Proceedings World Geothermal Congress 2015
Melbourne, Australia, 19-25 April 2015

Analysis of Thermal Manifestation in Suoh West Lampung Indonesia

A. Hidayatika[1,2], Pri Utami[1], Suharno[2], R. Amukti[2]

1Geological Engineering, Engineering Faculty, Gadjahmada University Jl. Grafika 2 Yogyakarta

2Geophysical Engineering, Engineering Faculty, Lampung University Jl. Prof. Dr. Sumantri Brojonegoro 1 Bandarlampung

Akr_tika@yahoo.co.id

Keywords: geothermal, geochemistry, manifestation

ABSTRACT

Suoh Geothermal Field is located in a pull-apart basin resulting from a step in the Great Sumatra Fault (GSF) which strikes NW. This Field is found within a valley which widens into a broad depression (the Suoh depression) and near the southern end of the Sumatra fault zone. Significant thermal features are located near the western and eastern margins of the depression. The Suoh depression is interpreted to have formed as a result of a fault jog, where the Great Sumatran Fault zone is offset dextrally by a pair of north-south faults. The dominant units are young alluvium (Qal) and Asam eruption deposits (Qae). South-west of the Souh depression the primary rock type is Tertiary Andesite (Tat). North-east of the depression are the Tekorberak Volcanics (Qsdt). The youngest volcanics in the area are the Loreng Volcanics (Qlr) located immediately west of the Kalibata thermal area. Thermal areas in Suoh consist of the Kalibata, Way Haru and Srirejo areas. Geochemistry interpretation was based on the Na-K-Mg and Cl-SO_4-HCO_3 ternary plots. Liquid geothermometry strongly suggest the Kalibata thermal features are connected to a benign geothermal system with temperatures of 250°C to 260°C. Estimated temperatures at Way Haru and Srirejo are lower, at 210 °C and 175 °C, respectively. The hottest fluids in the system upflow along the deep-seated Great Sumatra Fault and the western graben transform fault, heated by magmas associated with the Loreng Volcanics. These fluids flow out into the basin-filling volcanics and sediments and likely the underlying Tertiary volcanics to form the geothermal reservoir.

1. INTRODUCTION

The Indonesian government is intensively going into geothermal explorations and exploitations in Sumatra. One of these is in the southern part of Sumatra, specifically in Lampung Province. Data from Indonesian Ministry of Energy and Mineral Resources, 2012 show there are 5 geothermal fields which could be developed in Lampung. They are Suoh-Sekincau, Ulubelu, Rajabasa, Danau Ranau, and Way Ratai. This paper will focus on area of Suoh.

Suoh geothermal prospects is in the South of Sumatera, specifically in West Lampung District, Lampung Province. During a recent field visit it was found that access was possible with a four wheel drive vehicle, taking about 4 hours from Liwa. During the wet season a portion of the road is not be safe for vehicle passage because of muddy and hilly conditions.

Suoh geothermal prospects are found within a major valley and undulating areas with an altitude ranging from 750 m asl to 1718 m asl (peak of Mont. Sikincau) covered by volcanic rock formations which are a product of Mont. Sikincau activity. The Semangka valley lies near the southern end of the Sumatra fault zone. The prospects are defined by significant thermal areas which are located near the western and eastern margins of the depression.

The thermal features of the Suoh geothermal prospect in Sumatra encompass an area of approximately 250 km^2. Within this area a large number of surface thermal features occur including hot springs, fumaroles, steaming ground and gas emissions. The relationship between the various groups of springs and the associated fumaroles and steam heated features has not been determined in the past and thus the geothermal connection between the various parts of the prospect has been uncertain and undefined. Certainly, the large number of thermal features and the very high heat flow emanating from the prospect are indicative of the probable size of the geothermal systems present as well as the high permeability of the sub-surface rocks in the vicinity of the major features.

Geochemical sampling and analysis have been done at all known thermal areas in Suoh (Figure 1). These thermal areas are known as the Kalibata, Way Haru and Srirejo areas. The thermal features are considerably separated with the most impressive and widely spread activity found at Kalibata. Outside of these thermal areas there are no areas with significant hydrothermal alteration mapped.

2. GEOLOGICAL SETTING

2.1 Tectonic

Sumatra lies on the western side of the Sunda - Banda Island Arc system marking the boundary between the Indo - Australian and the Eurasian crustal plates. At this plate margin Indo - Australian oceanic crust is moving north at a rate of about 6 cm/yr relative to the continental Eurasian plate, resulting in oblique subduction under Sumatra (Hamilton, 1979). Although subduction processes are thought to have been active in the Sumatra area for more than 250 Ma the current geometry of the subduction system is relatively recent (Miocene - 20 Ma) postdating the collision of India with the Eurasian Plate. The oblique nature of the subduction system has resulted in the formation of the dextral (right lateral) Sumatra Fault zone which can be traced over the full length of Sumatra and coincides with the axis of the volcanic (magmatic) arc. NW - SE faults of the Sumatra Fault Zone dominate the structural trend in the western side of south Sumatra.

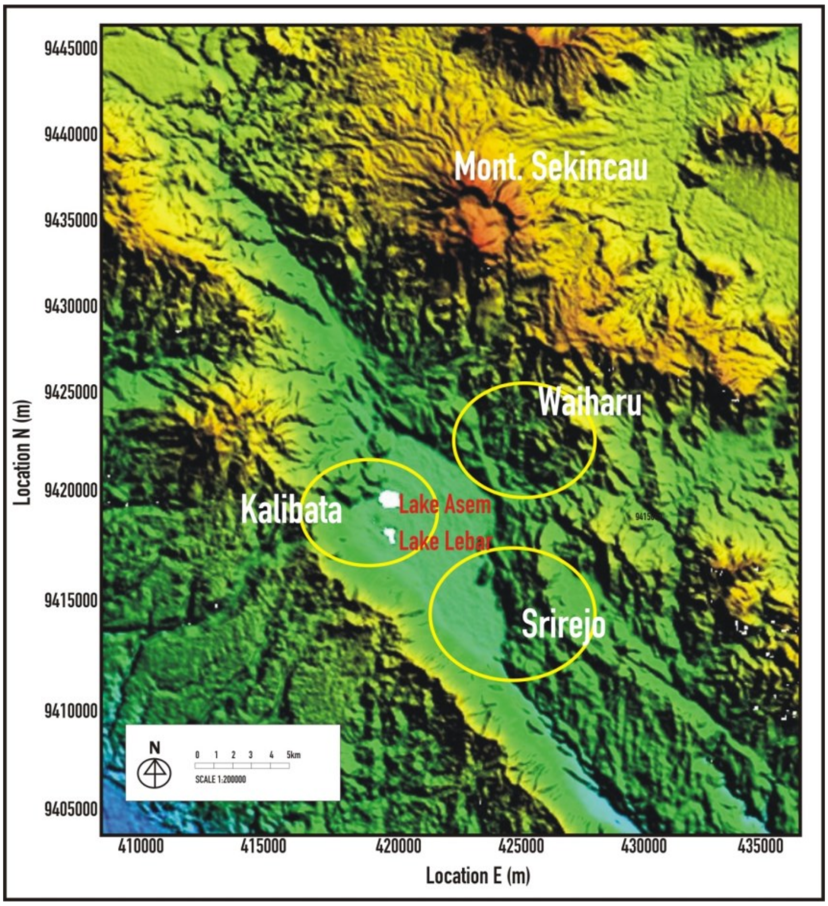

Figure 1: Location map of thermal manifestation in Suoh. Shown are all of the known areas with thermal manifestations including those inside and outside the WKP. These features have been sampled by Unocal (1989 and 1992), Kingston Morrison (for Amoseas, 1994) and Chevron 2010.

2.2 Regional Geology

The Suoh Depression - Gunung Sekincau area of South Sumatra lies within the Barisan magmatic arc zone of the subduction system with the Bengkulu fore arc basin to the SW and the South Sumatra back arc basin to the NE. This Barisan zone is named after the Barisan Mountains, west of Suoh, and is the focus for island arc volcanic activity related to the subduction processes.

The regional geology surrounding the Suoh - G. Sekincau area is dominated by four mainly volcanic units. The oldest (Oligo - Miocene) of these is the Hulusimpang Formation (Tomh) outcropping extensively along the uptrown SW side of the Semangka Fault (western side of Sumatra Fault Zone). This formation is also found on elevated blocks surrounded by younger volcanic on the NE side of the fault zone. The Hulusimpang is intruded by granodiorite bodies (Tmgr), inter-fingers with marine sediments (Tmos), and is overlain by volcanics (Tmba) and other marine sediments (Tml and Tmps). The Hulusimpang is a thick pile of basalt and andesitic deposits formed from coalescing eruptive centers.

The Ranau Formation (Tuff, QTr) is regarded as Plio - Pleistocene in age (Amin et al. 1994) and is thought to have been erupted from Danau Ranau caldera, which is about 50 km NW of the Suoh Depression. This is a rhyolitic pumice deposit thought to have been distributed by pyroclastic flows which are only partly welded close to Danau Ranau. It is notable that the tuff is now only shown in river valleys (Semangka river) and depression (Suoh, Tikorberak, Gedong Surian) possibly attesting to the ease with which this unit is eroded or that it is in fact younger than initially thought.

It is interesting that there is a marked change in lithology mapped to the west of the Suoh Depression where the Hulusimpang formation gives way to Old Quaternary Volcanics with no major change in elevation of the ridge. This Volcanic are also basalt and andesite in composition. The area to the north east of The Sumatra Fault Zone is dominated by Young quaternary volcanics (Qhv) which have been erupted from a number of volcanic centers, Mont. Sekincau being the youngest. These are again dominated by basaltic and andesitic rocks but include dacites. Young Quaternary Volcanics surround the Gedong Surian Depression (alluvial filled, Qa) east of Mont. Sekincau. The faults that are considered most certain based on field checking by Amoseas/Kingston Morrison (1994) are shown on the geologic map Figure 2.

3. ANALYSIS OF SUOH THERMAL MANIFESTATIONS

The temperature and pH of the waters throughout the prospect, and the chloride and sulphate concentrations are plotted against spring and fluid elevation, respectively. The waters at higher elevations, such as at Mt. Sekincau, are generally acid indicating that most of them have been steam heated. Hydrogen sulphide contained in the steam has oxidized to sulphuric acid creating the acidity. In contrast the waters at lowest elevation range from acid to neutral with most of the spring water that are strongly mineralized being neutral to slightly alkaline. Similarly the chloride concentrations in the waters range from less than 10 ppm in ground water to nearly 2000 ppm.

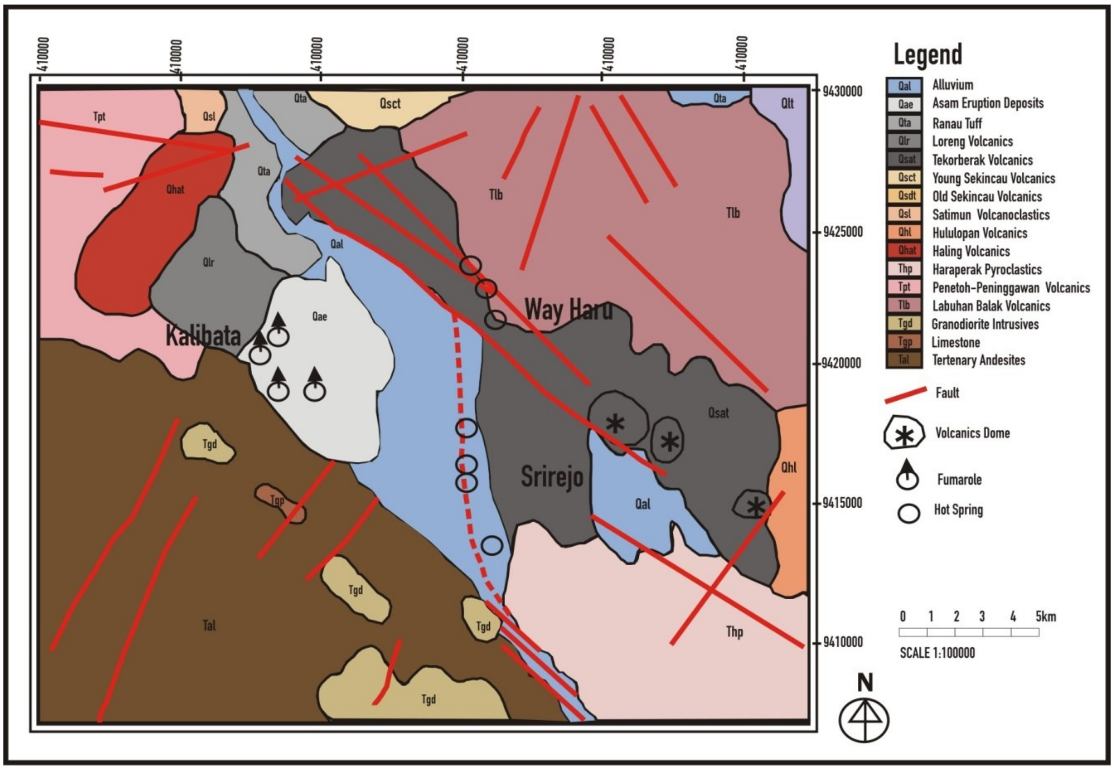

Figure 2: Generalized geologic map Suoh area. Map was developed using ITB mapping by Kingston Morrison forAmoseas (1994). Structures shown on the map were field checked and have the highest degree of certainty. (with modificated)

The level of concentration of chloride in the springs occurring at 230 to 400 m elevation is quite high indicating that considerable energy is available to deliver these waters to the surface in such large volumes. The hot neutral chloride water is the major energy source in water dominated systems and the volumes and concentrations of this type of water in the prospect area suggest that a major resource is present. Similarly the large amounts of silica sinter at Suoh are a good indication of relatively high temperature (> 200°C) waters underground.

The steam discharged from the fumaroles does not contain sulphur dioxide and the small concentrations of hydrochloric acid that appear in the steam is not regarded as being derived from a magmatic component. The large volumes of sulphur that surround many of the steam vents in the Sekincau area are thought to be derived directly from oxidation of hydrogen sulphide. The isotopic composition of the steam in this vicinity also tends to indicate a meteoric water origin. Nevertheless the high volumes of sulphur that are present must not be forgotten and, when drilling in these areas, account should be taken of the possibility of shallow acid conditions.

3.1 Way haru

The thermal activity at Way Haru consists of many boiling neutral chloride springs discharging from the banks of the Way Haru stream over distance of about 500m. Individual springs are generally small, but very numerous and the total flow from the features is enough to raise the temperature of the Way Haru stream (flow rate about 100 l/s) to about 50°C. There is no silica sinter and there are no fumaroles present.

3.2 Kalibata

The Kalibata thermal features extend over on area of about 5 km^2, from Danau Lebar in the south to the foothills of Mt. Kalibata in the northeast. All of the thermal activity at Kalibata is located outside of the area prospect. The thermal activity is very vigorous and includes large fumaroles, high flow rate boiling springs and extensive areas of steam-heated ground and mud pools. The fumaroles on the slopes of Mt. Kalibata in the north are solfataric in nature and occur in an area of highly altered ground dotted with numerous craters and sulphur deposits. There are two localized areas west of Danau Asam where large flow rate Cl springs are located. The southern most of the two springs has the highest flow rates (20-50 l/s) and discharges from a recently formed rift zone, which according to the local accounts, opened in 1994 following a large regional earthquake. There is a large silica terrace associated with this rift.

3.3 Srirejo

The thermal activity at Srirejo consists of hot neutral chloride springs that occur at intervals for several kilometers along the southern half of the eastern boundary of the Suoh depression. There are neither silica sinters nor fumaroles associated with these features.

The Suoh thermal areas have been sampled on 4 different occasions, the most recent samples are still at the laboratory so no results are reported for those samples. All of the analyses provide a consistent interpretation of the fluid geothermometers. The gas geothermometer data from the fumaroles at Kalibata also give consistent results and estimates of the reservoir temperature.

In any case, the geothermometer temperatures around the immediate environment of the hot springs are high and of the order 200°C and higher. In the western part of the Suoh depression could well exceed 260°C and the general trend for all the samples in this zone indicate temperature between 200°C and 270°C. Liquid geothermometry strongly suggest the Kalibata thermal features are connected to a benign geothermal system of 250°C to 260°C. Estimated temperatures at Way Haru and Srirejo are lower, at 210°C and 175°C respectively. Figure 3 shows the liquid geothermometry using a Na-K-Mg ternary diagram. This diagram shows the mixing lines and how they project to the full equilibrium line. There were 2 samples from Kalibata and Way Haru that plotted on or very near the equilibrium line. In these cases, where equilibrated samples are collected it indicates a very direct connection to the reservoir and the actual shallow reservoir temperature can be predicted with a high degree of certainty. As indicated by the Cl-SO_4-HCO_3 ternary plot these thermal areas plot as mature geothermal fluids (Figure 4). This indicates the waters in Suoh are sourced from benign systems and there is very low risk of encountering corrosive fluids.

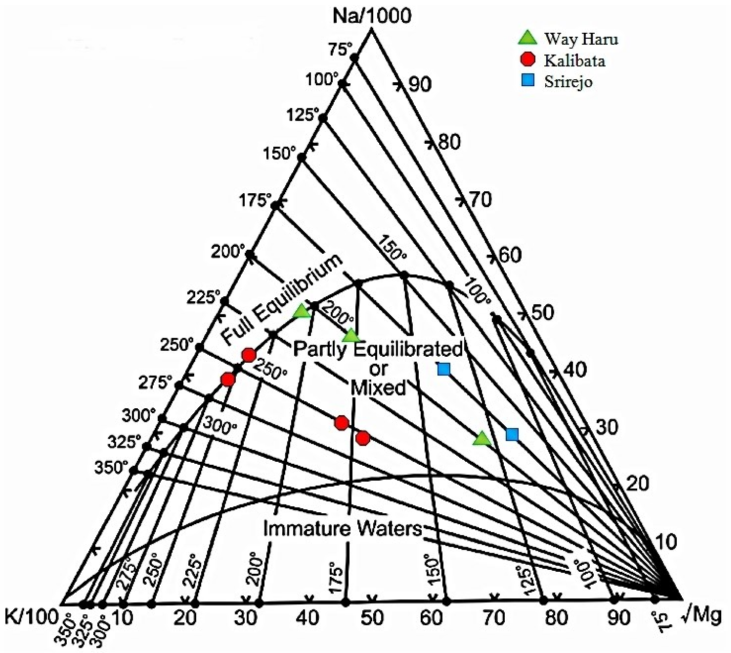

Figure 3: Na-K-Mg Ternary Diagram from Suoh thermal features. Show mixing lines and extrapolations to the equilibrated temperature line. Samples from Kalibata (275°C to 280°C) and Way Haru (210°C) include those that plotted on the equilibration line giving a high level of certainty for the reservoir temperature estimates for those two areas. Srirejo estimates are about 175°C reservoir temperature.

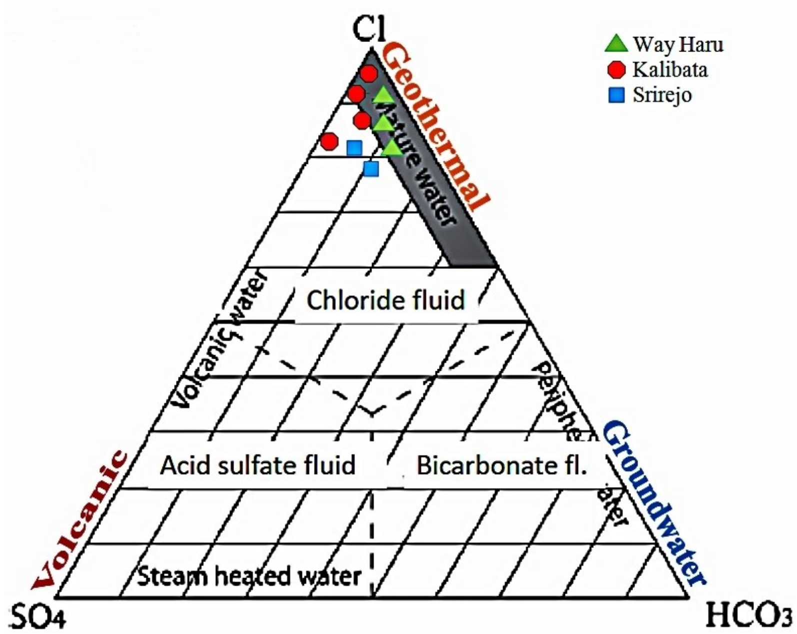

Figure 4: Cl-SO_4-HCO_3 Ternary Diagram from Suoh thermal features. Plotting near the Chloride area indicate fluids are sourced from a mature geothermal system indicating a source from a benign geothermal system.

4. SUMMARY

The Suoh geothermal system appears to be confined to a faulted block and has good, fault-controlled vertical permeability that allows a very high heat flow and high fluid surface discharge. The system lies in a basin with good potential recharge nearby, and hence the reservoir will be liquid dominated and will have a high thermal gradient. The estimated reservoir temperature of 275°C will be found at relative shallow depth of 600-1000 meters.

The hottest fluids in the system upflow along the deep-seated Great Sumatra Fault and the western graben transform fault, heated by magmas associated with the Loreng Volcanics. These fluids flow out into the basin-filling volcanics and sediments and likely the underlying Tertiary volcanics to form the geothermal reservoir. Based on fluid geothermometry, reservoir temperatures are at 250- 260°C. The waters leak to the surface in many places to form the surface thermal springs. A number of these "leaks" formed during hydrothermal eruptions associated with local or regional seismic activity during historical times. The temperature profile in the Kalibata reservoir is likely to be very close to the boiling point curve, based on the equilibrated nature of the surface fluids and the vigor of the historical hydrothermal eruptions. This means that the 275-280°C reservoirs should be at about 1000 m vertical depth, and 250°C fluids could be as shallow as 500 m vertical depth below the surface. Reservoir permeability is likely related to the NW oriented Great Sumatra Fault, the N-S step-over fault, and potentially lithological boundaries within the basin-filling sediments and volcanics.

REFERENCES

Akbar N.: Penyelidikan Lanjutan terhadap Gejala-gejala Panasbumi di daerah Lampung-Sumatera Selatan. The Volcanology and Geothermal Energy Survey Project Section. No.2, (1972).

Amin, T. C., Sidarto., Santosa, S., Gunawan, W.: Geologi Lembar Kotaagung, Sumatra. Geological Research And Development Center. Bandung, (1994).

Giggenbach, W F.: Geothermal solute equilibria. Derivation of Na-K-Mg-Ca geoindicators. Geochimica et Cosmochimica Acta 52, (1988), 27 49-2765.

Hadisudewo, D., Claproth, R. dan Somad, A.: Laporan Penelitian Geokimia Panasbumi Daerah Suoh-Antatai,Propinsi Lampung, Sumatra. Report No 303/DV/1985, Directorate of Volcanology, Bandung (1983).

Hamilton, W.: Tectonics of the Indonesian region. *United States Geological Survey Professional Paper,* (1979), p. 1078.

Sieh, K. dan Natawidjaja, D.: Neotektonik Patahan Sumatra, lndonesia. Journal of Geophysical Research, (2000) , 105: 28295-28326

Stehn, Ch.E.: Die semivulkanischen explosionen des Pematang Bata in der Soeoh - Senke (Sud-Sumatera) in Jahre 1933 (in German). Natuurk. Tijdschr. voor Ned.-lndie 94: 46-69 (1934).