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CHARACTERISTICS OF MOUNTAIN ARJUNO-WELIRANG GEOTHERMAL JAWA TIMUR PROVINCE, INDONESIA

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ABSTACT

The analysis of the Arjuno-Welirang geothermal field Jawa timur Province, Indonesia. The field situated at longitute beetwen 112^{o}29'12''and 112^{o}37'29'' and at latitute beetwen -7^{o}37'36'' and -7^{o}49'51''. The surface manifestation consist of hot spring, fumarol and alteration rocks. The hot spring discharge expose at elevation 1350 m asl, 1600 m asl, fumarol and solfatara spreadout within the summit of Mt. Arjuno and Mt. Welirang, at elevation about 3100 m asl. The alteration rocks spreadout in the two location such as at surounding Plupuh Crater and at a lower part of the Mt. Pundak. Geology Analysis, such as surface manifestation and geology structure analysis and geochemical analysisi conducted due to chracterises the reservoir condition of the Mt. Arjuno-Welirang geothermal system. Tentaive result of the research show that the Arjuno-Welirang geothermal system is *chlorite water*, althoght the result of reservoir analyss indicated the bicarbonat water (HCO_3). Its caused by interction between reservoir water with meteoric water and water level, closed to the surface. The reservoir temperature up to 175°C. The reservoir rocks of the system is andesitic basaltic rocks. The hydrothermaly system should be product of water interaction with vulkano-magmatik. The hot water before reach the surface predicted has interacted with sediment rocks. The other hand, that the manifestation is product the lateral flow or out flow.

Key word: geology, geochemis, geothermometer, geoindicator, Arjuno-Welirang geothermal field

PENDAHULUAN

Geothermal energy produces clean energy and sustainable. Geothermal Mt. Arjuno-Welirang located in East Java Province, is geographically located at between coordinates 112^{o}29'12" and112^{o}37'39 longitude, and between 7^{o}37'56 " and 7^{o}49'51 latitute. Arjuno-Welirang is a complex volcano with a height of 3350 m asl. Arjuno-Welirang complex located between two volcanoes are older,Mt. Ringgit to the east, and Mt. Linting in the south. The existence of geothermal Arjuno-Welirang characterized by the presence of hot springs, fumaroles and sinter deposition. In general, this area consist of lava and pyroclastic flows. Geothermal manifestations in this complex can be divided into three groups of five locations in the form of hot water (Padusan, Coban and Cangar), and fumaroles around the summit Welirang alteration, and alteration around Mt. Pundak to the bottom.

MATERIALS AND METHODS

Manifestation

Hot Padusan, located in two locations, appear in pyroclastic rocks and andesite lava boulders product Mt. Welirang, at an altitude of about 900 m asl (above sea level) temperature of 50°C and 55°C, the conditions of the local air temperature 22°C and 25°C. Kedaan water clear, odorless and does not feel, pH 5.87 to 6.30. Water discharge about 2 l/s, and found sinter carbonate and iron oxide are quite a lot (Geology and Geochemistry Survey Team, 2010).

Coban hot spring, appearing at an altitude of 1348 m app, on the sidelines of andesitic lava product Mt. Arjuno-old Welirang, temperature 39.4°C, the air temperature is 22.7°C. Water conditions: clear, odorless, pH 6.44, the discharge of about 0.1 l/s, contains a lot of iron oxide. Cangar hot spring, found in two places is about 100 m. Pyroclastic flow of products appearing on the Mt. Kembar at an elevation of 1604 to 1611 m asl, temperature 48.3°C and 54.1°C, the air temperature is 22.3°C and 24.1°C. Carbonate sinter layer thin and weak iron oxidation. State of clear water, colorless and tasteless.

Fumaroles found in cone complex Mt. Arjuno-Welirang: in the crater Mt. Arjuno, Mt. Kembar 1 & 2, and Mt. Welirang (Plupuh & Jero). Crater temperature range 94.1°C Plupuh to. 137.5°C. And Mount Solfatara fumaroles are at an elevation of 3050 Welirang sd 3150 m asl.

The alteration rocks found surounding the crater Plupuh, has a fairly wide spread up to the slopes the Mt. Welirang & Mt. Kembar 1, whitish, reddish and gray-brown. Alteration in the bottom of G. Shoulder appears, elevation> 1000 m app, whitish, found in lava Mt. Pundak next to the eruption.

Geological Structure and Sratigrafi

Most of the geothermal area Mt. Arjuno-Welirang a Quaternary volcanic products, composed of lava flows and pyroclastic eruption clasified based center of eruption. Startigrafi Mt. Arjuno-Welirang consists of: (a) Lava Anjasmara Unit, scattered in the western part, composed of basaltic andesite lava and volcanic breccia, clear vesicular structures, there is a stocky, thick unit of > 1000 m with steep topography with cesarean wall like caldera rim. (b) Old Lava Arjuno-Welirang, the west to the south, around Mt. Ringgit, Mt. Linting, northeastern Prigen and revealed little in the western part of Hot Coban. A rock-basaltic andesite lava with a porphyritic texture, hard and thickness of > 1000 m, is thought to be a complex body Welirang Arjuno-old who is still exposed at the surface. (c) Old Arjuno Pyroclastic Flow-Welirang, lies in the southern part, in the form of sized pumice lapilli to bombs, angled to angled responsibility, vesicular embedded in a matrix of brownish sandy tuffs, predicted products of the body's complex explosive Arjuno the age-old Welirang earlier quarter. (d) pyroclastic flows Guarantee, scattered in the northeast, composed by pyroclastic flows product G. Indemnity. (e) Side eruption, spread over three locations, namely lava product Mt. Bulak and Mt. pundakk in the north and lava product Mt. Dependents in the western part of the complex Arjuno-Welirang. Composed of andesitic-basaltic lava. This byproduct is formed after the formation of lava Arjuno-old. Welirang structures that emerge through the zone on the side, has a height of up to 300 m from the side slopes. (f) Lava Welirang 1, spread across the center to the north. The emergence of lava Welirang allegedly caused by the formation of a regional NW-SE structure for the rising lava. The structure is aligned with the center of the eruption of Mts. Kembar 1, 2 and Arjuno. (g) Pyroclastic Flow Welirang 1, scattered in the north, around Padusan, Pacet up at the foot Recalls Mt. Penanggungan. (h) Lava Arjuno, occupies the center of the complex Arjuno-Welirang to spread to the southeast. (i) Pyroclastic Flow Arjuno, scattered in the southeast, around Tambaksari. Composed of pyroclastic flows Arjuno product, with components sized basalt lava lapilli sd bombs and medium-sized tuff matrix. This unit is aligned override Arjuno lava unit. (j) Lava Welirang 2, crushing units lava eruption Welirang 1 with the same center. At the top there is an active crater (Kawah Jero is at the top and on the edge of the crater Pluluh), sulfur deposition is formed in large quantities, also dtemukan solfatara, fumaroles and alteration. Welirang basalt lava type, porphyritic texture, hollow (scoreous), alternating with pyroclastic flows. (k) Lava Twins 2, located between peaks Arjuno and Welirang, formed after the subsidence processes, flows westward to the area Cangar. Composition of basalt lava rocks. (l) Pyroclastic Flow Twin 2, spread to the east of the center of the eruption of Mt. Kembar 2, fill in the depression Arjuno, forming peaks G. Ringgit. (m) Lava Kembar 1, spread to the west and east of the summit eruption. And vesicular porphyritic rock textures. (N) Pyroclastic Flow Kembar 1, located in the southwest, near the springs toward the Brantas River City Stone and appears slightly in the central eastern part of the eruption. Brown pyroclastic flows, lapilli sized sd bomb, a volcanic ash matrix. On this unit appears Cangar hot water. (o) Lava Bakal, just a little, crushing lava and lava Arjuno Kembar 2 (Geology and Geochemistry Survey Team, 2010).

Geological structure of the study area can be distinguished by the direction of the alignment pattern structure that is: (a) Fault NS, represented by Cangar Fault, Pucung and Claket, a manifestation straightness, the emergence of the fault escarpment and waterfall. (b) Fault NW-SE, represented by Padusan Fault, Pecan, and Will. (c) SW-NE, represented by Welirang Fault, Kembar and Bulak. (d) Fault WE, represented by cesarean Ledug and Ringit. (e) the Caldera Rim Anjasmoro, type normal faults that form a circular steep escarpment. (f) Sector amblasan (collapse), indicated by the Fault Arjuno (Survey Team of Geology and Geochemistry, 2010).

Analysis of the Characteristics Geothermal Systems Arjuono-Welirang

The analysis conducted in this study consisted of (1) includes geological analysis includes analysis beerdasarkan rock alteration, stratigraphy and geological structures, (2) geochemical analysis includes analysis of equilibrium ion (ion balance), temperature analysis based geotermometer and geoindikator, reservoir analysis, and analysis using ternary diagrams for different reservoir characteristics.

Giggenbach (1988) share the solutes in two categories namely Tracer and Geoindikator. Geochemically inert tracer (eg Li, Rb, Cl & B), when added to the fluid would be permanent and traceable origin. Geoindikator is reactive solutes and reflect the environmental equilibrium, (such as Na and K).

Several types of chemical geoindikator geothermal by Giggenbach and Goguel (1989), namely: (a) Geoindikator Cl-SO_4-HCO_3, (b) Geoindikator Cl-B, (c) Geoindikator Na-K-Mg, (d) Geoindikator N2-CO_2-Ar, (e) Geoindikator SO_4-HCO_3-Cl. Triangle diagram Cl-SO_4-HCO_3 is a method used in the determination of the type of reservoir fluids in order to determine the characteristics of a reservoir. The relative content of which is used as a parameter is the content of chloride (Cl), sulfate (SO_4) and bicarbonate (HCO_3). Geoindikator Cl-Li-B is used to evaluate the process of dilution and boiling by comparing the concentration Cl/100 and B/4 that has been converted in units of percent. Moreover, this method is also used to determine the upflow zone and outflow of a geothermal system. Diagram Na/1000-K/100- $\sqrt{Mg}$ by Giggenbach (1988) is a method that works for suspect temperature reservoir and for water balance in lithology. Geoindikator N2-CO_2-Ar is a method for the determination of reservoir rock types.

Geotermometer consideration factors such as the selection is kind of manifestation in the form of hot water with the temperature of the hot springs are relatively high, and the type of hot water which includes water chloride or bicarbonate. Geothermal water can be classified into two types, namely: (a) Based on the concentration of dissolved mineral components (eg, quartz Geothermometer). (b) Based on the relative concentrations of two or more components of the solution (eg, Na/K geotermometer). Geotermometer types are used to determine the temperature of the reservoir, are: (1) Geotermometer silica (Fournier, 1985), is used based on the solubility of silica in water temperature function. Reactions that form the basis of silica dissolution in water is: SiO_2 (s) + $2H_2O$ ➔ H_4SiO_4. In general, the fluid in the geothermal system, having equilibrium with quartz (SiO_2). Geotermometer quartz is generally best used for reservoir temperatures >150^{o}C. For temperatures <150oC content of silica is controlled by calshedony (Simmons, 1998). (2) Geotermometer Na-K (Fournier, 1979; Giggenbach, 1988). Response to K, Na concentration ratio decreased to increased fluid temperature based on cation exchange reaction K^+ + $Na_{Felspar}$ ➔ Na^+ + $K_{Felspar}$, which is highly dependent on temperature. Geotermometer Na-K can be applied to the chloride water reservoir with temperature T> 180^{o}C. Geotermometer. This has the advantage that not much affected by the loss of steam. However, this geotermometer not good for use at temperatures T <100 ° C (Simmons, 1998). To determine the subsurface temperature Geotermometer Na-K include: (a) Na-K (Fourier and Giggenbach), for T > 180oC. (3) Geotermometer Na-K-Ca (Fournier and Truesdell, 1973), applied to water that has a high concentration of Ca. Assumptions used to make the equation geotermometer Na-K-Ca is as follows: (a) there is an excess of silica (usually correct), (b) Aluminum remain on solid phase (usually true because the fluid typically contains less Al). Geotermometer equation for this is: T ° C = [1647 / (log (Na / K) + β (log (√ Ca / Na) + 2.06) + 2.47)] - 273.15. To apply this geotermometer: (1) If [log √ Ca / Na) +2.06] <0, use β = 1/3. (2) If [log √ Ca / Na) +2.06]> 0, use β = 4/3, if T <100 ° C, the results are acceptable. (3) If the calculation of T in (2) > 100 ° C, recalculate with β = 1/3. Good temperature range for use geotermometer Na-K-Ca is 120oC sd 200oC. Another limitation is that the temperature is strongly influenced by changes in the concentration, i for boiling and dilution. Boiling causes loss of CO2, calcite precipitation occurs, Ca out of the solution, so that the calculation is too high T (Simmons, 1998). (4) Geotermometer K-Mg (Giggenbach, 1988), applied to the situation of equilibrium Na and Ca dissolved in the fluid and the rock has not been achieved. This Geotermometer can balance quickly in cold temperatures associated with the reaction: 0.8 K_{-mica} + 0.2 + 5.4 Cl + 2 K_{silica} + 1.6 ➔ 2.8$K_{feldspar}$ + H_2O + Mg^{2+}. Geothermal surface manifestations consisted mostly of fumaroles, hot springs, and ground heat. On groundwater conditions are far below the surface, the hot springs are not available. For that geotermometer water can not be used to memperediksi subsurface temperatures. Therefore, D'Amore and Panichi (1980) developed a gas Geothermometer. Depends on the equilibrium temperature of the gas-gas or gas minerals that are believed to control the concentration of gases such as CO2, H2S, H2, N2, NH3 and CH4 in geothermal reservoir fluids. In order to determine the reservoir quality of a geothermal system can be done ion equilibrium analysis (ion balance) (Andórson et. Al., 2000). In most solutions, the dominant ion is: Na^+, K^+, Ca^{+2}, Mg^{+2}, Cl^-, HCO_3^-, and SO_4^{-2}. Jadi, mNa + mK + 2mCa + 2mMg = mCl + $mHCO_3$ + $2mSO_4$. THE Reservoir quality can be seen from its equilibrium ion. Reservoir quality is good if the value of its ion balance < |5| %.

RESULT AND DISCUSSION

Result

Geological data as described in the material presented in the geological map of the Figure 1.

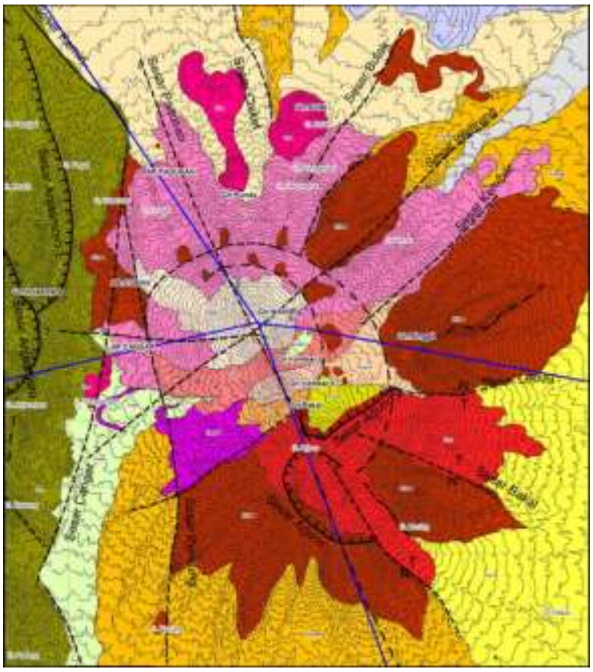

Figure 1. Geological maps, structure and topography geothermal area Arjuno-Welirang East Java province. From (Tim Survey Geologi dan Geokimia, 2010).

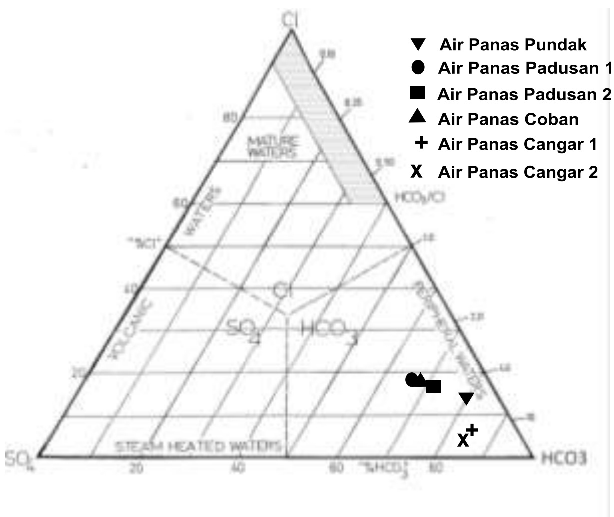

Figure 2. Diagram based upon the chemical characteristics of the reservoir water Arjuno-Welirang geothermal system.

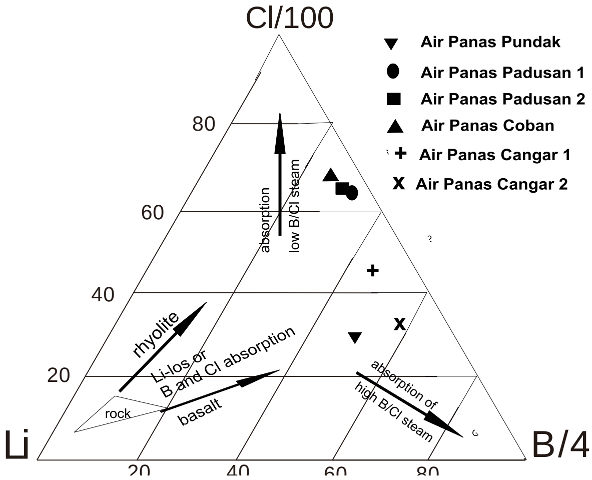

Figure 3. Geoindikator diagram Cl-Li-B water chemistry of geothermal systems Arjuno-Welirang geothermal systems.

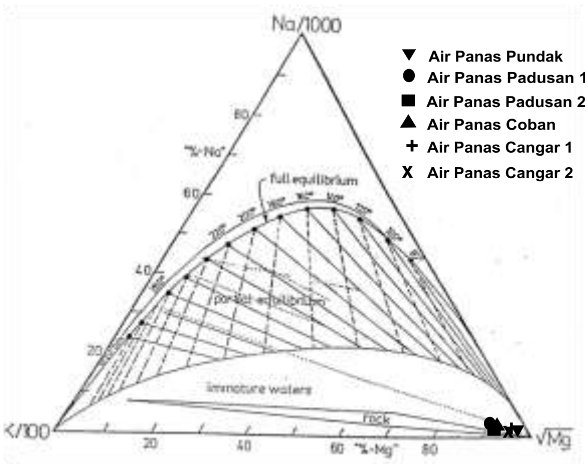

Figure 4. Diagram geoindikator Na-K-Mg water chemistry of Arjuno-Welrang geothermal systems.

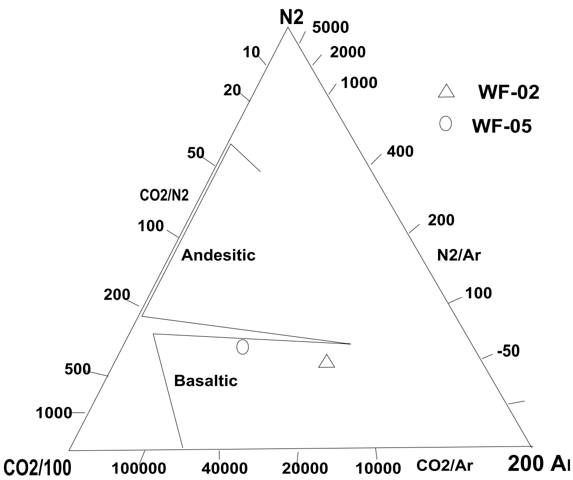

Figure 5. The diagram gas indicator Ar N2-CO2-water chemistry of Arjuno-Welirang geothermal systems.

Table 1. Ion balance water chemistry of Arjuno-Welirang geothermal systems.

No	Lokasi	Anion	Kation	%
1	Padusan 1	29,06	27,11	3,48
2	Padusan 2	30,38	28,8	2,67
3	Coban	22,68	21,3	3,13
4	Cangar 1	15,19	14,83	1,2
5	Cangar 2	9,46	9,32	0,74
6	Pundak	0,65	0,65	-0,31

Discussion

Manifestation

Geothermal manifestations Arjuno-Welirang consists of hot springs (Padusan, Coban and Cangar), fumaroles at the summit Welirang, and alteration alteration around G. Shoulders. Padusan hot springs are found at an elevation of 1300 m asl, prominence clear water color, pH 5.87 sd 6.30 and found strong sinter deposition. Cangar hot spring appear at an elevation of 1600 m asl, clear water color, found carbonate sinter layer thin and weak iron oxidation. Fumaroles and solfatar found at elevations up to 3050 3150 m asl, around the cone complex G. Arjuno-Welirang, the temperature reached 137.5 ° C. Alteration found around the crater Plupuh (altitude about 3100 m asl) with a fairly wide spread, and in aarah under G. Shoulder (altitude about 1000 m asl, is due next eruption. Based on data analysis manifestation (Hochstein and Browne, 2000), that indicated he fully Arjuno geothermal reservoir system in the form of chlorite-Welirang water, which extends from about Mt. Pudak and around hot springs Padusan (900 m asl) up to around the Cangar hot springs (1600 m asl).

Lithology and Geology Structure

Mostly all geothermal area Mt. Arjuno-Welirang composed by Quaternary volcanic rocks products. Welirang basalt lava type, porphyritic texture, hollow and vasikuler. Old lava Arjuno-Welirangtersusun of andesitic-basaltic lava rocks with porphyritic texture. Some places pages and muscular structure. Next to the eruption spread over three locations, namely lava Mt. Bulak, lava Mt. Pundak in the north and lava Mt. Dependents in the western part of the complex Arjuno-Welirang. Berkomposisi andesitic-basaltic lava. Lava Kembar 2 is between peak Arjuno and Welirang, formed after the subsidence. Lava flows to the west to the area Cangar hot spring. The composition of a basalt lava rock porphyritic texture.

Arjuno-Welirang geological structure consisting of: (a) NS faults, represented by cesarean Cangar, Puncung and Claket, a manifestation straightness. (b) Fault SW-NE, represented by cesarean Padusan, Pecan and Bakal, characterized by straightness of hot water and steep topography. Fault-fault is a fault controlling the emergence of hot water around Padusan. (c) Fault NW-SE, estimated as the main faults affecting the emergence of complex volcanic

Arjuno-Welirang, represented by cesarean Welirang, Twins and Bulak. (d) Fault WE, represented by cesarean and cesarean Ledug Ringgit.

Based on the analysis of geological data and geological structures, indicating that the Arjuno-Welirang geothermal system have sufficient permeability system, characterized by the emergence of the hot springs Cangar, Padusan and Coban, which extends from about Mt. Pudak and hot springs Padusan (900 m asl) up to around the hot springs Cangar (1600 m asl) and even up to the crater Plupuh (3100 m asl).

Geothermal Fluid

Characteristics of the geothermal fluid can provide information about the type of geothermal system, because the geothermal fluid derived from surface water (meteoric water) that go below the surface through cracks and or fluids derived from magmatic rocks in the form of water. It is important to determine the chemical composition of the fluid in the reservoir include reservoir characteristics, reservoir temperature, the origin of the fluid, fluid interaction with rocks and water surface panasbumidengan fluid interaction (mixing).

Based on the chemical analysis of the water from the ion equilibrium manifestations of geothermal systems Arjuno-Welirang, Table 1 indicates that the quality of the geothermal reservoir Arjuno-Welirang including good quality. This is evidenced by the ion equilibrium prices <| 5 |%.

Reservoir characteristics can be analyzed using geoindikator Cl-SO_4-HCO_3. Results of geochemical analysis of geothermal systems Arjuno-Welirang Tennary indicated by the diagram Cl-SO_4-HCO_3 Figure 2. From Figure 2, it appears that the HCO_3 geothermal reservoir Arjuno-Welirang contains between 65% to 80%. This indicates that the reservoir has a fluid bicarbonate type.

On systems that are dominated by volcanic rocks, water HCO_3 generally formed in marginal areas and near the surface, where CO_2 gas along with water vapor condensed into the ground water, the steam condensation water can heat the soil to form HCO_3 solution. HCO_3 water formed under ground water level and generally weakly acidic, but with the loss of dissolved CO_2, increasing the acidity of the water can be neutral or slightly alkaline.

The process of boiling and dilution can be evaluated based on a comparison of concentration Cl/100 and B / 4. Additionally the ternary diagram Li-Cl-B can also be used to determine the upflow zone and outflow of a geothermal system. Tennary diagram Cl-Li-B distem analysis geothermal Arjuno-Welirang shown in Figure 3. In Figure 3, it appears that the Cl content is relatively high, it indicates that the hot water coming from the volcano-magmatic. However, if you pay attention to the hot water Cangar 1, and shoulders indicates that the hot water interacted with sedimentary rocks rich in organic substances, this is indicated by the content of B / Cl high.

Plot the results on the hot water Padusan 1, 2 and Coban, located on the top right corner toward Cl/100, means that the process of absorption of magmatic gases with the ratio B / Cl low. While the plot results in the manifestation of hot water Cangar 1 is at the center of the corner and angle Cl B / 4, it is shown that the absorption of magmatic gases with the ratio B / Cl balanced. Hot water at the point of manifestation Cangar 1 and shoulders are at the bottom of the right triangle adjacent to the angle B / Cl, it is shown that the absorption of magmatic gases with the ratio B / Cl high.

For hot water flow pattern and subsurface processes based on the results of the plot in Figure 3, indicated he fully that the hot water geothermal system Arjuno-Welirang have value ratio B / Cl is low to moderate, indicating that the hot water in the study area is generally a flow sideways (lateral flow or outflow).

√ Na/1000-K/100- Mg triangular diagram (Fig. 4) indicated by Giggenbach (1988) is a method to estimate the reservoir temperature and fluid balance knowing. Relatively high content of Mg as shown in Figure 4, shows that the geothermal water-Welirang Arjuno influenced by dilution with ground water (Nicholson, 1993). This is supported by the value of the ratio of Cl and Na / K is low. Influence of ground water and surface water visible from most types of hot water in the form of HCO3.

Based on the results of the plot in Figure 4, all the hot springs located on the immature water. Immature water conditions shows that the influence of surface water (metoric water) are mixed with the hot fluid at the time of the formation of the hot springs. Besides the hot water is influenced by the interaction between the fluid rock in hot conditions.

Geoindikator diagram Tennary N2 gas-CO2-Ar is a method used in the determination of reservoir rock types at the time of data unavailability fluid chemistry. This method is used to determine the zone of andesitic and basaltic zone of the reservoir rock types of geothermal systems.

Plot the results in Figure 5 geoindikator CO2/N2, N2/Ar and CO2/Ar, it can be seen that the manifestations WF-02 and WF-05 are included in the zone of andesitic-basaltic. This suggests that the field of geothermal reservoir rock type Arjuno-Welirang form andesitic-basaltic rocks.

Geothermal reservoir temperature estimates Arjuno-Welirang done by analyzing the data on regional geochemical manifestations hot Padusan 1, 2, Coban, Cangar 1, 2 and shoulders. Calculation of reservoir temperature estimates based on calculations using the data covering SiO2 max-steam loss calculations, no-steam loss and chalcedony showed that for no-steam has a temperature loss between 87 ° C to 175 ° C, max-steam loss has a temperature between 89 ° C to 164 ° C, and chalcedony has a temperature between 55 ° C to 153 ° C. Geotermometer temperature estimation with SiO2, would be good if it is used for temperatures> 150 ° C and geotermometer chalcedony, sksn bsik Jiks used for temperatures <150 ° C (Simmons, 1998). Tentative conclusions based geotermometer silica, indicating that the geothermal reservoir temperatures Arjuno-Welirang ranged from 55 ° C to 175 ° C.

Geotermometer Na-K-Ca good to apply to water that has a high concentration of Ca (Giggenbach, 1988). Temperature calculations using the Na-K-Ca with $\beta = 4/3$ in hot water Padusan 1 & 2, Coban and Cangar 1, the value of temperature> 100 ° C while the hot springs and Shoulders Coban 2 has a value of temperature <100 ° C , then the result is not acceptable. To re-calculation is done using $\beta = 1/3$, which gives the results of calculation of temperature between 209 ° C to 224 ° C. From the results of the estimation using geotermometer Na-K-Ca is not good enough to use, because geotermometer Na-K-Ca will function well in the temperature range between 120oC sd 200oC. Temperature of the results geotermometer Na-Ca-K can not be used even if the high Ca concentration.

Determination of subsurface temperature using geotermometer Na-K can use the Na-K (Fourier and Giggenbach). Reservoir temperature calculation Arjuno-Welirang using Na-K (Fourier), get a temperature between 300°C and 450°C and the Na-K (Giggenbach) get a temperature between 292°C and 463°C. The temperature calculation results should be accepted because the chlorite reservoir water (water chloride), Na-K geotermometer be good for $T > 180^oC$ and is not good for T < 100°C (Simmons, 1998). But the best resolution for geotermometer Na-K is at temperatures between 120^oC and 200^oC. On the other hand the determination of the temperature using the Na-K geotermometer unstable for high Ca. Therefore, the calculation of the temperature with geotermometer Na-K can not be used.

Geotermometer K-Mg applied to the situation dissolved Na and Ca equilibrium yet. Based on calculations derived reservoir Arjuno-Welirang temperatures range from 45°C to 85°C. Geotermometer K-Mg good for chlorite water reservoir (Mg concentrations <1.0). the calculation of the temperature Arjuno-Welirang reservoir using K-Mg geotermometer showed a lower value than the actual temperature, because the content of Mg in the reservoir Arjuno-Welirang far > 1.0, (because the response K-Mg reaction is much faster with increasing Mg values).

At fumaroles Mt. Arjuno-Welirang, H_2S gas smell was overpowering, and a strong hissing sound. Gases detected are CO_2, H2S, SO_2, O_2, Ar, and N_2 concentrations are expressed in mol%. With the concentration of gas content is dominated by CO_2, H_2S, SO_2 gas compared to other relatively very little. Presence of H_2S and SO_2 gas indicates the area is on volcanic environment. While it is possible N_2 gas from the degradation of organic matter in the earth's crust that interacted with magma. Based on the calculation of the CO_2 and H_2S gas geotermometri refer to Giggenbach (1980) obtained a temperature between 260°C and 263°C.

Based on calculations using multiple geotermometer geotermometer water and gas, then the conclusion can be obtained while in the area of geothermal reservoir temperatures Arjuno-Welirang range from 55°C to 175°C. However, this conclusion is not final as data for geochemical analysis of water samples indicated he fully that all the water is heavily influenced by meteoric water and groundwater.

CONCLUSSION

Based on geological analysis refers to the geological structure and manifestations, the chemical analysis refer to ion balance, geoindikator and geotermometer, be concluded while the Arjuno-Welirang geothermal system is a chlorite water system (water dominsted type), although the analysis of reservoir characteristics of Figure 2 indicated he fully bicarbonat HCO_3 water. This was caused by water mixing with meteoric water reservoir and groundwater near the surface. Reservoir temperature reaches 175°C, and can be expected to remain higher than due to the calculation of the temperature with Mg > 1.0. the reservoir rocks are basaltic and andesitic reservoir is spread in the west to the Mt. Arjuno-Welirang. The manifestations of geothermal hot springs Mt. Arjuno-Welirang water with concentrations of bicarbonate HCO_3 is high enough. Fluid bicarbonate is usually formed in the marginal areas of geothermal reservoir at shallow depths where CO_2 gas along with water vapor condenses. Based on the content of the element Cl, Li and B to indicate that the hot water coming from the volcano-magmatic. Before the fluid up to the surface as hot springs, believed to have interacted with sedimentary rocks. In addition it indicates that the hot water in the area is generally a manifestation of hot water flow sideways (lateral flow or outflow). Based geoindikator Na-K-Mg indicates that the hot water in the region-Welirang Arjuno influenced by dilution with ground water. Determination of reservoir temperature using geoindikator Na-K-Mg can not be used, because of the relatively high content of Mg. Influence of ground water and surface water were detected from most types of hot water in the form of HCO3. To estimate reservoir rock composer based geoindikator the outflow region is thought to authors reservoir rocks are andesitic-basaltic rocks.

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REFERENCES

Andórson S., D´Amore F., and Gerardo J. (2000): Isotopic and chemical techniques in geothermal exploration (ed. S. Arnórsson). Vienna, International Atomic Energy Agency, 351p

D'Amore, F. and Panichi, C. (1980): Evaluation of deep temperatures in hydrothermal systems by new gas geothermometer, Geochim. Cosmochim. Acta, 44, 549- 556.

Fournier, R. O., and Truesdell, A. H., 1973. An empirical Na-K-Ca geothermometer for natural water: geochemica Cosmochemica Acta. Vol. 43, p. 1543-1550

Fournier, R. 0., 1985. The behavior of silics hydrothermal solutions: Reiews in Economic Geology, vol 5, p. 221-22, v.2, p. 45-62

Giggenbach, W. F., 1988. Gothermal solte equilibria. Derivation of Na-K-Ca geoindicators: geochemica Cosmochemica Acta. Vol. 52, p. 2749-2765.

Giggenbach and Goguel. 1989. Chemical Techniques in Geothermal Exploration. New Zealand: Chemistry Division, DSIR, Private Bag

Hochstein, M.P. dan Browne, P.R.L., 2000, Surface Manifestation of Geothermal Systems with Volcanic Heat Sources, In Encyclopedia of Volcanoes, H. Sigurdsson, B.F. Houghton, S.R. McNutt, H. Rymer and J. Stix (eds.), Academic Press.

Nidya, F., 2013. Analisis Karakteristik Panasbumi Daerah Outflow G. Arjuno-Welirang Berdasarkan Data Geologi, Geokimia and Geofisika. Sekripsi S1 Teknik Geofisika, Fakultas Teknik Universitas Lampung, Bandar Lampung.

Simmons, S.F. 1998. Geochemistry Lecture Notes. Geothermal Institute. University of Auckland.

Tim Survey Terpadu Geologi dan Geokimia PSDG, 2010. Laporan Akhir Survey Geologi Dan Geokimia Daerah Panasbumi Arjuno-Welirang Kabupaten Mojokerto dan Malang Provinsi Jawa Timur. Bandung.