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Control on the occurrences thermal springs at the southeastern area of Singkarak Lake, West Sumatra : preliminary study results

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ABSTRACT

Several thermal springs are discharging at the southeastern area of Singkarak Lake, West Sumatra. Indonesia. Two springs with temperature in range of 44 – 69 ^{o}C discharging in association with extensive outcrop of fossil travertine (up to 9000 m^3). Lineament of travertine outcrops strike in NNE-SSW, which is possibly the extensional fracture component of Sumani Fault striking NW-SE. Permian limestone at the western of Singkarak Lake might be dissolved by magmatic thermal water depositing calcium-carbonate mineral on the surface. The deep-seated fault of Sumatran Fault System possibly acts as the heat transfer media and controlling the thermal regime at the peripheral of Singkarak Lake rather than volcanic control. The preliminary finding results would add the insight of geothermal exploration strategies in Singkarak in relating to permeability mapping.

1. INTRODUCTION

In several tectonics and volcanic lakes, or pull-apart basins along Sumatran Fault, springs are discharging at their vicinity, namely: Toba, Ranau, Tarutung, etc (Hochstein & Sudarman, 1993; Muraoka et al., 2010). However, there are only a few thermal springs discharging at the vicinity of Singkarak Lake, West Sumatra. A regional geological map shows that most thermal springs in Solok and Padang Quadrangle are discharging from the vicinity of volcanic centers (i.e. Gunung Talang), not on the vicinity of pull-apart area (i.e. Singkarak Lake). Two hot springs complex are accidentally observed during our structural geology mapping to decipher evolution of Singkarak Lake. The hot springs are discharging at southeastern of Lake Singkarak, namely Nagari Tanjuang Bingkuang village, sub-district Kubung (Fig.1 & Table 1). At least based on our online literature searching, these springs are not discussed or mapped yet for research purpose. In this short paper, we attempt to describe the structural characteristic of these thermal manifestations based on travertine distribution, fracture types, and its relationship to regional tectonics.

2.GEOLOGICAL SETTING

Tectonically, Lake Singkarak has long been considered was formed in a pull-apart setting between two major segments of the Sumatran Fault System (SFS), with Sianok Fault and Sumani Fault as the bounding faults (Barber & Crow, 2005; Fig.1). The lake was bounded by 400 m height escarpment, indicating the presence of two opposing oblique normal faults, suggesting a domination of extensional tectonic regime. Neotectonic movement of those faults was observed by a one kilometer surface displacement of young lahar deposit, lake terraces, valley alluvium, and stream courses offset (Tjia & Posavec, 1972). Major historical earthquakes along those major fault segment occurred in 1822, 1926, and 1943 (Katili & Hehuwat, 1967; Sieh & Natawidjaja, 2000). A fault slip rate is estimated at 11 mm/yr (Sieh & Natawidjaja, 2000)

The Sumani Fault runs in NW-SE direction for 60 km, from the eastern flank of Talang Volcano to the western shore of Lake Singkarak, forming a simple straight fault geometry (Figure 1). On the other side, the Sianok Fault runs for 90 km, from the northeast shore of Lake Singkarak to northwest along the southwest flank of Marapi Volcano. The southeast end of Sianok Fault was deemed to be arcuate along the eastern shore of Lake Singkarak, suggesting the normal faulting with downthrown block slip into the lake (Sieh & Natawidjaja, 2000). Furthermore, Bellier & Sébrier (1994) also proposed that the Sianok Fault later developed their new southeast extension, hypothetically crossing the lake floor.

As described by Silitonga & Kastowo (1995) and Kastowo et al. (1996), the oldest stratigraphic unit in Singkarak is the limestone member of Kuantan which is Carboniferous-Permian age, exposed at western wall of Singkarak Lake. The other members of Kuantan, the shale and phyllite unit are exposed on the south-west of the lake (Fig.1). These Paleozoic rocks were overlain by sandy limestone dated at early Triassic and intruded by granite-granodiorite at Middle-Late Triassic, exposed at SE of Singkarak. The youngest rock units are the undifferentiated volcanic rocks and alluvium deposit of Quaternary age (Silitonga & Kastowo, 1995; Kastowo et al., 1996).

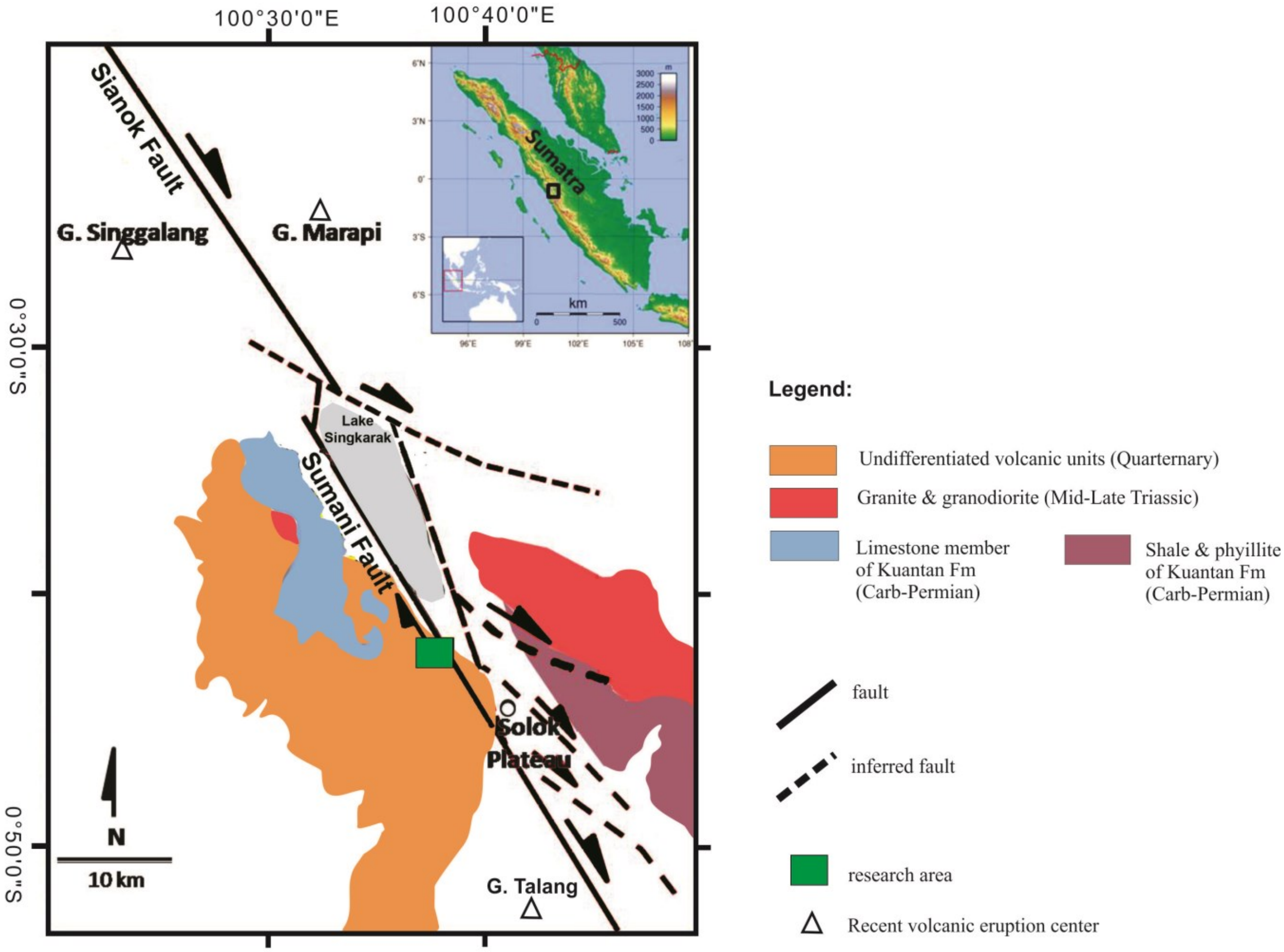

Figure 1: Simplified geological framework of Singkarak Lake, West Sumatra, Indonesia. The lithological distribution is based on Silitonga & Kastowo (1995) and Kastowo et al. (1996). The structural lineament is based on our delineation on DEM (30m).

2. THERMAL MANIFESTATION

The thermal springs are discharging along the cliff of stream (Fig. 2), aligned at NNE-SSW over a distance 0.6 km. The spring AP-1 (AP stands for *air panas* of Indonesian as meaning of hot spring) has greatest temperature (69^{o}C) in the area, 6.5 of pH, and with flow rate less than 0.5 l/s. In AP-1, travertine sinter are widely spread out at the surrounding area. We interpret them as young travertine, since there are many quite fresh tree trunks are covered by travertine sinter (Fig.2).

The second springs, namely AP-2 has lower temperature (44- 45^{o}C), with 6.5 of pH, and discharging fluid at approximately 1 l/s. Travertine sinter are also widely spread out that the springs complex and it is more extensive than in AP-1 (Fig.2). These fossil travertines with its cave structure are exposed at the bisected topography due to the current road cut. The dimension of travertine exposure is 50m long, 15m wide, and 12 m high (or 9000m^3 in volume). There were not obvious springs observed within the cave. The springs are discharging at the top and lower hill of the cave. A pond (100 m^2) filled by rain water occur at the top of travertine cave. It seems that impermeable soils cover the top of the travertine cave which inhibit infiltration of current meteoric water. The presence of following sequence (from top to below): springs above the cave, soil, and the cave itself suggest that the travertine cave is older than the current discharging springs and travertine in AP-1.

Table 1: Data location and characteristics of springs at southeastern Singkarak

Springs	x	y	Elv. (m)	pH	Temp.(°C)	Sinters
AP-1	0°45'54.0"S	100°35'57.7"E	484	6.5	69	young travertine
AP-2	0°45'39.0"S	100°36'05.5"E	454	6.5 -7	44-45	fossil travertine (cave)

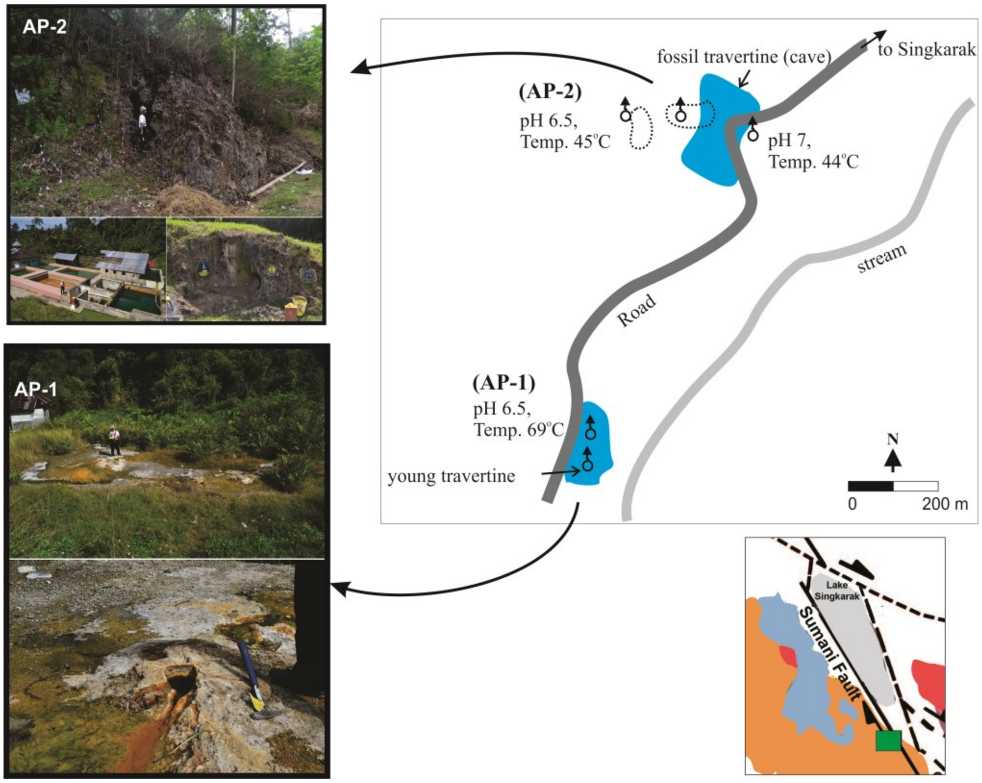

Figure 2: Detail map and photos of springs at southeastern Singkarak.

3. DISCUSSION

Both travertine outcrops in AP-1 and AP-2 as well as their active springs are aligned in NNE-SSW. The NNE-SSW fracture trend are also observed at the minor fracture occurring in travertine of AP-2. In general, the presence of systematic pattern of travertine could imply the presence of opening fracture, as is occurring in other places such as at Pamukkale (Turkey), Repolano (Italy), Tarutung (North Sumatra, Indonesia) and Yellowstone (USA) (Hancock et al., 1999; Brogi, 2010; Nukman & Moeck, 2013; Filippis & Billi, 2012,). The prolong opening fractures allows the existing bicarbonate water in the area continuously discharge and depositing travertine on the near or on the surface.

In terms of regional tectonic trend, the NNE- SSW structural trend in southeastern Singkarak is the extensional fracture component formed by compressional stress in NNE-SSW as the regional maximum principal stress (σ_1; Fig3). This extensional fracture occur within Sumani Fault striking NW-SE (Fig.3). The permeability pattern within the Sumani Fault zone is following the extensional fracture pattern in NNE-SSW. The NNE-SSW trend is similarly found at other travertine exposure in North Sumatra (i.e. Tarutung) which are exposed within the central segment of Sumatra Fault. Tarutung's travertine mostly occur in extensional fracture (NNE-SSW), besides occurring in transtensional fracture in NW-SE trend (Nukman & Moeck, 2013).

The travertine in Sumatra is commonly one of several evidences of the outflow in a geothermal system, in particular the system within volcanic settings. However, our previous study shows that travertine might occur at the surrounded upflow zone where the crustal deep seated fault are present (i.e. SFS; Nukman, 2014). In case of springs in southeastern Singkarak, the travertine is possibly controlled by dissolution of Permian Limestone. The limestone exposure is located at the NW area (Fig.1); whereas the thermal fluid might be transferred through the western strand of SFS (i.e. Sumani Fault) and flowing to the southeast. Geochemical study would be useful to confirm this model.

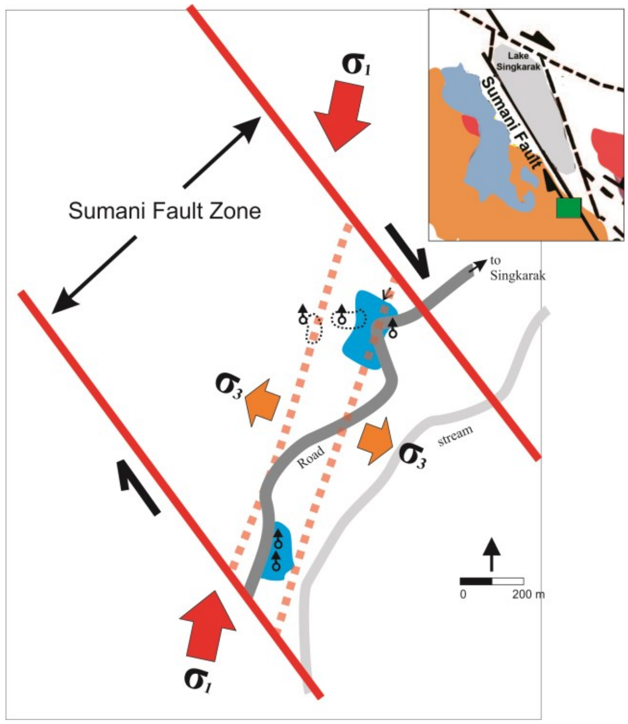

Figure 3: Locality of inferred fracture at southeastern Singkarak, shown as red-dashed line

4. SUMMARY

Travertine in southeastern Singkarak is indicated an active fault control which strikes in NNE-SSW. This fault is the extensional component as caused by the NNE-SSW of regional compression. The NNE-SSW fracture in the spring area is located within the western segment of SFS in Singkarak, namely Sumani Fault. Study of the travertine occurrences at the vicinity Singkarak pull-apart basin is adding the database of travertine studies in relation to tectonics and permeability mapping. The geochemical analysis of springs at southeastern Singkarak is required for further research steps to complete the interpretation of thermal system at the vicinity of Singkarak Lake area.

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