in Kedah, Penang and the hottest has been reported South-West of Kuala Lumpur (Puchong, 40ºC in a depth of 30 m). Therefore, it could be promising to gage how gradually the temperature decreases in proportional distances away from the main fractured zones detected in this study.

c) If a.2. (Test Drill) is not successful for geothermal energy production, or would disturb existing operation or the landscape, other options can be taken: Revisiting selected hot springs areas for detailed analyses e.g. as proposed by Chow et al. (2010) mineral water production in 3-

4 areas, viability of hot water supply or district cooling (Bohne, 2010) in already developed urban areas (Setapak, Selayang) and resort areas (Sungkai, Tambun, et al.), and tailored touristic development according to commercial aspects including road accessibility. Aquaculture applications as proposed in the web presentation http://geothermal.marin.org/GEOpresentation/sld026.htm still need to be explored.

d) Further development into tourism: At present, at least 22 thermal areas are in their natural state and another 26 have been developed for the purposes of recreational activities. Although at least 20 long since developed hot springs seem to have good tourism potential, only 9 of them (Baling, Tambun, Sungkai, Selayang, Pedas, Gadek, Jasin, Grisek and Labis) are well developed enough beyond a family business to attract a larger number of visitors. Most of the other reachable hot springs are just occasionally frequented by locals as objects of curiosity or used as picnic spots (Samsuri, 1997). Even though a growing number of local citizens are getting more aware of the health and therapeutic properties of hot springs, iyant is felt that programs should be devised to utilize the recreational resources in West Malaysia to their optimum level.

With the finding of two previously unknown fractured zones, the reconnaissance study has come up with prolific and astonishing information about West Malaysia's generic renewable geothermal potential. It is considered phase 0, because this step targets at an overall view with the result of a selection of proposed sites. Hence, it is hoped that this study has opened the door for state-of-the-art geothermal projects.

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Figures captions:

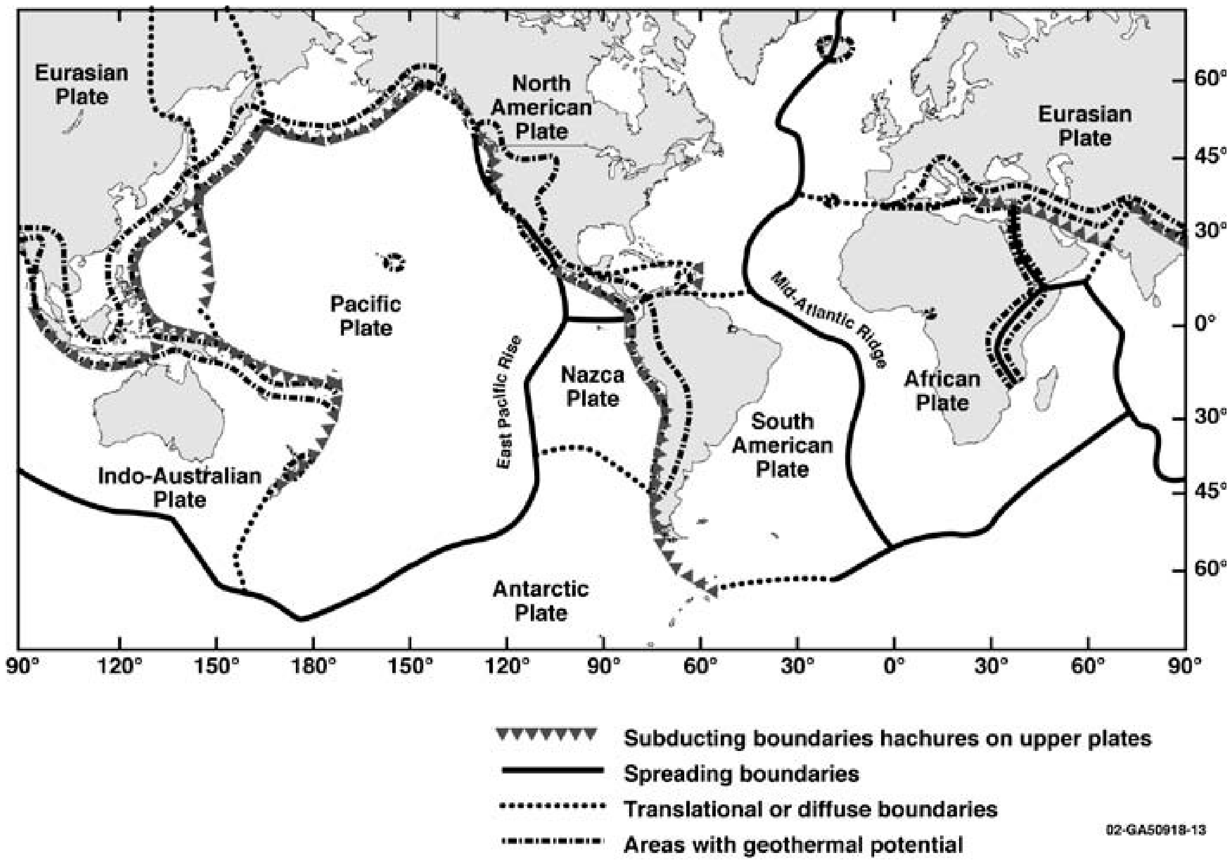
Figure 1: Map of Major Tectonic Plates of the Earth (Tilling, date unknown)

Figure 2: The Geological Map Peninsula Malaysia and 11 Selected Hot Springs Locations

Figure 3: Remote Sensing map shoes the morphology and structural elements with spring temperature and geothermal potential after Thermobarometry in Perak and Kedah (North Malaysia)

Figure 4: Portfolio Matrix of 7 Prioritized Sites for Geothermal Potential Assessment

Figure 1:



Eurasian Plate
North American Plate
Eurasian Plate
Pacific Plate
East Pacific Rise
Nazca Plate
Mid-Atlantic Ridge
African Plate
South American Plate
Indo-Australian Plate
Antarctic Plate
60°
45°
30°
0°
30°
45°
60°
90°
120°
150°
180°
150°
120°
90°
60°
30°
0°
30°
60°
90°
Subducting boundaries hachures on upper plates
Spreading boundaries
Translational or diffuse boundaries
Areas with geothermal potential
02-GA50918-13

Figure 2:

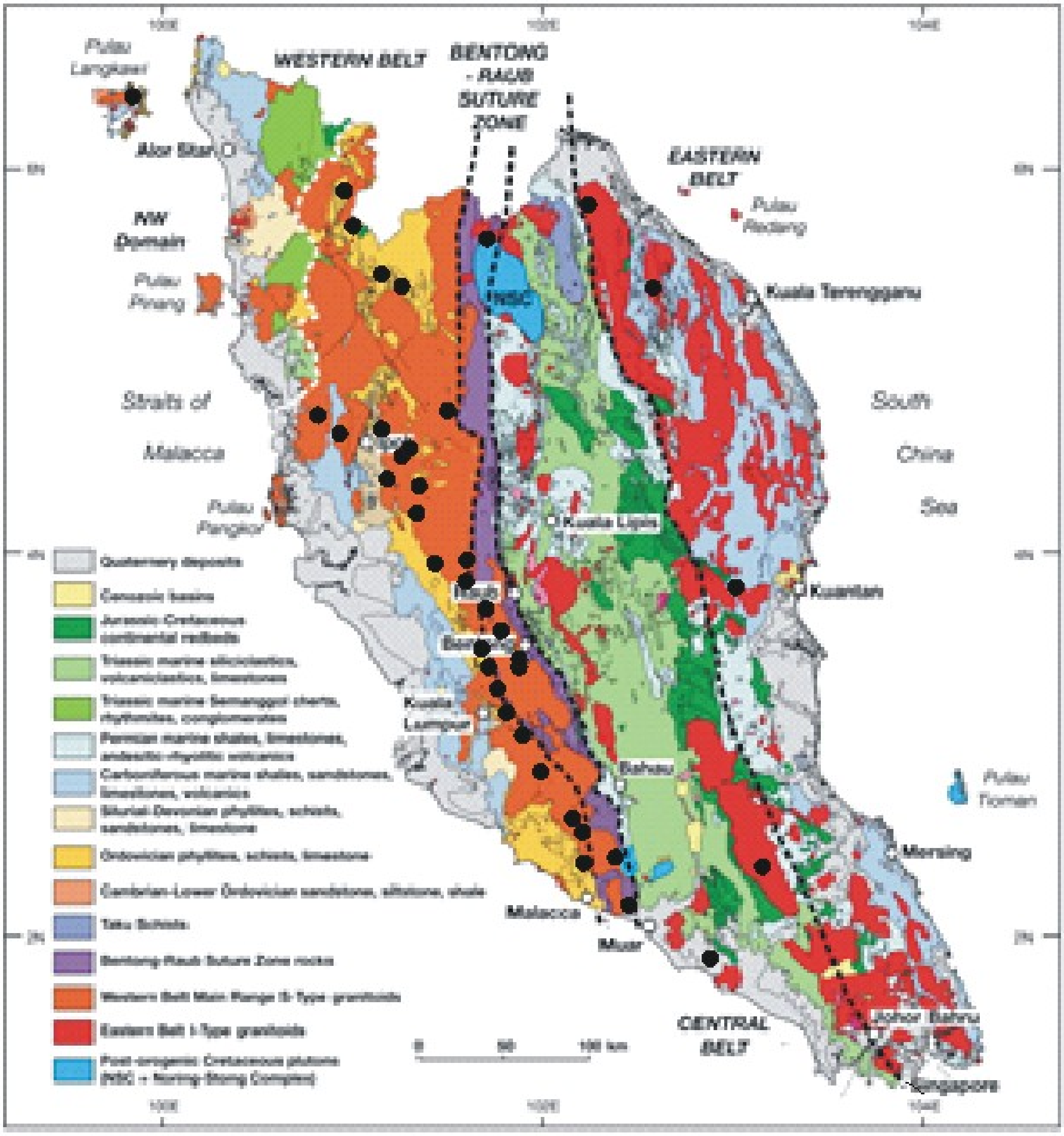

Pulau Langkawi
WESTERN BELT
BENTONG - RAUB SUTURE ZONE
Alor Star
EASTERN BELT
Pulau Redang
NW Domain
Pulau Pinang
NSC
Kuala Terengganu
Straits of Malacca
South China Sea
Pulau Pangkor
Kuala Lipis
Quaternary deposits
Cenozoic basins
Raub
Kuantan
Bentong
Kuala Lumpur
Bahau
Pulau Tioman
Mersing
Taku Schists
Malacca
Muar
Bentong-Raub Suture Zone rocks
Eastern Belt I-Type granitoids
CENTRAL BELT
Johor Bahru
Singapore

Figure 3:

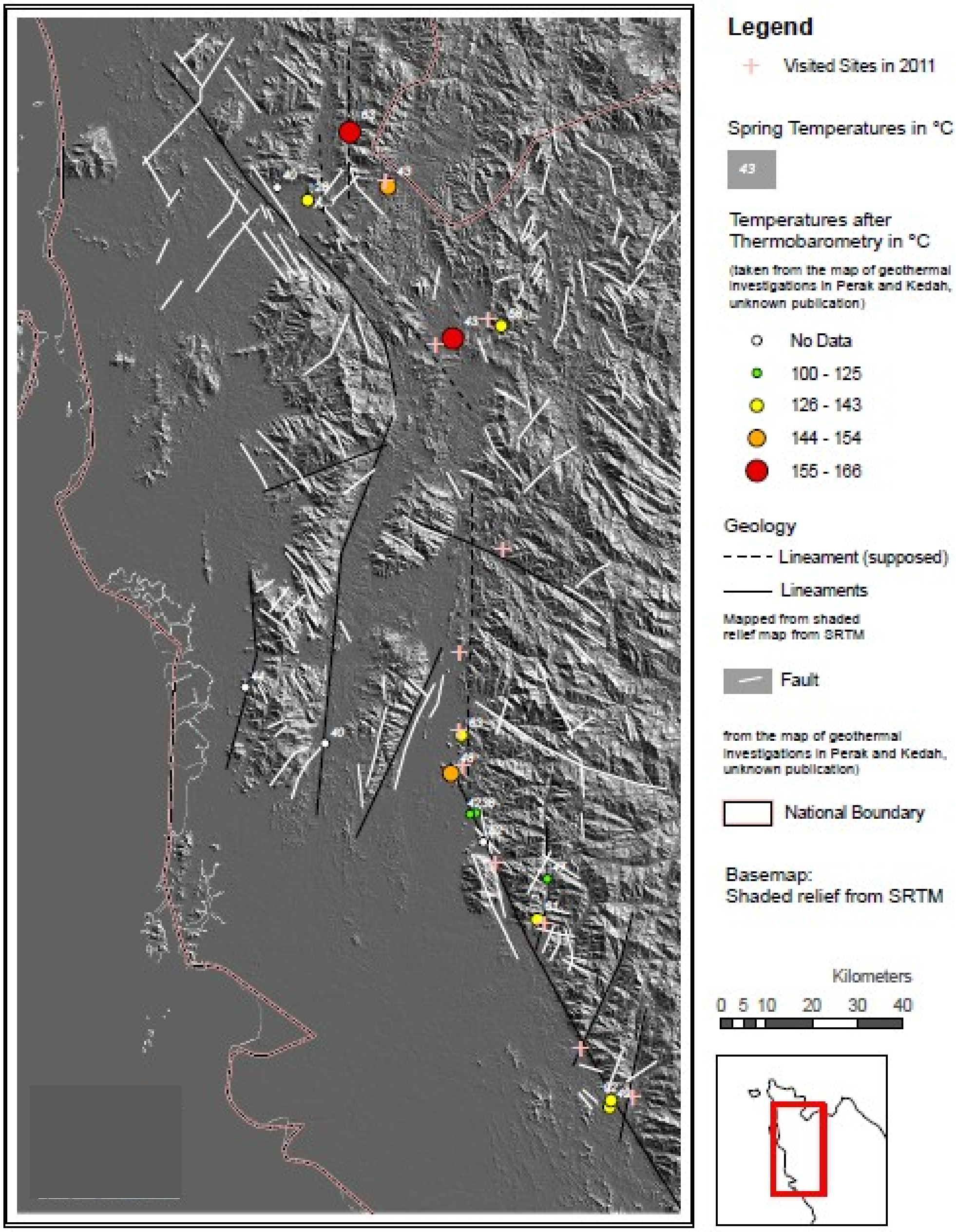
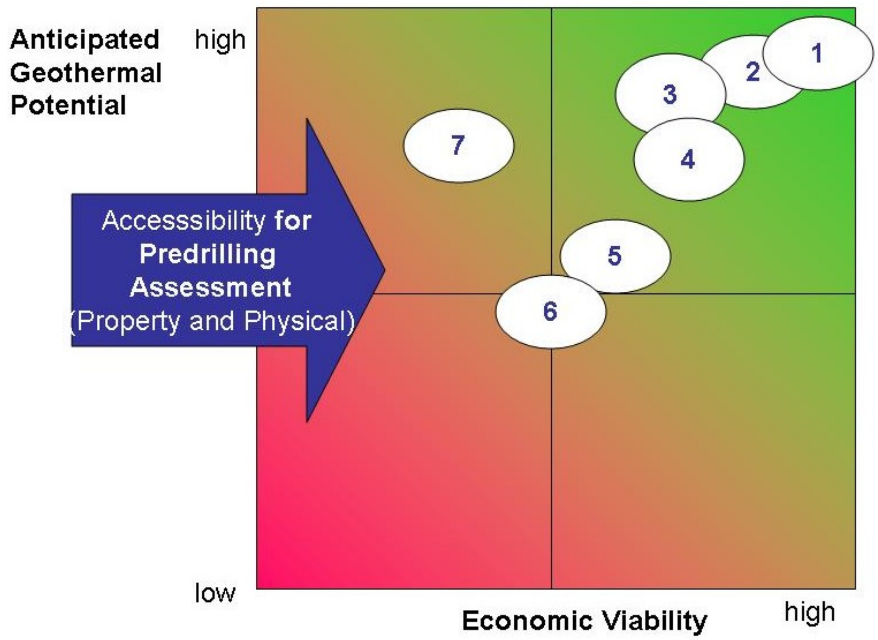

Legend
Visited Sites in 2011
Spring Temperatures in °C
43
Temperatures after
Thermobarometry in °C
(taken from the map of geothermal investigations in Perak and Kedah, unknown publication)
No Data
100 - 125
126 - 143
144 - 154
155 - 166
Geology
Lineament (supposed)
Lineaments
Mapped from shaded relief map from SRTM
Fault
from the map of geothermal investigations in Perak and Kedah, unknown publication)
National Boundary
Basemap:
Shaded relief from SRTM
Kilometers
0 5 10 20 30 40

Figure 4:


Anticipated Geothermal Potential
high
low
Economic Viability
high
Accesssibility for Predrilling Assessment (Property and Physical)
1
2
3
4
5
6
7