Geothermal Study of the Airklinsar Geothermal Field Empat Lawang District, Sumatera Selatan Province, Indonesia

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***Abstract*- The first geothermal exploration activities in Empat Lawang District, Soth Sumatera Province, Indonesia were carried out in the Airklinsar field, Ulub Musi Sub-District. The discharge test measurements show that wells Airklinsar spring produce predominantly from a single-phase, reservoir (liquid) with a temperature of 225°C and 223°C. The temperature analisys using silica and Na-Mg geotheermometers. The chemical composition of the reservoir water was analyzed by standard methods and subsequently classified using Cl-SO4, HCO3 and Cl-Li-B triangular diagrams. A Na-K-Mg triangular diagram was used to classify waters according to the state of equilibrium at given temperatures. The geothermal waters are of chloride type and from a relatively old hydrothermal system. Thermal fluid is in equilibrium with reservoir rocks. The chemical geothermome-ters were used to predict subsurface temperature. Silica geothermometers give temperature more close to measured temperature whereas cation geothermo-meters show significantly higher Silica geothermometers.**

***Index Term*-- geological, geochemical, geothermometers, geoindicator, Airklinsar geothermalfiel**

I. INTRODUCTION

The Airklinsar geothermal field is one of the prospective areas in Sumatera Selatan Province, Indonesia for geothermal exploration which is located on one of the Bukit Bukit barisan mountaneous. In the other hands, its also is located on one of the major tectonic belts of the Fault Sumatera System. The hot springs are located mainly on major active fractures and volcanic areas. The Airklinsar is one of the interisting areas in Empat Lawang District. The Airklinsar is one of the prospective areas in Empat Lawang District, Sumatera Selatan Province for geothermal exploration which was initiated by Virgo Team are the first in June 2012.

II. MATERIAL AND METHOD

A. *Geology of Airklinsar*

The Airklinsar geothermal field is situated on the major tectonic belts of the Fault Sumatera System. There are volcanic areas spread throughout the country. The country has many hot springs with a variety of temperatures ranging up to 98°C. The hot springs are located mainly on major active fractures and volcanic areas one of which is Airklinsar. The Airklinsar hot spring is spreadout within the Ulu Musi and Talang Padang Sub-District of Empat Lawang District. The geological of the Ulu Musi and Talang Padang Sub-District extends elongated the Fault Sumatera System between the Sumatera Selatan and Bengkulu Provinces, bisides of Bukit Barisan mountanious. The Fault Sumatera System runs the length of the Sumatera Island and transects the Conozoic volcanic arc [1]. The activity of magma was prominent during midlle Miocene extend to Pliocene [2].

The Airklinsar geothermal field is spreadout as shown in Figure 1. The lithologies such as Qa is Aluvium, QTv is Rhyoandesite Volcanic Unit, Tmbt is Baturaja Foration, Tma is Air Benakat Formation, Tomt is Talang Akar Formation, and Tpok is Kikim Formation. The rocks of the Airklinsar geothermal field are divided into six zones that are characterized in Figure 1 modified from [3].

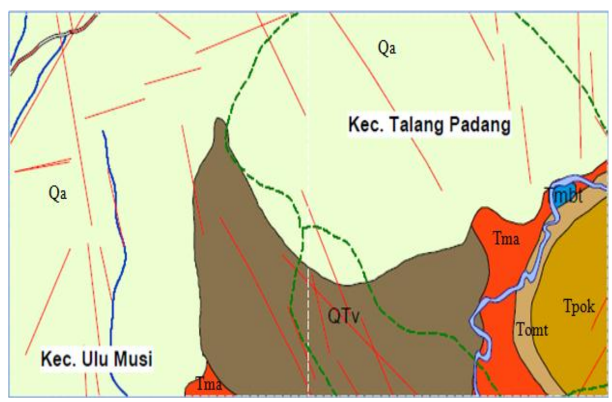

Fig. 1. The Geology of Airkinsar geothermal field within the Ulu Musi and Talang Padang Sub-Districs. Qa is Aluvium, QTv is Rhyoandesite Volcanic Unit, Tmbt is Baturaja Foration, Tma is Air Benakat Formation, Tomt is Talang Akar Formation, and Tpok is Kikim Formation.

B. *Cemical Analysis*

The geochemical study is based on discharge water samples collected from the hot spring Airklinsar discharge. The water samples collected from the discharge of two hot water springs. These samples were collected in June 2012. Samples were untreated and included acidified water. Chemical analyses of Na, K, Ca, Mg, B, Li, and SO4 were carried out in the site laboratory of Lampung University (Bandar Lampung), and the SiO2 pH, Cl, HCO3, in laboratory of Sriwijaya University (Palembang).

The relative Cl, SO4 and HCO3 contents thermal waters. The composition area the where ionic solute geothermal should beindicated reservoir condition. Li, Cl and B are conservative elements in the geothermal system. They are fixed in fluid phases and have not equilibrated. The conservative elements are the best geoindicators of the origin of the geothermal system. B/Cl ratio and Cl-Li-B ternary diagram were used to indicate the source of the fluid.

Temperature calculation based on silica geothermometer, Na-K geothermometers (Fournier and Giggenbach) [4, 5], K-Mg geothermometer [6]. Besides, the ternary diagram Na-K and K-Mg also use for evaluating equilibration temperatures.

III. RESULT

The average chemical compositions of the geothermal water from the Airklinsar hot spring discharg are presented in Table I. A plot of the relative concentrations of Cl, SO4 and HCO3 is ilustrated in Figure 2. A plot of the relative concentrations of Cl, Li and B is shown in Figure 3. A plot of the Na-K-Mg ternary diagram shows the equilibrium between the geothermal fluids and rock and reservoir temperature is shown in Figure 4. The subsurface temperatures calculated using geothermometer presented in Table II.

TABLE I
THE AVERAGE CHEMICAL COMPOSITIONS OF THE GEOTHERMAL WATER FROM AIRKINSAR HOT SPRING DISCHARGE

No	Sample	(ppm)
1	Na	32
2	K	9.1
3	Ca	133
4	Mg	1.5
5	B	17
6	Li	0.223
7	SO_4	340
8	HCO_3	61
9	SiO_2	50
10	Cl	664

IV. DISCUSSION

The Airklinsar possesses great potentiality for the utilization of geothermal energy. The region has been centre of attraction to a number of visiting national scientists, encouraging them to collect and analyse geothermal water samples at different localities on a sporadic basis. One of such studies has determined the temperature and reservoir characteristic.

A. Classification of the thermal fluids

The average chemical compositions of the geothermal water from the Airklinsar are presented in Table 1. The discharge water from Airklinsar hot spring are of the chlorate type with alkaline pH (6.2-7.8) and with total dissolved solids in range of 500-750 mg/kg. A Cl and Ca are predominant cations with concentration of 664 and 133 mg/l respectively, whereas Mg is present in about (1.5 mg/l). The chemical compositions of the waters were classified on the basis of major ions using the CI-SO4-HCO triangular diagram of Giggenbach (see Figure 2) [7, 8]. The sample plot to area of immature waters and can be classified as Cl-rich geothermal water.

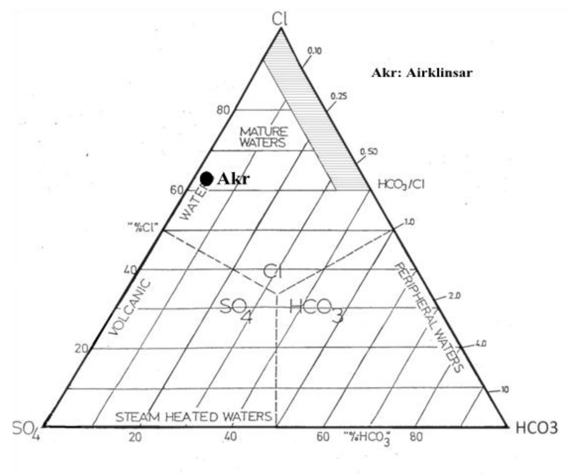

Fig. 2. Airklinsar hot spring situation in the ternary diagram of Cl-SO4 and HCO3, due to characterised the reservoir. HCO3/Cl closed to 0.09 with %Cl is 62.3% and %HCO3 is 5.7%.

Cl and B are conservative elements in the geothermal system. They are fixed in fluid phase and have not equilibrated. The conservative elements are the best geo-indicators of the origin of the geothermal system. B/Cl ratio and Cl-Li-B ternary diagram were used to indicate the source of the fluid. A plot of the relative concentrations of Cl, Li and B is shown in Figure 3. The geothermal waters have high Cl content relative to Li and B, indicating that they are from an old hydrothermal system and that fluid migrated from the old basement rock.

The B/Cl ratio of the water from airklinsar hot spring is 0.03 (see Figure 3) [8]. The B/Cl ratio should be representative of andesitic reservoir and rhyolitic system or due to absorption into alteration clays along the geothermal flow. The geothermal waters have high Cl content relative to Li and B, indicating that sample come from an old hydrothermal system and that fluid migrated from the old basement rock.

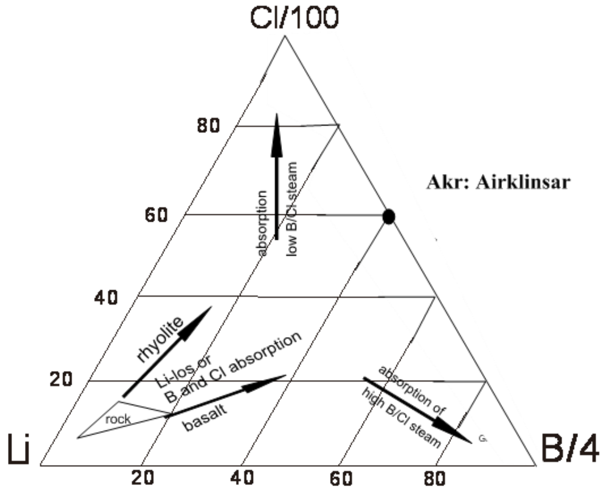

Fig. 3. Airklinsar hot spring situation in the ternary diagram of Cl-Li and B. B/Cl closed to 0.03 with %Cl and %B are 60% and 40% respectively.

By considering the diagram presented in Figure 4, the Airklinsar hot springs plot in the immature water part, so using the chemical geothermometers is not reliable according to the theory used to establish the diagram. Presumably, fast circulation of fluid through the rock fractures, the sample have not gained equilibrium with rock, (see Na-K-Mg diagram, Figure 4). This causes the water to be iimmature, considering the ion exchange processes that, equilibrium has not been reached yet with rock minerals because of circulation flow. The sample plot to area of immature waters and can be classified as Cl-rich geothermal water which formed by the interaction of geothermal fluids with the host rock and dilution with low salinity water at depth [9].

B. Subsurface Temperature Estimation

Chemical geothermometers are used in order to estimate the reservoir temperature. The important criteria for chemical geothermometer application to thermal spring are the pH, temperature and discharge rate of the spring. Both silica and cation geothermometers are applied to the Airklinsar hot springs. Some give unreliable results such as either lower than spring temperature or extremely high temperature. These equations are based on geothermometers for quartz, which assume hat these minerals used in geothermometers, are not in equilibrium with rock – water interaction in reservoir.

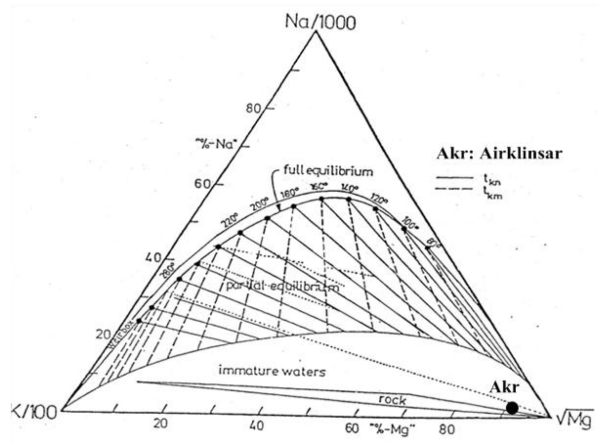

Fig. 4. Airklinsar hot spring situation in the ternary diagram of K-Na and Mg, with %Na is 2,4% and %Mg is 91%.

TABLE II
TEMPERATURE CALCULATION OF THE AIRKLINSAR HOT SPRING CHEMISTRY GEOTHERMOMETER

No.	Geothermometes	Temperatures
1	SiO_2 no steam loss	102,0°C
2	SiO_2 max steam loss	102,7 °C
3	Na-K (Fournier)	325,8 °C
4	Na-K (Giggenbach)	331,5 °C
5	K-Mg	86,8 °C

The silica and cation geothermometers were used for the evaluation of subsurface temperature for well discharges (Table 2). The Na-K-Ca geothermometers of and Giggenbach (1988) were used. Source of temperature equations: T (Na-K) [5, 10], T-SiO2 no steam loss, T-Sio2-maxsteam loss [4, 8, 11, 12]. These give reservoir temperatures ranging from 86°C to 330 °C. In comparison with SiO geothermometer, the temperature calculated by the quarts geothermometer [4] is about 102°C. It may be inferred that quartz controls the dissolved silica concentration in the deep reservoir [13]. The temperatures obtained from cation geothermometers are significantly higher than from silica geothermometers. The Na-K geothermometer of [4] and [5] suggested reservoir temperature in the range of 326-331°C which is higher than SiO geothermometers range of 102-103°C [8].

The Na-K-Mg triangular diagram shows the equilibrium between the geothermal fluids and rock and reservoir temperature (Figure 4). Figure 4 shows that samples from studied Airklinsar hot spring geothermal field fall on the immature water, suggested attainment of the water rock equilibrium [8]. By considering the diagram presented in Figure 4, the Airklinsar hot springs plot in the immature water part, so using the chemical geothermometers is not reliable according to the theory used to establish the diagram. In this Na-K-Mg diagram the sample have not gained equilibrium with rock, presumably due to fast circulation of luid through the rock fractures. This causes the water to be immature, equilibrium has not been reached yet with rock minerals because of circulation flow. Figure 4 shows that samples from studied Airklinsar hot spring geothermal fields.

C. Reservoir Estimation

Even though the above table suggests that none of the springs have a huge mass flow rate, a number of springs emerging in the vicinity could have lowered the flow rate. Water containing chloride concentration about 650 ppm from Airklinsar does meet the mixing characteristics since their pH values do lie between 6 and 8. The waters at Airklinsar hot spring lying in this region have relatively high chloride, suggesting that the chloride waters as indicated by the Giggenbach's diagram of concentrations of the major anions, Cl, SO4 and HCO3 (Figure 2). The characteristic the reservoir represented the HCO3/Cl closed to 0.09 with %Cl is 62.3% and %HCO3 is 5.7%.

D. Mixing Characteristics of Thermal Waters

The following characteristics of mixing are described by [8], (1) A huge mass flow rate of spring, (2) Calcite unsaturation, (3) A high concentration of silica relative to discharge temperature. Calcite is either supersaturated, suggesting that there is mixing. No high concentration of silica is observed relative to discharge temperature in the spring waters. It leads to conclude that the waters are mixed.

V. CONCLUSIONS

The geothermal waters discharged from Airklinsar geothermal field of the Empat Lawang is of chlorate type with a high concentration of Cl. Chemical compositions of reservoir waters indicate that the reservoir is located in the liquid dominant zone and geothermal waters come from an old geothermal system. Thermal fluid is in equilibrium with reservoir rocks, which can be the product of water-rock interaction at high temperature. Common geothermometer have been used for estimating the subsurface temperature. The results from Na-K geothermometers and Na-K-Mg geoindi-cator, indicate that the reservoir temperature. The calculated temperatures using Na-K geothermometers indicate at a range 326^oC to 331^oC. However the Na-K-Mg geoindi-cator is not indicate the clear temperature.

Common geothermometers have been used for estimating the subsurface temperature. The results from silica geothermometers indicate that quartz can control silica concentration in the reservoir or quartz geothermometers better indicate the reservoir temperature. The calculated temperatures using quartz thermometer is 102^oC and 102.7^oC. Cation geothermometers give temperature significantly higher than quartz geothermometers.

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