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Geoheritage Potential of Non-Volcanic Hot Springs in Bangka Island: Implications for Geotourism Activities

Potensi Geoheritage Mata Air Panas Non-Vulkanik di Pulau Bangka: Implikasi bagi Aktivitas Geowisata

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Abstract-. Natural hot springs are important for various domestic purposes, health treatments, recreational bathing as well as settings for socio-cultural and traditional functions for thousands of years. However, most people are not aware and familiar with the key geological processes of these hot springs. There are three natural hot springs were discovered in the Bangka Island, while the origin and source of these hot springs are still poorly understood. This study provides the water characteristics of those springs and discusses of their origin by considering geological setting, as well as identified these hot springs as geoheritage sites potential. The surface temperatures of thermal springs range from 46 - 49° C, and the pH values ranges from 5.0 to 6.0. The hydro-geochemical characteristic of hot springs is divided into two types, mature water and peripheral water. The anion composition (Cl-SO4-HCO_3) obtained from water samples of the Permis Hot Spring contains high Cl, indicates as mature water type, and unrelated to recent volcanism. On the other hand, a water sample from the Nyelanding Hot Spring is relatively high HCO_3 which indicate as pheripheral water type, and far from the primary source. The Na-K-Mg ternary diagram reveals that water samples of the Permis hot spring is partial equilibrium water type with high Na and Cl compositions, while the Nyelanding one is immature water type characterised by high Mg content. Radiogenic granitic host rock represents the main heat source for both non-volcanic hot springs in Bangka Islands. The heat is derived from deep-shallow circulation of meteoric water through fractures that cut into the granitic plutons. These hot springs are unique and show special features that play an important role in understanding of the dynamic of the Earth. These hot springs also have some significant geoheritage values, such as scientific, aesthetic, and recreational. Therefore, these hot springs have the potential to be properly conserved, managed and developed geoheritage sites and utilised for a sustainable geotourism development in Bangka Island.

Abstrak-. *Mata air panas alami memiliki peran penting untuk berbagai keperluan domestik, pengobatan kesehatan, pemandian rekreasi, serta fungsi sosial-budaya dan tradisional selama ribuan tahun. Namun demikian, sebagian besar masyarakat belum menyadari dan memahami proses geologi utama yang mengendalikan kemunculan mata air panas tersebut. Terdapat tiga mata air panas di Pulau Bangka, namun asal-usul dan sumber panasnya masih belum dipahami dengan baik. Studi ini menyajikan karakteristik air dari ketiga mata air tersebut dan membahas asal-usulnya dengan mempertimbangkan tatanan geologi, sekaligus mengidentifikasi potensi nilai geoheritage dari masing-masing lokasi. Suhu permukaan ketiga mata air panas berkisar antara 46–49 °C, dengan nilai pH antara 5,0 hingga 6,0. Karakteristik hidro-geokimia menunjukkan adanya dua tipe air panas secara geotermal, yaitu air matang dan air perifer. Komposisi anion (Cl–SO_4–HCO_3) pada sampel air dari Mata Air Panas Permis menunjukkan kadar Cl yang tinggi, mengindikasikan tipe air geothermal matang, serta tidak berhubungan dengan aktivitas vulkanik muda. Sebaliknya, sampel dari Mata Air Panas Nyelanding memiliki kadar HCO_3 yang relatif tinggi sehingga diklasifikasikan sebagai air perifer, yang menandakan jarak yang lebih jauh dari sumber panas utamanya. Diagram ternary Na–K–Mg memperlihatkan bahwa sampel air dari Mata Air Panas Permis termasuk tipe air dengan keseimbangan parsial dengan kandungan Na dan Cl yang tinggi, sementara sampel dari Nyelanding merupakan tipe air yang belum matang secara geotermal yang dicirikan oleh tingginya kandungan Mg. Batuan granit radiogenik berperan sebagai sumber panas utama bagi kedua mata air panas non-vulkanik di Pulau Bangka. Panas tersebut berasal dari sirkulasi air meteorik yang bergerak dari kedalaman ke permukaan melalui zona rekahan yang memotong tubuh granit. Mata air panas ini bersifat unik dan menunjukkan karakteristik khusus yang berperan penting*

Keyword: Non-volcanic hot springs, geoheritage, geotourism, Bangka Island

dalam memahami dinamika bumi. Selain itu, mata air panas tersebut memiliki nilai geoheritage yang signifikan, mencakup nilai ilmiah, estetika, dan rekreasi. Oleh karena itu, ketiga lokasi ini berpotensi untuk dikonservasi, dikelola, dan dikembangkan secara tepat sebagai situs geoheritage serta dimanfaatkan untuk pengembangan geowisata berkelanjutan di Pulau Bangka.

Kata Kunci: *mata air panas non-vulkanik, warisan geologi, geowisata, Pulau Bangka*

INTRODUCTION

Hot springs are important for the future renewable energy of geothermal resources, whereas the hot springs are also significant for various domestic purposes, health treatments, wellness, and recreational purposes. Based on their origin, the thermal springs is classified into two types, volcanic thermal sources which are associated with volcanic activity (Du *et al.*, 2005; Qin *et al.*, 2005; Sanada *et al.*, 2006), and non-volcanic type that usually related with granite intrusion body and fault networks (Yaguchi *et al.*, 2014; Baioumy *et al.*, 2024).

In Indonesia, hot springs as manifestation of geothermal system are distributed from Sabang to Merauke with potential resources of 11,073 MW (ESDM, 2017). Most of them are associated with volcanic environment, but some are considered as non-volcanic origin, e.g the hot springs at Bangka Island which discussed here. Based on geophysical and Landsat imagery analyses, some previous researchers indicated that the Permis and Nyelanding hot springs in the Bangka Island are associated with radiogenic processes of the granitic rocks (Siregar and Kurniawan, 2018; Putri and Harianja, 2021; Siregar *et al.*, 2021). These non-volcanic hot springs are interesting to be studied deeper due to the rare occurrence compared to the volcanic thermal springs. The occurrence of this type of hot spring could be considered as geodiversity that has the potential to become geological heritage (or usually called 'geoheritage'). Geoheritage is defined as particular occurrences of minerals, rocks, fossils, soils, landforms and geological processes with exceptional values (Brilha, 2013). The remarkable features and value of the geoheritage sites are also attracting people for "geotourism" activities. Newsome and Dowling (2005) stated that geotourism in the field of geology is defined as a kind of tourism based on geological heritage features which are potential to attract visitors to come and enjoy them. Through geotourism, we hope a better understanding of the Earth can be achieved so that its geological attractions can be acknowledged.

This paper provides the characteristics of non-volcanic thermal springs in the Bangka Island, and their origin by considering geological setting and water geochemistry, as well as identifies the potential of these hot springs as geoheritage sites which can be utilised for geotourism objects and attractions.

GEOLOGICAL SETTING

Bangka Island lies in the southern continuation of the South East Asian Tin Belt extending from Myanmar and Thailand through Malaysian Peninsula to the Indonesian Islands (Schwartz *et al.*, 1995; Irzon *et al.*, 2023). The origin of Bangka Island (Figure 1) was related to subduction and accretion of the Sibusmasu islands arches (China-Siam-Burma-Malaysia-Sumatra acronym) to the Indonesian terranes during the closure of Palaeotethys from the turn of the Devonian to the Middle Triassic and of the Neotethys from Permian to Paleogene (Metcalfe, 2002; Searle *et al.*, 2012). These tectonic events were responsible for the formation of three granites provinces which differ both in geochemical and petrological characteristics (Hutchinson and Taylor, 1978): (1) The West Granite Province with Cretaceous granites of S- and I-types; (2) The East Granite Province with Permo-Triassic granites of I-type; and (3) The Central Granite Province with predominantly Triassic granite of S-type. This geological setting may responsible for the thermal hot spring's occurrences in the Bangka Island. The presence of hot springs in Bangka Island such as in Pemali, Dendang, Permis and Nyelanding areas have an almost similar process to the ones in Thailand and West Malaysia which were considered as non-volcanic origin associated with granitic host rock (Raksaskulwong, 2015; Baioumy *et al.*, 2024).

METHODS

Four water samples were taken from two different locations in Bangka Island, Permis (22AA04) and Nyelanding (22YU08). Based on geological and thermal considerations to represent non-volcanic origin of hots springs in the Bangka Island, those were subjected for geochemical analyses, including anion, as well as major and trace elements using ICP-OES, AAS, volumetric and turbidimetry. The sampling was carried out in March 2022. Water samples were collected in 500-mL polyethylene containers (Toupal *et al.* 2022). Nitric acid was used to acidify materials to pH 2, while materials for anion analysis were not acidified. Cation elements were measured using the ICP-OES. Na and K were measured using FAAS. Furthermore, SO_4 was determined using the gravimetric method, while Cl and HCO_3 were analyzed using volumetric techniques. In order to identify the radioactivity level in the study area, some rock samples were measured by to the Thermo Geiger–Müller counter type FH 40 G Multi Purposes Digital Survey Meter.

RESULTS

Geology of the non-volcanic hot springs

The Bangka Islands possesses many unique and interesting geological sites and geological features which have geoheritage potentials (Figure 2), one of them is Nyelanding Hot Springs. They are some hot springs in the Bangka Island, such as Terak, Pemali, Sungailiat/Pelawan, Dendang, Permis, and Nyelanding. This study focus on Nyelanding and Permis hot springs due to their unique features. The location and geological setting of these hot springs are associated with the granitic rocks and geological structures. The Nyelanding Hot Spring is located at the Nyelanding Village, South Bangka. The surface temperatures of hot springs are around 49° C, with pH values 5.0. Geology of this area consists of dominantly Tanjung Genting Formation controlled by faults.

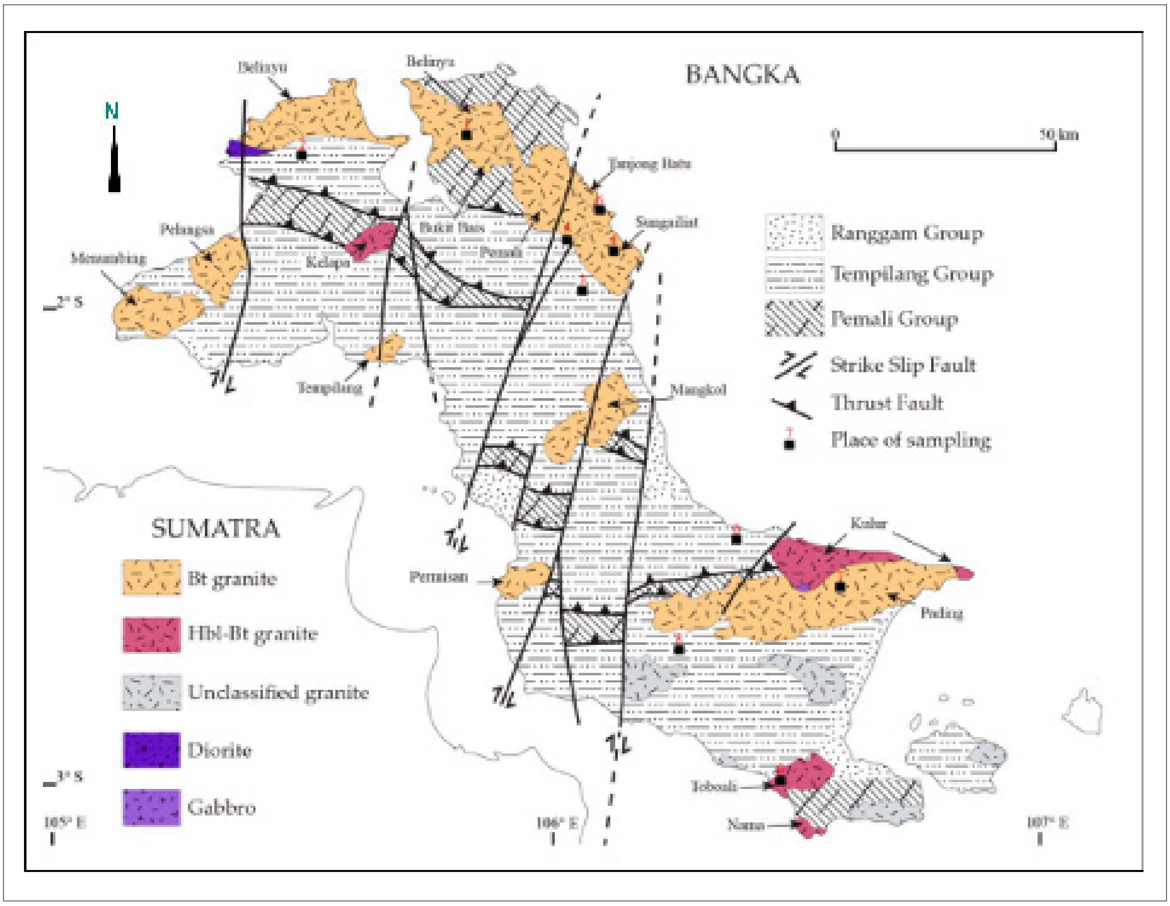

Figure 1. Geological map of Bangka Island (modified from Schwartz *et al.*, 1995)

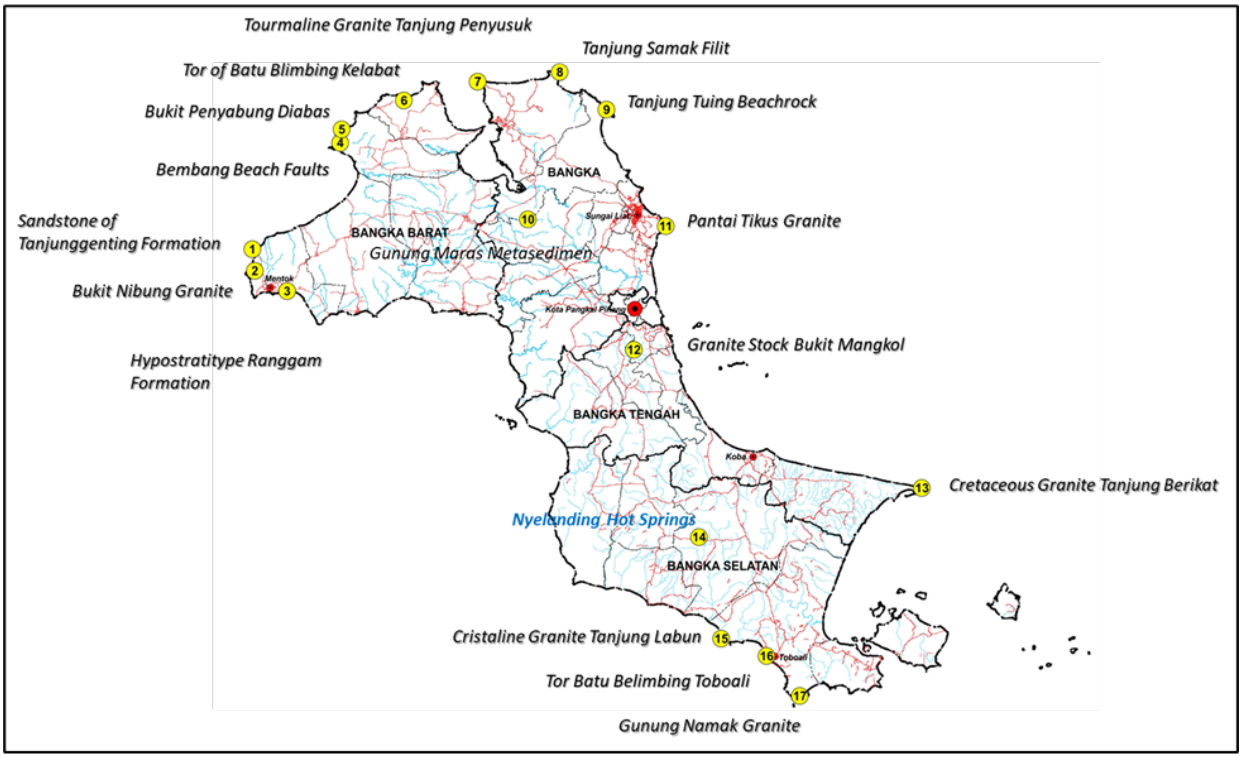

Figure 2. Geoheritage sites potential in the Bangka Island

Altered sandstones of the Tanjung Genting Formation are exposed around the hot spring, well bedded, light gray color and slightly brown to pink in weathered condition, very fine-grained, hard and compact, massive, and well sorted. There are also minor joints parallel to and cutting the sandstone layers. By community, this hot spring have been used as bathing pool, and small ponds at the edge of pool used for drinking water. At the bottom of ponds, there are some bubbles outward from the rock cracks (Figure 3).

Figure 3. Photograph of the hot springs in the Bangka Island, (A) the bathing pool of the Nyelanding Hot Spring; and (B) the natural pond of the Permis Hot Springs

The Permis hot spring is located at the Permisan Hill, South Bangka. There are three ponds in this area (Figure 3), each spaced between 10-20 m apart. The surface temperatures of this springs is around 46°-48° C, with pH values 5.0-6.0. Lithologically, Permisan Granite dominates in this area with white to grey colors, anhedral and phaneritic textures, and consist of quartz, biotite, muscovite, and plagioclase minerals. The Permisan Granite is part of the Triassic Klabat Granite which intruded sandstones of the Tanjung Genting Formation.

Thermal Water Chemistry

The surface temperature of the Nyelanding Hot Springs is 49° C, little bit higher than the Permis Hot Springs (ranges from 46° - 48° C). The pH values of analyzed samples range 5.0 – 6.0. The pH values of the Nyelanding Hot Spring slightly higher than Permis Hot Spring. The cation contents obtained from the analyzed water samples indicates that the Permis Hot Spring has significant higher values on the Ca, Na, K, and Mg of 704 ppm, 1429 ppm, 49 ppm, and 21.4 ppm, respectively than Nyelanding Hot Spring of 3 ppm, 2 ppm, 4 ppm, and 1.1 ppm respectively, as shown in Table 1. Anion concentration also shows significant different values between the Nyelanding and Permis hot springs. The Nyelanding Hot Spring has very low concentration on Cl^-, SO4, and $HCO3^-$ of 1 ppm, 0.6 ppm, and 23.18 ppm respectively, compared to the Permis Hot Spring (3367 ppm, 5.1 ppm, 58.56 ppm respectively).

The triangular plots of the major cation and anion were used to identify the type, origin, and maturity geothermal systems of the hot springs. $Cl-SO_4-HCO_3$ ternary diagram show water samples of the Permis Hot Spring has relatively high Cl (neutral chloride waters), classified as mature type water, however the Nyelanding Hot Spring has high HCO_3 (bicarbonate water), categorized as peripheral water type (Figure 4a). This indicate that the Permis Hot Spring may influenced by volcanic, deep source and high temperature, neutral chloride reservoir in magmatic environment. On the other hand, the Nyelanding Hot Spring is considered a non-volcanic hot spring, far geothermal source, had lateral flow, and associated with leaching process or surface water mixing.

Table 1. pH, surface temperature, and concentrations of some cations and anions (ppm) of the hot springs

Location	pH	T°C	Ca	Na	K	Mg	Cl^-	$SO4^=$	$HCO3^-$	B	Li
Nyelanding (22 YU 08)	5	49	3	2	4	1.1	1	0.6	23.18	0.01	0.005
Permis (22 AA 04-1)	6	46	704	1429	49	21.4	3367	5.1	58.56	0.5	2.8

Cl-Li-B ternary diagram shows that the water samples from the Permis Hot Spring is near the Cl corner which indicating low absorption of B/Cl steam, fluid migrates from much deeper of the older hydrothermal systems. On the other hand, the Nyelanding Hot Spring is in the middle close to the Li corner, where fluid migrates near to the surface. Both are far from angle B, which indicates that during the journey of the hot water from the spring to the surface, there is a slight dilution by the rock through which the hot water flows.

The Na-K-Mg triangle diagram can be used to determine the fluid balance of a geothermal reservoir and to determine a suitable geothermal geothermometer in the study area. Based on the Na-K-Mg equilibrium analysis, it can be seen that sample from the Nyelanding Hot Spring is near Mg corner. This shows that geothermal water is included in immature water. This indicates that although the output water is chloride water from reservoir water, it has been mixed near the surface. On the other hand, the sample from the Permis Hot Spring is relatively high Na and Cl, fall in the middle of triangle at partial equilibrium. This indicates a product of deep source of geothermal systems, low Mg-high Na and Cl, geothermal waters being cooled and quenched through mixing with groundwater associated with sandstone and limestone of Tanjung Genting Formation.

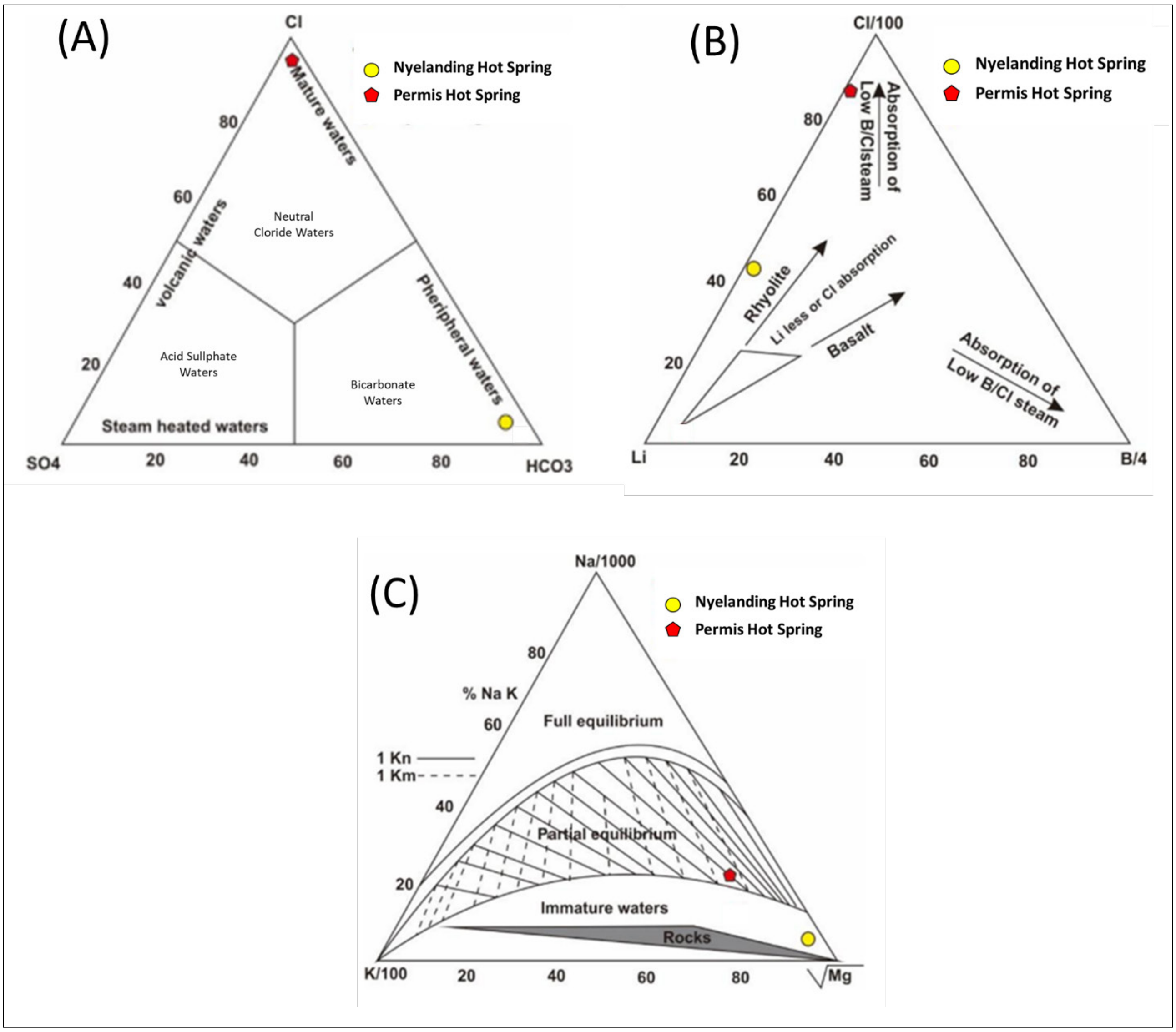

Figure 4. The triangular plots for the major cations and anions of the analyzed hot springs. (A) Cl-SO4-HCO3 ternary diagram shows that Nyelanding Hot Spring is plotted in the bicarbonate waters, while the Permis Hot Spring are plotted in the neutral chloride waters, (B) Cl-Li-B ternary diagram shows that Nyelanding Hot Spring is in the middle close to the Li corner, fluid migrates near to the surface, however Permis Hot Spring high Cl indicating low absorption of B/Cl steam, fluid migrates from much deeper of the old hydrothermal systems, (C) The Na-K-Mg triangle diagram reveal that Nyelanding Hot Spring is imnmature waters, while the Permis Hot Spring is partial equilibrium.

Radioactivity

Geiger Counter measurements of 8 (eight) samples were made to determine the average radioactivity and frequency distribution of radio activities of different rock units in the Bangka Island (Table 2). The results show that granitic rocks are the highest radioactivity level with ranges from 335 nSV/h - 588 nSV/h, followed by metasediment rocks of the Tanjung Genting Formation and Pemali Complex of 70 nSV/h - 123 nSV/h, and the lowest is diabase ranges from 71 nSV/h – 78 nSV/h. This indicates that the radioactive elements within the granitic rocks may influence on the genetic of thermal springs in the Bangka Islands.

DISCUSSION

Geoheritage Values

A hot spring is potential to become a geoheritage since it possesses some values such as scientific, educational, cultural and aesthetical values (The Geological Society of America, 2012). Several studies on non-volcanic geothermal locations carried out on Bangka Island have identified geological structures (Pitulima & Siregar, 2016; Setiawan & Adithya, 2015), constituent rock elements (Anggraini *et al.*, 2019; Siregar *et al.*, 2021; Widyaningrum & Kurniawan, 2019), geothermal structures (Siregar & Kurniawan, 2018), and hotspring flows (Purwoto *et al.*, 2015; Putri

& Harianja, 2021). The occurrence of the hot springs is generally controlled by the geological structures and closely associated with the granite intrusion and the older magmatic activity in the Bangka Islands. Both of hot springs, Nyelanding and Permis, are located near the plutonic granite and along the major fault zone. The distribution of the plutonic rocks as carrier of radioactive elements can produce heat of radiogenic geothermal systems. This scientific evidence could strengthen the identification of geoheritage value in this study area. Understanding the value of these hot spring's sites are important to preserve them for future generation.

Table 2. Radioactivity level of different type of rock units in the Bangka Islands

No	Location	Sample No	Rock Type	Radiation Dose	RSD (%)	Average	Dev. Standard
1	Air Terjun Bukit Tani	RadR-11	Granite	588	4.69	558.00	26.15
				540			
				546			
2	Bukit Menubing	RadR-12	Granite	460	1.09	460.00	5.00
				455			
				464			
3	Bukit Nibung	RadR-13	Granite	505	2.55	493.33	12.58
				480			
				495			
4	Pantai Jerangkat	RadR-17A	Diabas	78	4.72	74.33	3.51
				74			
				71			
		RadR-17B	Granite	350	8.93	353.25	31.55
				335			
				398			
5	Tanjung Pandang	RadR-14	Sandy claystone (Metasediment)	80	11.11	90.00	10.00
				90			
				100			
6	Pantai Bemban	RadR-16A	Sandy claystone (Metasediment)	123	5.04	116.33	5.86
				112			
				114			
		RadR-16B	Blacky claystone	70	5.81	75.00	4.36
				78			
				77			

Geotourism Potential

A hot spring is also potential to be promoted as a geotourism site, since it can attract people to visit the site and enjoy some specific activities by using the fresh hot water such as boiling eggs, experiencing the natural "sauna" bath that might give freshness to the body, and the skin treatment. In addition, a hot spring can also attract people because of their unique visual impact as well as invite the interest of geoscientists to study their occurrences and other experts to develop the site. The Nyelanding Hot Springs has already been used as bathing pool by local people and become tourism destination, while the Permis Hot Spring is still natural and not yet attract people. Both sites could be conserved and developed as tourism sites by utilizing the hot springs. These sites should be provided with a space, facilities, and well organized tourism and recreational programmes. Some other activities can also be conducted around the area such as jungle trekking and hiking. This tourism activities provide benefit for local community and contribute to increase local economy.

CONCLUSIONS

The Nyelanding and Permis hot springs have been potentially considered to be geoheritage sites as unique radiogenic geothermal systems. Based on $Cl-SO_4-HCO_3$ ternary diagram, Permis Hot Spring classified as mature type water while the Nyelanding Hot Spring categorized as peripheral water type. Radioactive elements within the granitic rocks may influence on the genetic of thermal springs in the Bangka Islands. Both hot springs possess geoheritage values, such as scientific, recreational, functional, and economic values. These geoheritage sites are potential for geotourism due to will attract the attention of geoscientists to study more detail on these hot springs, and public to visit the area and enjoy some specific programmes and activities. This study also recommends that this area should be conserved as geoheritage sites and developed for sustainable geotourism by providing infrastructure and facilities.

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