EXPLORATION AND ENGINEERING STUDY OF SOME HOT SPRING SYSTEMS IN WESTERN THAILAND FOR LOCAL TOURISM DEVELOPMENT

Pham Huy Giao[1] and Prinya Putthapiban[2]

[1]*Geosystem Exploration and Petroleum Geoengineering Program, School of Engineering and Technology, Asian Institute of Technology (AIT);* [2]*Geoscience Programme, Department of Physics, Faculty of Science, Mahidol University, Kanchanaburi campus, Thailand.*

ABSTRACT

Hot spring systems in Thailand are in general of two types, either directly connected to a granitic basement or indirectly communicated through an intermediate sedimentary rock layer. They are commonly found along some fault systems, such as the Three Pagodas fault zone of western Thailand. The changing characteristics of many hot springs during the 26 December 2004 Sumatra Earthquake include both temperature and chemical compositions indicate the value to study them in connection with the regional tectonics. However, in this paper the focus is on investigation of hot spring sites for development of tourist/local industry as it has been done in many locations in Thailand. The results of geophysical and geotechnical investigations, jointly conducted by the AIT and Mahidol University research teams, in Kanchanaburi province of western Thailand are presented.

Keywords: hot springs, geothermal system, electric imaging,

INTRODUCTION

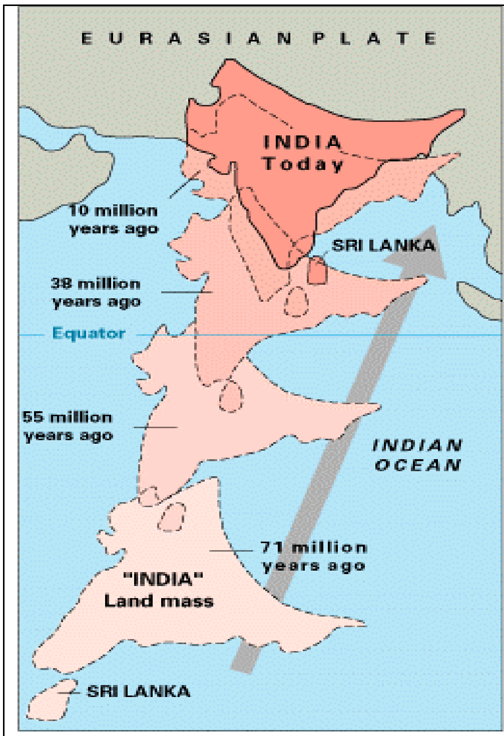

Fig. 1a Collision of the India plate with the Eurasian plate at various times (*http://www.usgs.gov/*)

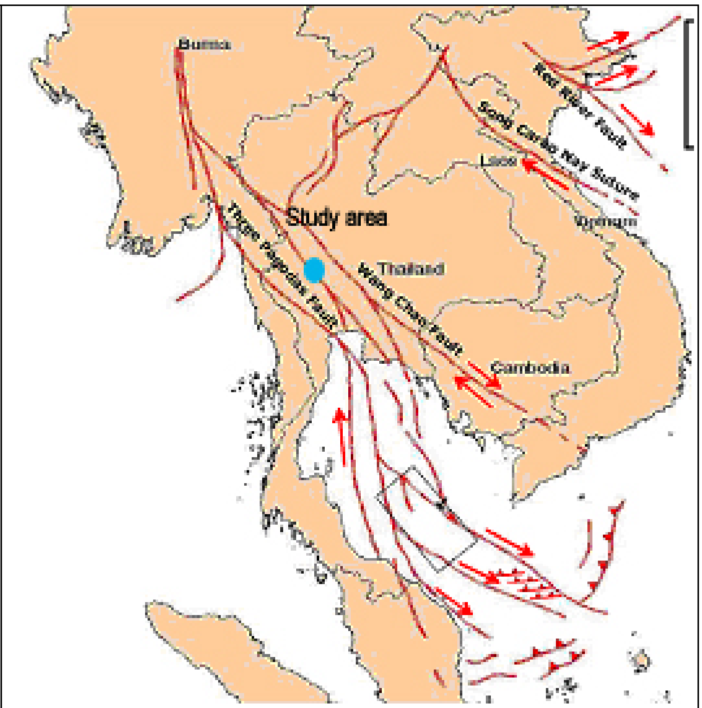

Fig. 1b Some fault systems in the SE Asia (based on Packham, 1993)

The present day structural framework of SE Asia is believed due to the collision of Indian plate with Eurasia plate during the Latest Cretaceous-Early Tertiary (Fig. 1a), which resulted in large dextral fault systems, including the Red River fault system of North Vietnam, the Wang Chao (Mae Ping) fault system and the Three Pagodas fault system of the mainland Southeast Asia. In Thailand, along the Three Pagodas fault zone, many hot springs have been observed, some of them associated with the granitic terrains. Typically are the hot springs in Kanchanaburi province, many of which are popular touristic spots in Thailand like Hindat, Wang Kha Nai and play an important role in the local tourist industry. Besides the mentioned economic significance, nowadays the investigation of the hot springs is also of interest to those studying on the tectonic sensitivity of this western area of Thailand. As a matter of fact, at the time of the earthquake and the induced tsunami in the Indian Ocean on 26 December 2004, it was observed that the temperatures of hot springs along Si Sawat and Three Pagodas Faults (Fig. 1b) increased and their chemistry were also affected. For example, in the well located at Paktho district, it was noticed on 28 December, the water temperature increased to 48^0C and the water became lower in Fe+. The temperature had then decreased of 2^0C per day and it took almost 10 days to bring the water back to room temperature at 29^0C. Similar changes in temperature and other physical and chemical parameters have frequently been observed at least two hot spring locations.

According to the publication of the Department of Mineral Resources of Thailand (DMR, 2004), two types of hot springs are commonly found in Thailand as shown in Fig. 2, i.e., (a) the hot spring directly related to or coming from an igneous rock fracture (Fig. 2a) and (b) the hot spring found in a sedimentary rock layer overlying a granitic basement (Fig. 2b). In such convection model, the hot water is flowing up from the underlying granitic basement and is stored in the overlying rock layer. In general, the latter type of hot spring has temperature and minerals content lower than those of the former.

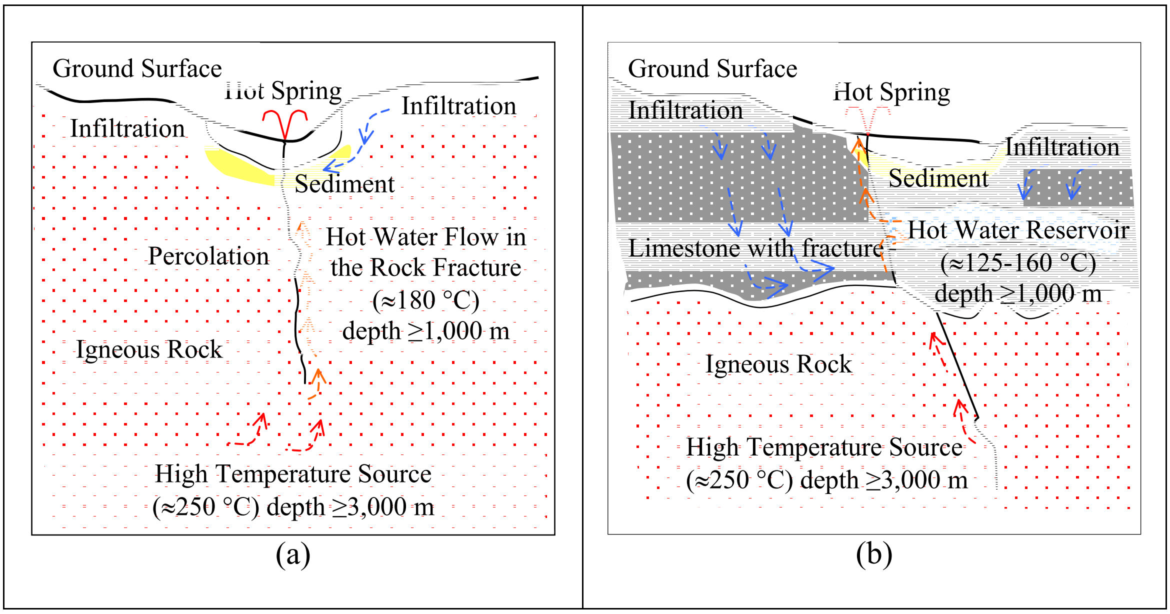

Fig. 2 Two models of hot spring system in Thailand: (a) Type 1: High temperature (>70°C) and high mineral content; (b) Type 2: Medium to low temperature (<60°C) and low mineral content (modified from DMR, 2004).

Many of the Karnchanaburi hot springs are commonly located along the line of Three Pagodas Faults (Fig. 1a). This major fault runs from Myanmar to the middle of the Chao Phraya basin and extend farther to the gulf of Thailand. In March 1959, a quake on the Three Pagoda's Fault produced a 300-meter long, 2-meter wide and 1.5-meter deep ravine in the ground. One of the common objectives when investigating a hot spring site is to drill additional boreholes to tap more hot water from the depth. The often questions asked by the site geologist regarding the new borehole location are: (i) how far it can be from the existing spring location?; (ii) on which side of the stream along that springs have surfaced it can be placed?; (iii) in which direction the new borehole can be placed, more on the hillside or more downward to the valley?. It is quite easy to end up with a new dry borehole. One may drill the borehole on the wrong side of the fault and the borehole could not intercept the flowing hot water bearing fault. Even in the case of selecting on the correct side of the fault, but the borehole is placed too far from the major fault line, the temperature of water that been tapped in the minor ruptured zone may not high as expected. Geophysical methods can certainly assist the geologist to locate the new borehole location, especially to find out the hot water-bearing fault including both its orientation and dipping. The results will be much better if besides the geophysical survey one can also perform some other engineering works, including drilling and laboratory testing. For the study area (see Fig. 1b) the main geophysical tool is electric imaging method, which has been widely applied to solve geotechnical and geoenvironmental problems, e.g., investigation of landslides and septic tank pollution (Loke, 2007); mapping of industrial waste deposits and buried quarry (Ogilvy et al., 1999); salt intrusion mapping (Abdul et al., 2002); characterization of soft clays and monitoring of the ground improvement process (Giao et al., 2003); detection of sinkholes (Van Schoor, 2002) and so on.

In our field work, the two-dimensional EI survey was employed, using the Syscal R1+ equipment and a 48-electrode automatic cable system. The minimum electrode spacing was 5 m, which gradually increased to 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70 and 75 m, respectively. The procedure of electric imaging survey is illustrated in Fig. 3 below:

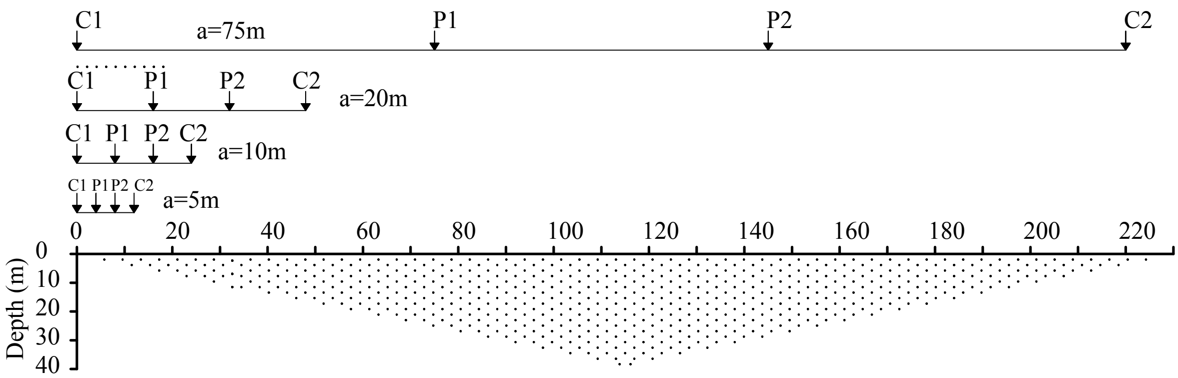

Fig. 3 Procedure of electric imaging

INVESTIGAITION OF THE WANGKANAI HOT SPRING SITE

Wangkanai hot spring site is found at the Wat Wangkanai Tayikaram temple, having coordinates of 13°58'2.38"N and 99°38'18.81"E. The temple is of more than 100 years old and has operated hot water baths for long time. Since 1997, the water supply from the limited number of existing wells become not enough to meet the demands and the temple plans to drill some more hot groundwater well to solve this problem. At this site, there are found five hot springs as shown in Figure 4. Based on a recent borehole of 32 m deep (DGR, 2007), the water table is located at 9 m deep, the flow rate is of 22 m^3/hr, the dissolved iron is 0.14 mg/l, dissolved chloride is 11 mg/l, hardness is 660 mg/l and total dissolved solid (TDR) is 691 mg/l. The temperature of hot water is about 35^{o}C. It indicates that the hot spring system here belongs to the second type mentioned above in Fig. 2b.

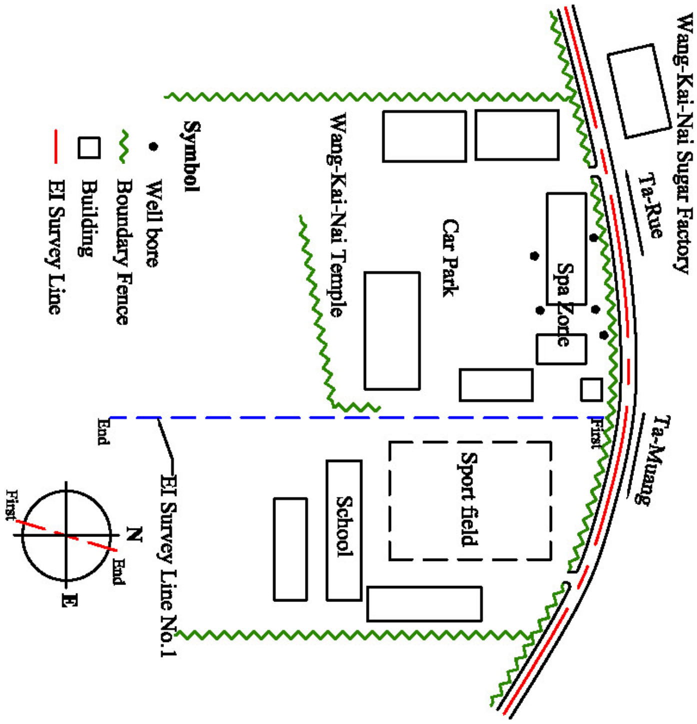

Fig. 4 Wat Wangkanai Tayikaram temple site and layout of the EI survey line

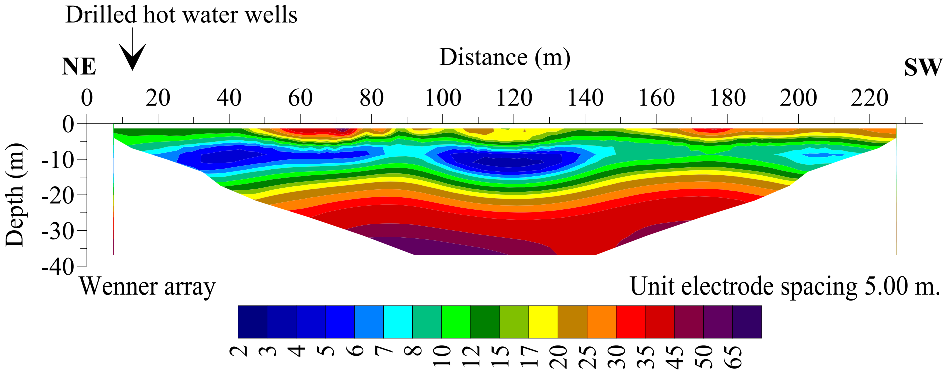

Figure 5 Results of the EI survey at Wat Wangkanai site

The survey line is 235m long and oriented SW-NE (see Figs. 4 & 5), starting with the mark of 0 m at the SW end. The existing hot water wells are located around the mark of 0 m, beneath the segment of this survey line one can observe a low resistivity anomaly from to 2 to 6 Ωm, which is interpreted as the thermal water storing reservoir with high conductivity due to its high mineral contents (DGR, 2007). The higher resistivity zone from about 20 m downwards, which is underlying the above mentioned low resistivity layer correspond to a layer of more compacted rock with less porosity and permeability. The hot water comes through this layer by narrow fractures, which can be connected to a deeper zone with high temperature.

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Table 1 Geological profile from a 30-m borehole drilled at Wangkanai site

Depth interval	Lithologic description from top to bottom
0 – 3 m	*Dark brown clay (partial back filled materials)*
3 – 6 m	*Gravelly clay, brownish black, well sorted and sub-rounded mainly quartz pebbles (approximately 5-10 %) of average 0.5 cm diameter*
6 – 12 m	*Clayee gravel, yellowish brown, poorly sorted but well-rounded pebbles of approximately 50 % of size ranges from 0.2 to 1 cm diameter.*
12 – 15 m	*Gravelly clay with 20 % clay, brownish, sub-rounded and poor sorted with pebble size range from 0.5 to 1.0 cm.*
15 – 22.5 m	*Gravel bed, pebble size range from 0.5 to 2.5 cm, sub-rounded, fairly sorted with variety of pebbles.*
22.5 – 30m	*Gravel bed, pebble size range from 1.0 to 3.0 cm, well-rounded, fairly sorted with quartz, quartzite, chert pebbles.*

INVESTIGAITION OF THE HINDAT HOT SPRING SITE

Hindat hot spring site is located at Ban Kuymang, having coordinates of 14°37'31.40"N and 98°43'28.17"E. This hot spring was discovered by Japanese military during World War II. Nowadays, it is operated and managed by the Hindat Local Administration Office for tourism industry.

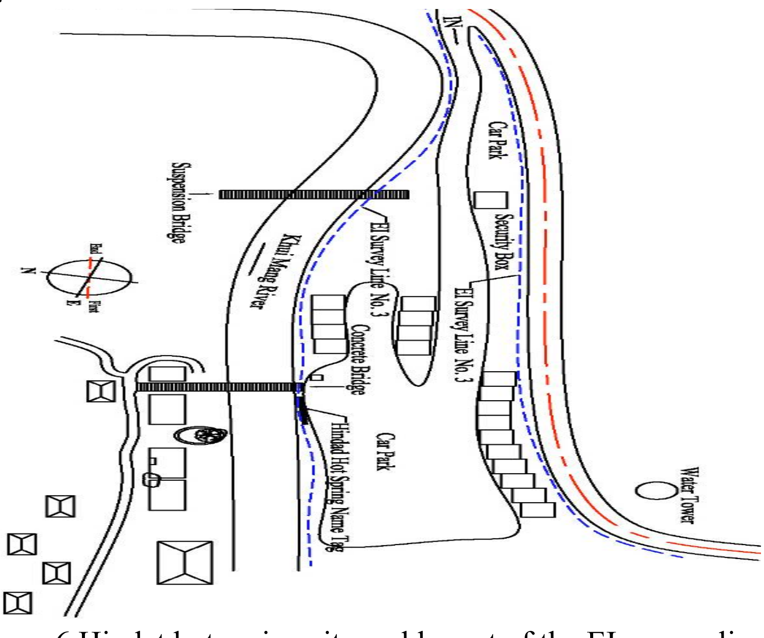

Figure 6 Hindat hot spring site and layout of the EI survey lines

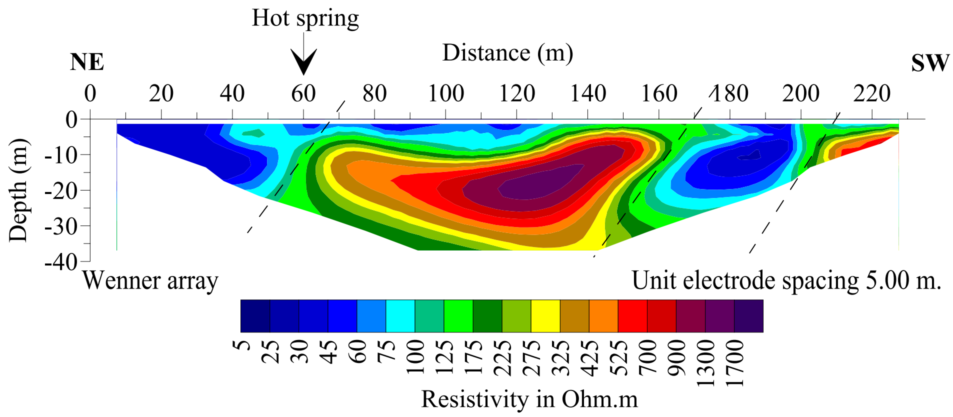

Figure 7a EI results of Hindat hot spring for the survey line 1

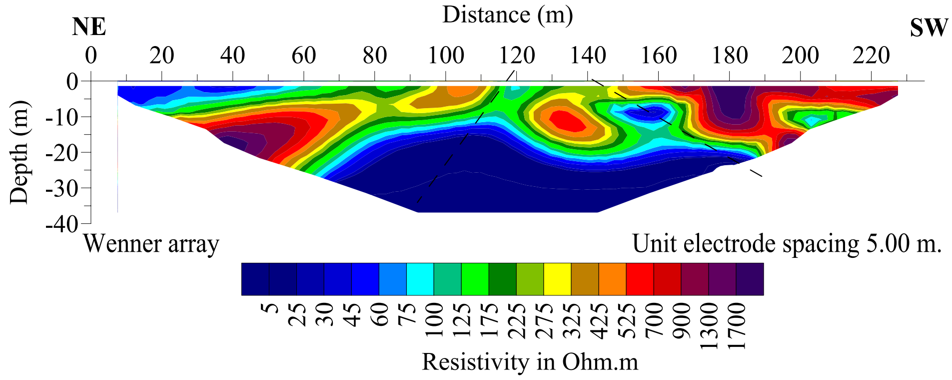

Figure 7b EI results of Hindat hot spring for the survey line 2

Table 2 Geological profile from a 46-m borehole drilled at Hindat site

Depth interval	Lithologic description from top to bottom
0 – 3 m	*Gravel, yellowish brown, poorly sorted with very coarse pebbles*
3 – 20 m	*Sandstone, fine-grained sandstone and siltstone*
20 - 26 m	*Conglomeratic sandstone and pebbly sandstone.*
26 – 35 m	*Siltstone, fine grained sandstone*
35 – 46 m	*Conglomerate and conglomeratic sandstone.*

According to DGR (2007), the results of the physical and chemical properties for the Hindat hot spring are as follows: pH is 7.36, temperature of hot water is about 40°C, and the amount of fluoride concentration in the hot water is 1.6 ppm**.** The EI survey procedure is similar to that at the Wangkanai site. Two survey lines, oriented NE-SW were performed (as seen by the dashed lines in Fig. 6) and the EI results are shown in Fig. 7a-b. For the survey line 1 the hot spring is located at the mark of 60 m (Fig. 7a), beneath the segment of this survey line from 0 m to 70 m one can observe a low resistivity anomaly down to 5 Ωm, which is interpreted as the thermal water storing reservoir channel with high conductivity due to its high mineral contents. in Fig. 7b, there is observed a high resistivity anomaly from 500 to 1700 Ωm at the middle of pseudosection (from the marks 70 m and 120 m), which can be the weathered and fresh igneous rock. For the survey line 2 at Hindat the EI results are shown in Figure 7b, in which one can observe a high resistivity zone in the range of 400 to 1800 Ωm, which is underlain by a zone of low resistivity zone down to 60 Ωm.

RESULTS OF HYDROCHEMICAL TESTING

Groundwater samples from 7 sites in the study area (denoted from MW1 to MW7 as shown in Fig. 8) were analyzed for physical and chemical parameters based on the Drinking Water Standard. MW4 site represents the Wangkanai site, and MW6 & 7 represent the Hindat site. The pH values are within the acceptable limits ranging between 6.8 and 7.9. The electrical conductivity varied within the range of 540 to 5,300 microsiemens/cm and was found to be quite high. The TDS varies from 350 to 3,440 mg/l. The total hardness reported as $CaCO_3$ falls within the range of 200 to 900 mg/l and the water is classified as very hard water (Sawyer et al, 1994). The range of sodium concentration is from 8 to 820 mg/l, whereas the potassium concentration varies from 2 to 7 mg/l. The concentrations of calcium and magnesium range from 45 to 180 mg/l and 20 to 110 mg/l, respectively. These concentrations of calcium and magnesium ions are related to the hardness of the water. The chloride concentration varies widely from 1 to 1,600 mg/. The concentration of bicarbonates and carbonates are considered the most important anion in natural water. They control the pH and alkalinity of water. The bicarbonate concentrations range from 330 to 490 mg/l whereas the concentration of carbonate is not detected in this study area. The nitrate concentrations range from 1 to 8 mg/l which within the acceptable limit (< 45 mg/l). The range in sulphate concentration of 1 to 230 mg/l falls within the permissible level (<250 mg/l).

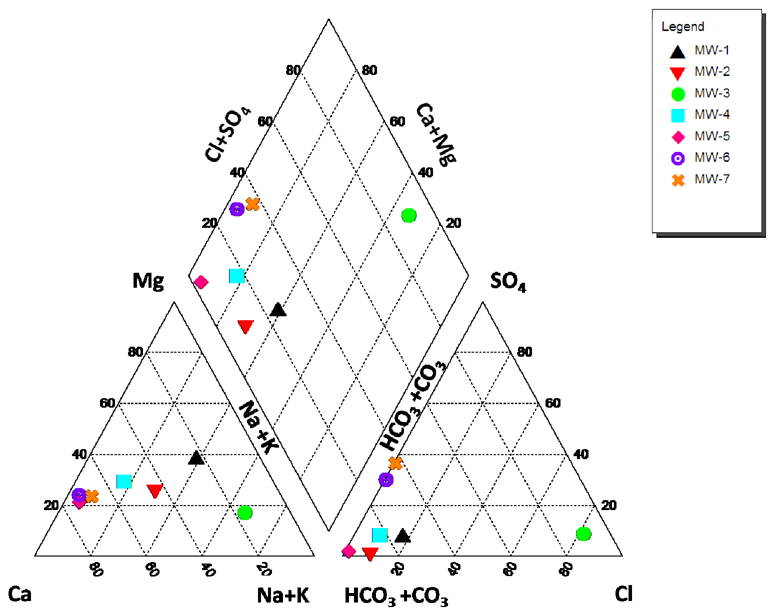

Fig. 8 Hydrochemical facies of groundwater in the study area

The Piper Trilinear Diagram (Piper, 1944) is employed herein to classify groundwater at Wangkanai and Hindat based on the dominant cations and anions. A lot of data fall within the diamond-shaped area on the diagram, thus classifying the hydrochemical facies of the groundwater in the study area as Ca-Mg-HCO3-CO3 type (Fig. 8). This area of the diagram is called "carbonate hardness facies" or "hydrochemical facies type I". The carbonate hardness exceeds 50 percent, showing the chemical properties of the groundwater which are dominated by alkaline earths and weak acids.

CONCLUSIONS

In this study electric imaging was successfully employed in investigation of two hot spring sites in Kanchanaburi province, Wangkanai and Hidat. These hot water systems are of type 2 as classified by DMR (2004), which has medium to low temperature and its hot water is coming from an intermediate sedimentary rock overlying an igneous basement. The borehole drilled at these two study sites have confirmed the underlying rock layer as sedimentary rock beds. The target of shallow exploration works at these sites are zones of low resistivity corresponding to the hot-water bearing or flowing rocks, underlying beneath the spring locations. The hydrogeochemical testing results show high conductivity of the hot water at both sites, justifying this assumption. It is expected that the methodology used in this study can be applied for investigation and development of other hot spring sites of similar occurrence conditions in Western Thailand.

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