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Tectonic and Structural Setting of Geothermal System in Southern Thailand

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ABSTRACT

The tectonic and structural setting in Southern Thailand dominated by the strike-slip systems of the Ranong and Khlong Marui faults systems. These fault zones are oriented in the NE-SW from the Gulf of Thailand to the Andaman Sea through the Thai Peninsula. They cut across Paleozoic to Cenozoic sedimentary units and Mesozoic granitic bodies. More than 31 low- to medium-enthalpy hot springs are located along these strike-slip systems. The orientations of the fracture systems were extracted by remote sensing interpretations and field observations before being statistically analyzed in the rose diagram. Four lineament directions, orientated in the NE-SW, NW-SE, N-S, and E-W are interpreted according to the Riedel shear system of the NE-SW left-lateral shearing of the Ranong and Khlong Marui faults ultimately caused by the Indian-Eurasia collision. We expect that this tectonic and structural setting controls the non-volcanic geothermal system of Southern Thailand, however in what manner remains to be determined.

1. INTRODUCTION

The geothermal system in Southern Thailand is represented by the low- to medium-enthalpy hot springs (Chuaviroj, 1988; Ngamsom and Dürrast, 2021). More than 31 hot springs are located along the NE-SW strike-slip zones from the Gulf of Thailand to the Andaman Sea through the Thai Peninsula (i.e. Chuaviroj, 1988; Ngamsom et al., 2020). These strike-slip zones, namely the Ranong and Khlong Marui faults, dominate the tectonic and structural setting in Southern Thailand (i.e. Charusiri et al., 2002; Kanjanapayont, 2015). In Thailand, the strike-slip faults generally influence the geothermal system in term of fluid pathway, for example, Mae Chan fault at Mae Chan hot spring (Amatyakul et al., 2015, 2021) and Fang hot spring (Amatyakul et al., 2016) in Northern Thailand, Ranong and Khlong Marui faults near Kapong hot spring in Southern Thailand (Ngamsom et al., 2020).

In macroscopic scale, faults are usually traced by lineaments which are the results of remote sensing interpretation. The lineament analysis is a good tool to apply to fluid pathway of the geothermal system (i.e. Saepuloh et al., 2018). In this study, we present the lineament interpretation combined with the field observation to figure out the tectonic and structural setting of the hot springs in Southern Thailand.

2. GEOLOGICAL SETTING

The area of Southern Thailand consists of Paleozoic to Cenozoic sedimentary rock and Late Paleozoic to Mesozoic igneous rock (Department of Mineral Resources, 1982) (Fig. 1). The Cambrian-Ordovician sedimentary rock generally comprises sandstone, shale and limestone with argillaceous layer. Quartzite and phyllite can be locally found in the Cambrian rock. The Silurian-Carboniferous rock is mainly composed of a variety of clastic sedimentary rocks including sandstone, siltstone, shale, mudstone, and conglomerate. This clastic rocks typically mix with chert, limestone lenses, schist, and quartzite. The Carboniferous-Permian is dominated by mudstone, sandstone, shale, chert, and limestone. Paleozoic fossils almost presents in all of rock units. The Mesozoic sedimentary rock is usually presented by red beds of sandstone, siltstone, shale, and conglomerate. The Mesozoic igneous rock is normally shown by the Triassic and Cretaceous granitic rocks. The rocks are surrounded by an alluvial and coastal deposits of the Quaternary sediments.

The Paleozoic to Cenozoic sedimentary units and Mesozoic granitic bodies lie in the N-S and cross cut by the NE-SW Ranong and Khlong.Marui faults. These strike-slip faults initially moved by the right-lateral in the Late Mesozoic, before switching to the left-lateral in the Cenozoic (Kanjanapayont, 2015; Kanjanapayont et al., 2012; Watkinson et al., 2008). The brittle deformation of the later left-lateral causes the exhumation of the mylonites of these shear zones (Kanjanapayont, 2015; Kanjanapayont et al., 2012; Watkinson et al., 2008). Since Cenozoic, Indian-Eurasia collision has influenced the tectonic setting in the Sundaland or Southeast Asia region (i.e. Charusiri et al., 2002).

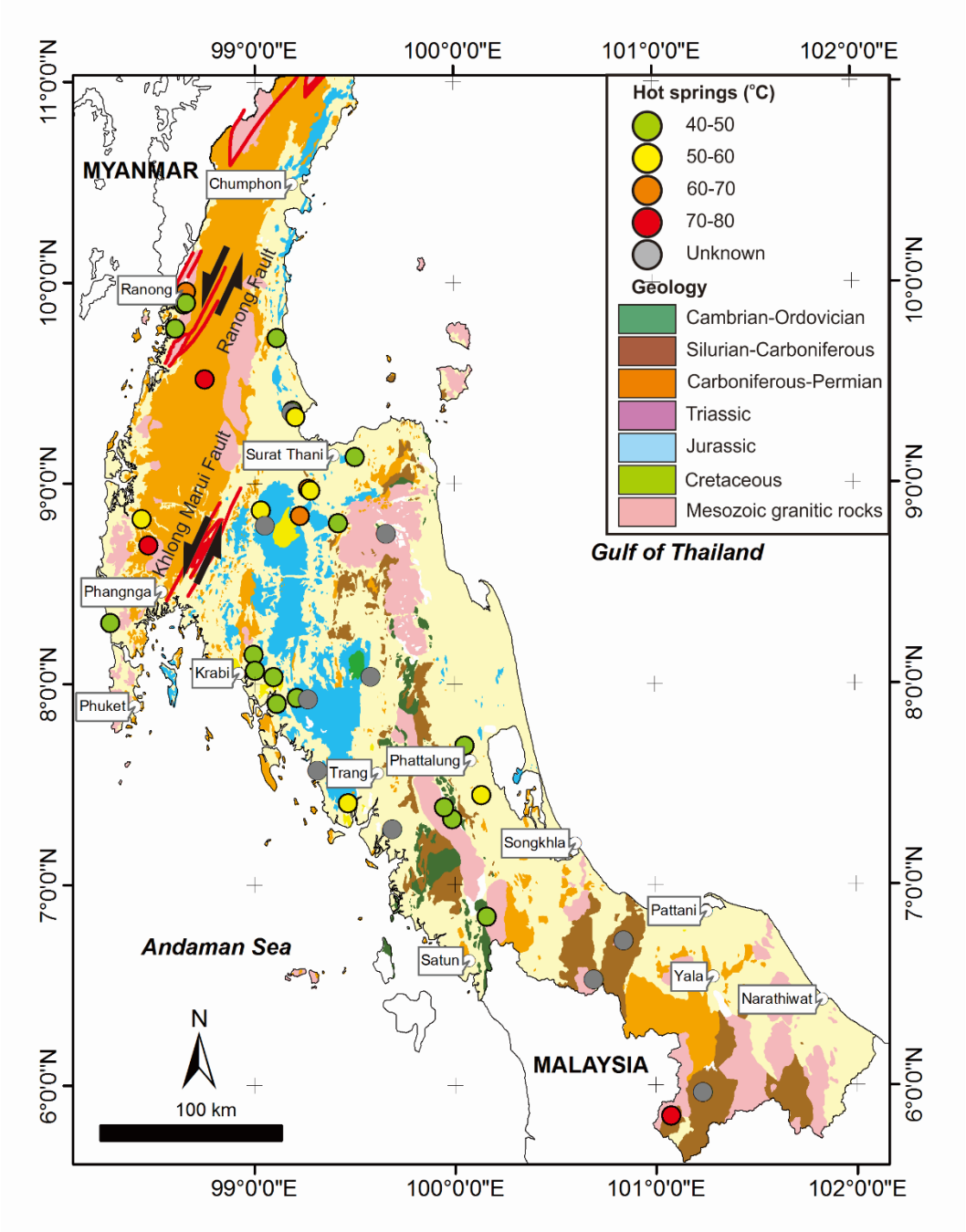

Figure 1: The geological map of Southern Thailand and major strike-slip faults which are Ranong and Khlong Marui faults, and the locations of hot springs in Southern Thailand (Department of Mineral Resources, 1982).

3. METHODOLOGY

In this study, geological structures are observed in the macroscopic and mesoscopic scales. The macro-structures was done by remote sensing interpretation. Digital Elevation Model (DEM) was integrated in ArcGIS geodatabase for spatial lineament interpretation. The spatial lineament orientations were classified and plotted in the rose diagram. Field observation was performed for mesoscopic fractures including faults and joints. The orientation of fractures around the hot springs was measured by geological compass before plotted in the rose diagrams.

The rose diagrams of both macroscopic and mesoscopic structures were together interpreted with the field evidences for the kinematic structural model of the area. The structural model was implied to the tectonic and structural setting, which may related to the geothermal system in the Southern Thailand.

4. RESULTS

4.1 Lineaments from DEM

The lineaments can be classified in to 4 sets by their orientations, which are the NE-SW, NW-SE, N-S, and E-W directions (Fig. 2). The number of the lineament is denser in the area near the Ranong and Khlong Marui faults. The NW-SW is the longest and the most widespread through the Southern Thailand. This NW-SE lineament set is generally bounded other three sets. The NW-SE and E-W sets are predominately appeared in the upper part of the Southern Thailand, and stick to the NE-SW set. The shortest N-S set is limited into the small area between the longer three sets. These four lineament sets obviously show in the rose diagrams (Fig. 3).

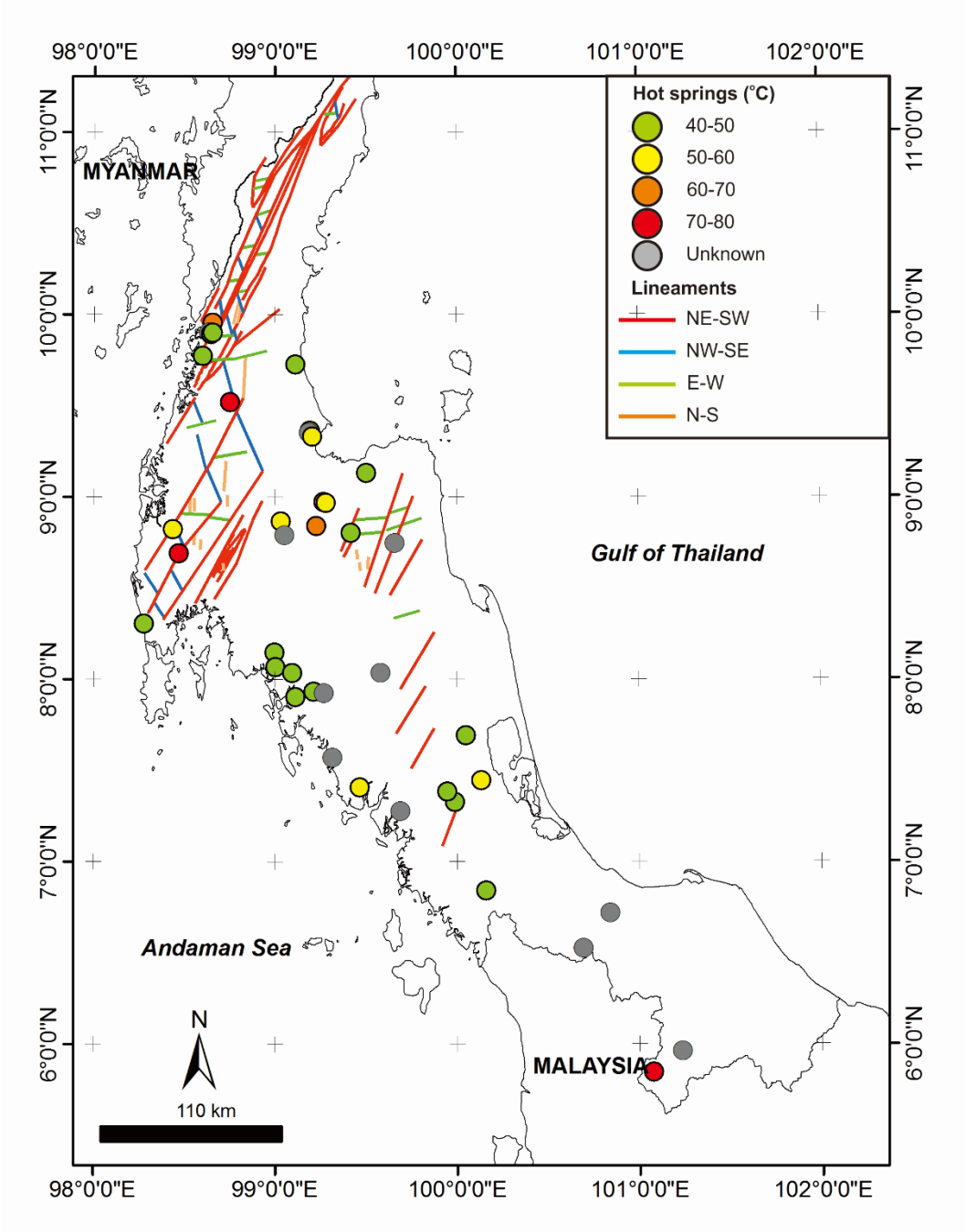

Figure 2: The four lineament sets around the hot springs in Southern Thailand.

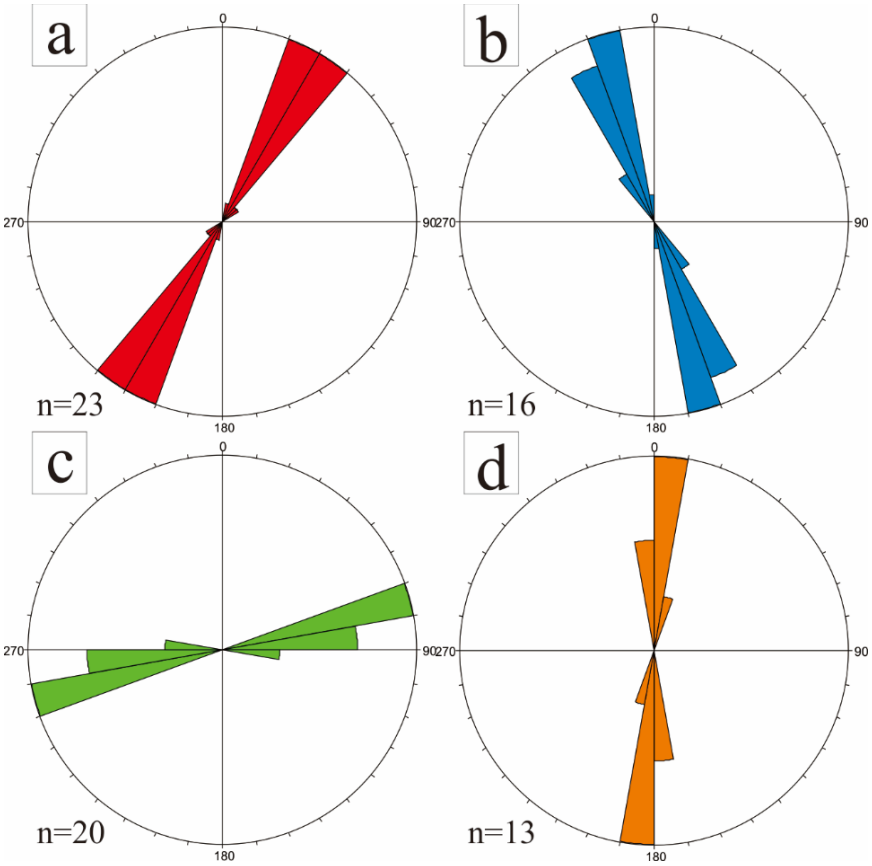

Figure 3: The lineaments shows the orientations of fractures in (a) NE-SW, (b) NW-SE, (c) N-S, (d) E-W.

4.2 Fractures from field investigation

The hot springs around the Ranong and Khlong Marui faults were visited for geological data collection (Fig. 4). Many hot springs are covered by artificial buildings that not showing any natural outcrops. The good geological features usually present in the stream cut outcrops. Fractures including faults and joints show the major orientation in the NE-SW and NW-SE. The E-W and N-S is the minor trend in the outcrop exposures, and they are usually bounded by the NE-SW and NW-SE trends.

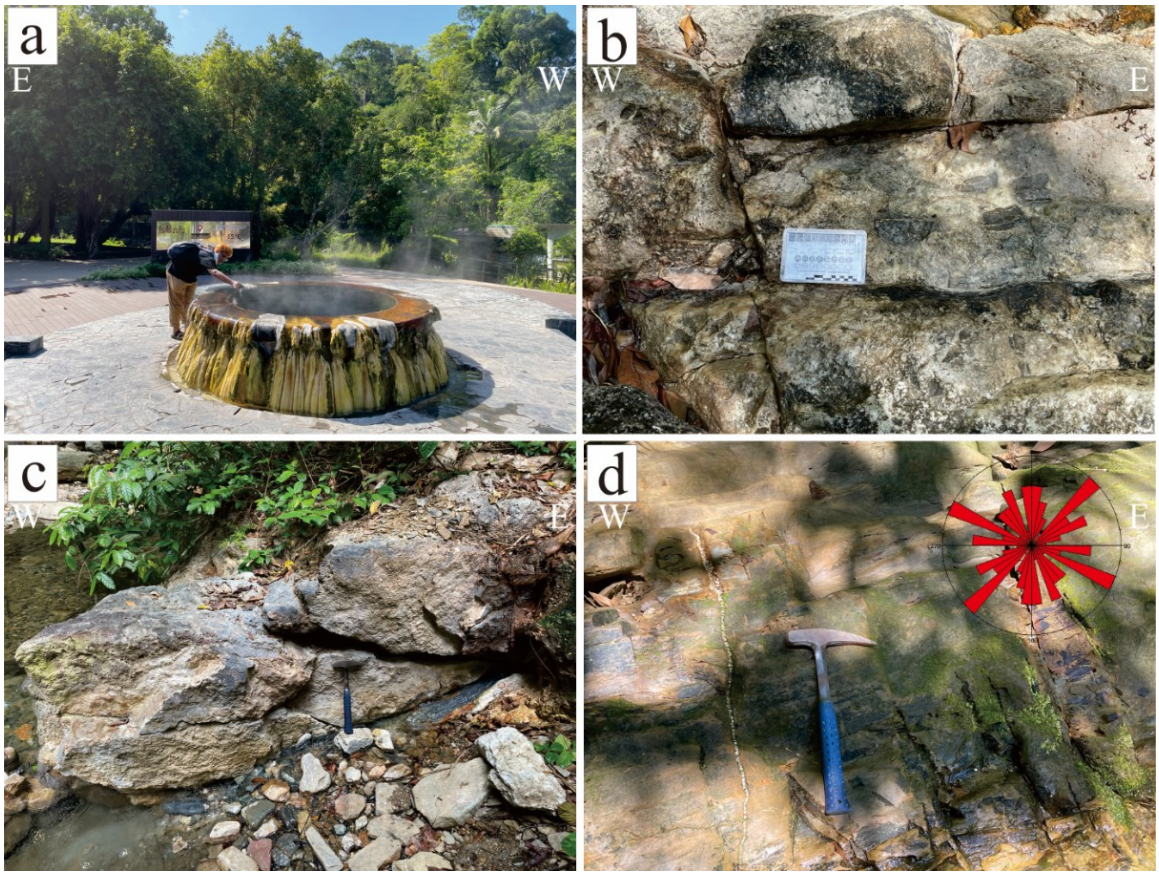

Figure 4: The outcrops around the Southern Thailand hot springs; (a) public park of Raksawarin hot spring in Ranong, (b) fracture at Porn Rang hot spring in Ranong, (c) fracture at Hui Nam Ron hot spring in Ranong, (d) fractures in the Permo-Carboniferous rock and rose diagram of the fractures from the field investigation.

5. DISCUSSIONS AND CONCLUSIONS

From remote sensing interpretation and field observation, four directions of lineament and fracture orientations are interpreted to the Riedel shear system (Fig. 5). The NE-SW trend, which is the most common lineaments and fractures in the study area, is the major structure of this strike-slip system. R-shear is represented by the N-S direction, while R'-shear is shown by two directions in NW-SE. The E-W direction stands for P-shear. All of the Riedel shear components is kinematically fitted to the left-lateral shearing of the Ranong and Khlong Marui faults in the Cenozoic (Kanjanapayont, 2015; Kanjanapayont et al., 2012; Watkinson et al., 2008). This left-lateral Riedel shear system conforms to the NE-SW left-lateral shear in the N-S compression and E-W extension model caused by the Indian-Eurasia collision (i.e. Charusiri et al., 2002). We therefore expected that the NE-SW left-lateral Riedel shear system caused by the Indian-Eurasia collision may controls the non-volcanic geothermal system of Southern Thailand. However, further study need to be done to improve the geological model.

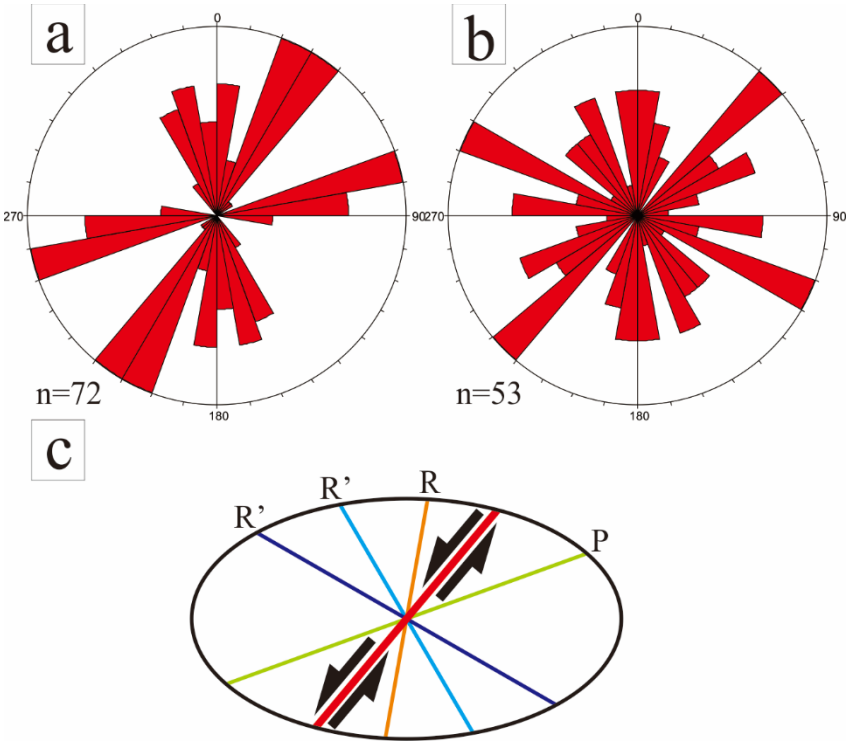

Figure 5: Structural setting of the geothermal system in Southern Thailand; (a) rose diagram shows lineaments form DEM, (b) fracture orientations in the outcrops, (c) the NE-SW strike-slip fault and its Riedel shear system.

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