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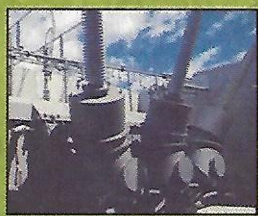

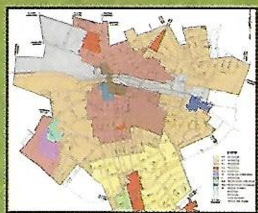

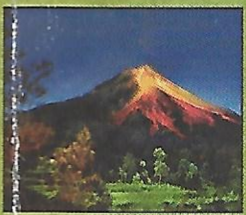

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DAFTAR ISI

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HYDROCHEMICAL OF HOT SPRING WATER OF UNGARAN GEOTHERMAL FIELD, SEMARANG REGENCY, CENTRAL JAVA PROVINCE, INDONESIA

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Sari

Di sekitar G. Ungaran, Jawa Tengah dijumpai beberapa mata air panas atau hangat yang merupakan manifestasi dari sistem panas bumi G. Ungaran. Maksud penelitian adalah melakukan studi hidrogeologi dilengkapi dengan pengumpulan data kimia air. Tujuan penelitian ini adalah untuk mengetahui komposisi, kualitas, tipe kimia serta proses-proses hidrokimia yang terjadi dalam sistem panas bumi tersebut. Data-data mataair panas atau hangat diambil dari mataair di Nglimut (mewakili bagian utara); Diwak, Kaliulo dan Kendalisodo (timur) serta Gedongsongo (lereng selatan). Metode yang dilakukan adalah survei hidrogeologi permukaan serta analisis data sekunder kimia air terhadap mataair panas atau hangat di sekitar G. Ungaran

Air panas dari mataair Gedongsongo bertipe air asam sulfat, merupakan uap hasil pemanasan air meteorik dengan berbagai proses hidrokimia seperti percampuran dan pelarutan. Air hangat dari mataair Nglimut, Diwak dan Kendalisodo bersifat netral dengan tipe bikarbonat, berasal dari pengenceran air meteorik dengan proses hidrokimia yang dominan yaitu pertukaran ion. Air hangat di Kaliulo merupakan air bertipe sodium klorida, dipengaruhi oleh proses pelarutan dan percampuran antara air meteorik dengan air konat.

Kata kunci : panas bumi, Ungaran, hidrokimia, mataair panas, airtanah

Abstract

There are some hot or warm spring at Ungaran Mt. in Central Java and its vicinity as geothermal manifestation related with Mt. Ungaran geothermal system. Purpose of this research is hydrogeological study, accompanied by chemical water data collecting. Some hot or warm spring have been analyzed for their water to know about chemical composition, qualities, chemical types, hydrochemical processes and their relation with geothermal system. The secondary data have been taken from hot/warm spring from surroundings area of Ungaran Mt., i.e. Nglimut (represent of northern area); Diwak, Kaliulo and Kendalisodo (at the eastern part) and also Gedongsongo (at southern slope). Method of the research are surface hydrological survey and analysis of secondary chemical water data of hot or warm spring at surrounding of Mt. Ungaran.

The hot water of Gedongsongo springs are acid sulfate types, as steam heated meteoric waters with any hydrochemical processes like mixing and simple dissolution. Warm water from Nglimut, Diwak, Kendalisodo springs are neutral bicarbonate types, sourced from dilution of meteoric water with ion exchange as dominant hydrochemical process. Warm water from Kaliulo is end point water, with sodium chloride water type, yielded from simple dissolution and mixing between meteoric and connate water.

Key words : geothermal, Ungaran, hydrochemical, hot spring, groundwater

INTRODUCTION

Ungaran area, in Semarang District, Central Java Province (Figure 1) is one of potential geothermal fields in Indonesia. At this area hot spring can be found at several manifestation point, such as Nglimut, Gedongsongo, Diwak and Kaliulo. This manifestation exist as geothermal system of Ungaran Mt.

This research aimed for hydrochemical data collecting of hot or warm water from springs at research area from secondary data. Goal of this research is understanding about geochemical of hot water, both of composition, chemical type and genetic of hot water in relation with hydrogeological research. Hydrochemical processes of groundwater in this geothermal system will be look for knowing correlation between rocks and groundwater quality.

METHODOLOGY

The research have been carried out by geological observation in the field, included geomorphology, petrology and hydrogeology. The secondary data have been analysis involved physical/chemical of hot water from several springs. Those data collected from Budiardjo et al (1991), Trend Team Jawa – IBT (1997) and STTNAS and Dinas P & E Jateng (2004) either. Analysis of primary data from field and secondary data have been done to know about hydrochemical of hot water in the Ungaran geothermal system.

GEOLOGY OF UNGARAN AREA

The research area is belong to Quaternary Volcano Complex of Ungaran Mt. or in North Serayu Range after physiography classification by Van Bemmelen (1949). This zone was Geosyncline of Northern Java which uplifted in Late Pliocene (Trend Team Jawa – IBT, 1997). Morphology of this area show undulating to hilly topography (Figure 2).

Geologically, this area is lied in the north side of western part of Kendeng Anticlinorium and directly bounded by North Serayu Basin. Regionally, according to Genevraye & Samuel (1972) this area consist of rock formations from old to young successively are Pelang, Kerek, Banyak, Kalibeng, Damar and Notopuro Formations.

Gedongsongo is the main manifestation of Ungaran geothermal system which associated with Ungaran strato andesitic Quaternary volcano. Stratigraphy of this area composed of andesitic to basaltic lava and pyroclastic rocks such as volcanic breccia intercalated with tuff originated from old formation after Ungaran caldera (Budiardjo et al, 1991).

The Kendeng Zone itself, have east-west orientation which spread from Ungaran Mt. at west until Brantas River at the east. Geological structure of geothermal system of Ungaran Mt. controlled by graben structure. The old volcanic rocks of pre-caldera formation controlled by northwest – southeast and northeast-southwest faults. The post-caldera volcanic rocks less controlled by regional faults. Therefore, young volcanic rocks may be not acts as reservoir rocks but it can be potential cap rocks (Budiardjo et al, 1991).

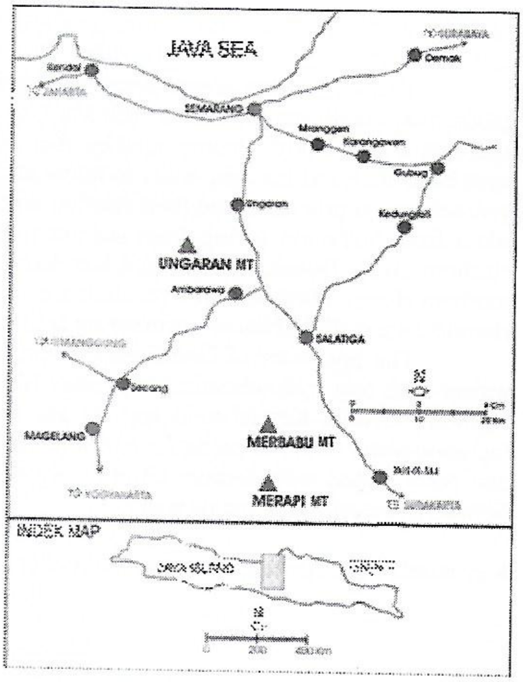

Figure 1. Location of research area (red square).

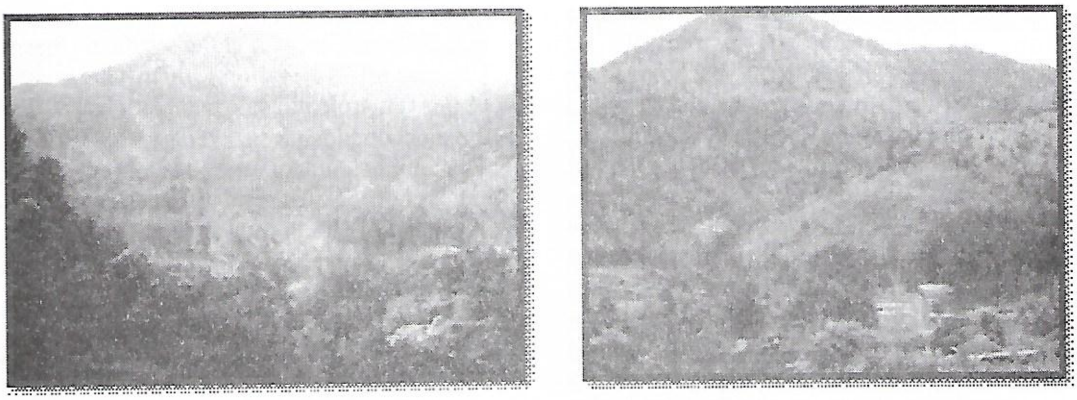

Figure 2. Hilly morphology of Gedongsongo geothermal area.

HYDROGEOLOGI AND MANIFESTATION

The Ungaran geothermal system associated with Young Quaternary Ungaran volcanism. The manifestation found are fumarole with temperature 68°C, hot spring with temperature 36°C, sulfur deposits and alteration rocks at Gedongsongo (Figure 3). Hot/warm water exposed at Nglimut, Diwak and Kaliulo in distances as far as 3.5, 10 and 15 km from Gedongsongo's fumarole (Budiardjo et al, 1991).

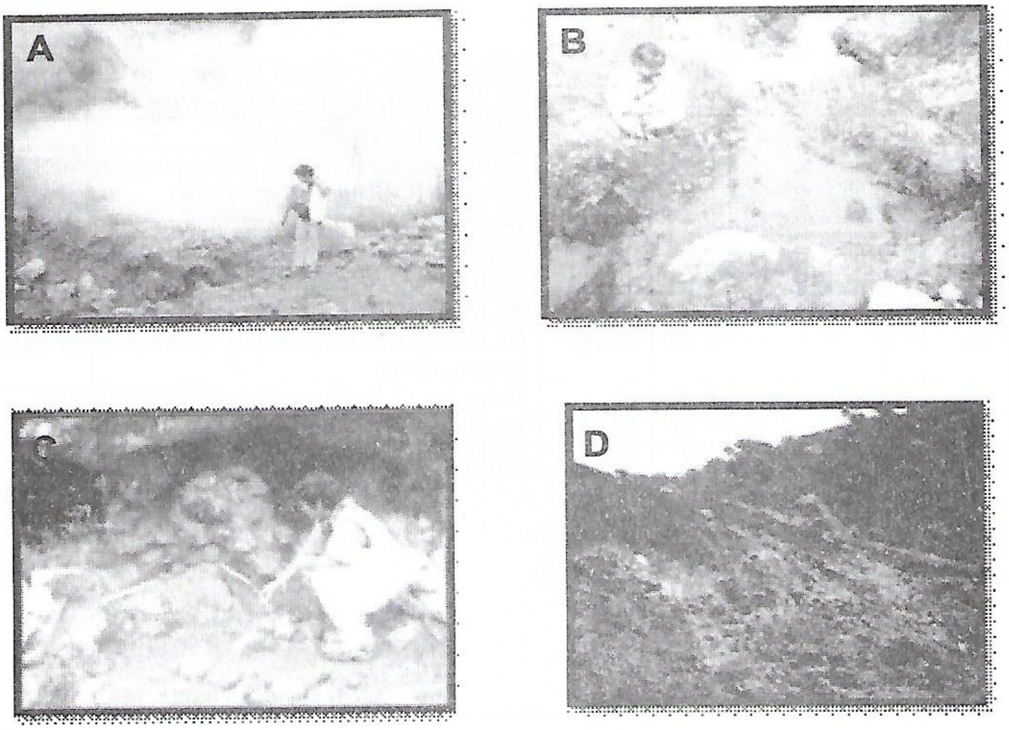

Figure 3. Geothermal manifestation at Gedongsongo.
A. Fumarole C. Sulfur deposits
B. Hot spring D. Alteration rocks

The hydrology system developed at southern slope of Ungaran Mt, especially at Gedongsongo. This system become more gently eastward to lower elevation (Diwak) (Trend Team Jawa – IBT, 1997).

Young volcanic rocks composed of tuff, lahar and andesite breccia with moderate – high permeability. The Quaternary rocks like tuff, tuffaceous sandstone, volcanic breccia and lahar of Damar, Notopuro and Pucangan Formations show low – moderate permeability. While, calcareous sandstone, tuffaceous claystone of Kalibeng Formation as well as basalt/andesite dykes at the east and also andesite to basalt lavas at the southern part of Ungaran Mt. show low permeability. The aquifers indicate characteristics both of aquifers with crack and pore flowing (medium or locally productivity) and small productivity and also rare groundwater aquifers.

Gedongsongo is the main geothermal manifestation, located at the southern slope of Ungaran Mt, at elevation 1300 m. Gas analysis of this fumarole indicate magmatic gas. CO_2 is the most dominant gas, average 97% total gas. This high content may be related with calcareous rocks of reservoir under depth. The high ratio of H_2S to CO_2 showed that the steam have been flown under long distance from the depth (Trend Team Jawa – IBT, 1997).

HYDROCHEMICAL DATA AND ANALYSIS

Some chemical data of hot water have been collected from several springs by preliminary authors. Characteristics of those water summarized at Table 1 below.

Table 1. Physical/chemical data of hot water samples.

No.	Location	pH	Silica (ppm)	Chemical Type
1.	Nglimut	6,7	105	Ca,Mg-HCO_3 (Calcium Magnesium Bicarbonate)
2.		6,62	124	Na,Mg-HCO_3 (Sodium Magnesium Bicarbonate)
3.	Gedongsongo	2,42	230	$NaSO_4$ (Sodium Sulfate)
4.		5,54	120	Ca-HCO_3,SO_4 (Calcium Bicarbonate Sulfate)
5.		5,93	124	$CaHCO_3$ (Calcium Bicarbonate)
6.		2,48	129,66	Na,Mg- SO_4 (Sodium Magnesium Sulfate)
7.	Diwak	8,69	110	Na,Mg-HCO_3 (Sodium Magnesium Bicarbonate)
8.		6,61	104	Na,Mg-HCO_3 (Sodium Magnesium Bicarbonate)
9.		6,38	118	Na,Mg-HCO_3 (Sodium Magnesium Bicarbonate)
10.		6,60	73,50	Na,Ca,Mg-HCO_3 (Sodium Calcium Magnesium Bicarbonate)
11.	Kaliulo	7,08	40	Na-HCO_3,Cl (Sodium Bicarbonate Chloride)
12.		7,22	52,08	NaCl (Sodium Chloride)
13.	Kendalisodo	7,3	150	Na,Mg-HCO_3 (Sodium Magnesium Bicarbonate)

Notes : Source of samples data
No. 1,2,4,5,7–9,13 : Budiardjo *et al* (1991)
No. 3,11 : Trend Team Jawa – IBT (1997)
No. 6,10,12 : STTNAS and Dinas P & E (2004)

Plotting of chemical data in Piper diagram (Figure 4) show that Nglimut, Diwak and Kendalisodo water commonly belong to class 1 (earth alkali more than alkali content) and 3 (weak acid more dominant than strong acid), class 5 (high carbonate hardness). Plotting to Durov Diagram show B area (Figure 5). The dominant Ca and Mg in this water usually associated with certain minerals (Lloyd & Heathcote, 1985). The hydrochemical processes usually occurred by ion exchange.

Whereas, Gedongsongo and Kaliulo water shows class 2 (alkali more than soil alkali content), class 4 (strong acid more than weak acid), and class 7 (high non alkali carbonate). In Durov Diagram, this groundwater show the mixing and simple dissolution processes as the dominant hydrochemical process. Lava mostly influence the local recharge. On the other hand, water from Kaliulo spring show end point water. This water's type similar with sea water, then interpreted as connate water.

Plotting of all data in Gigenbach diagram show that water commonly fall in shallow water or immature water. Water from Nglimut, Diwak, Gedongsongo and Kendalisodo came from shallow depth with not so long flowage. Kaliulo's water, on the other hand, show partial equilibrium dilution or mixing indicated long way and many hydrochemical processes (Figure 6).

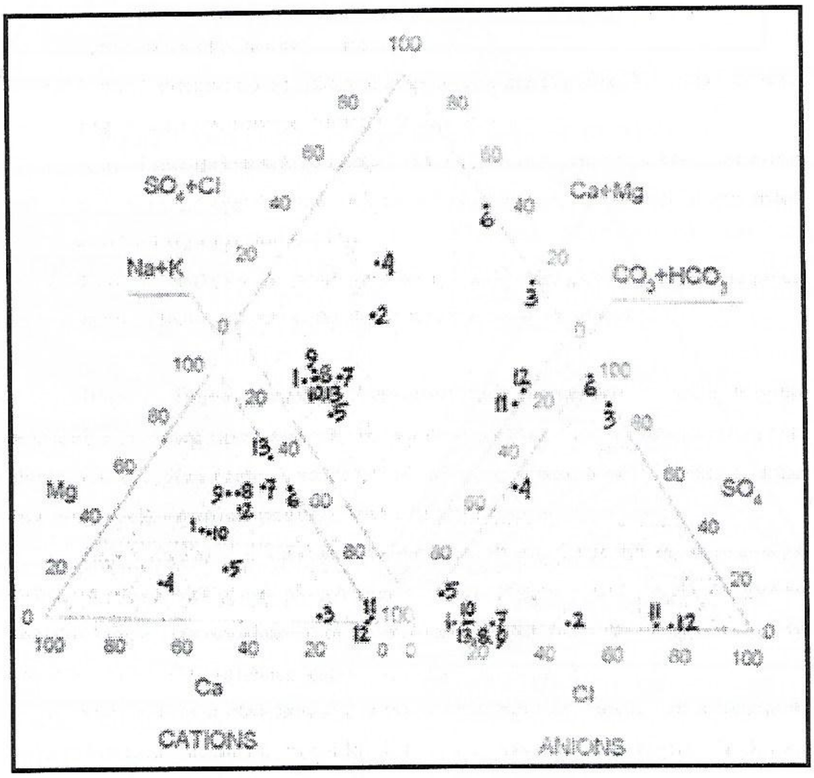

Figure 4. Data plotting in Piper diagram.

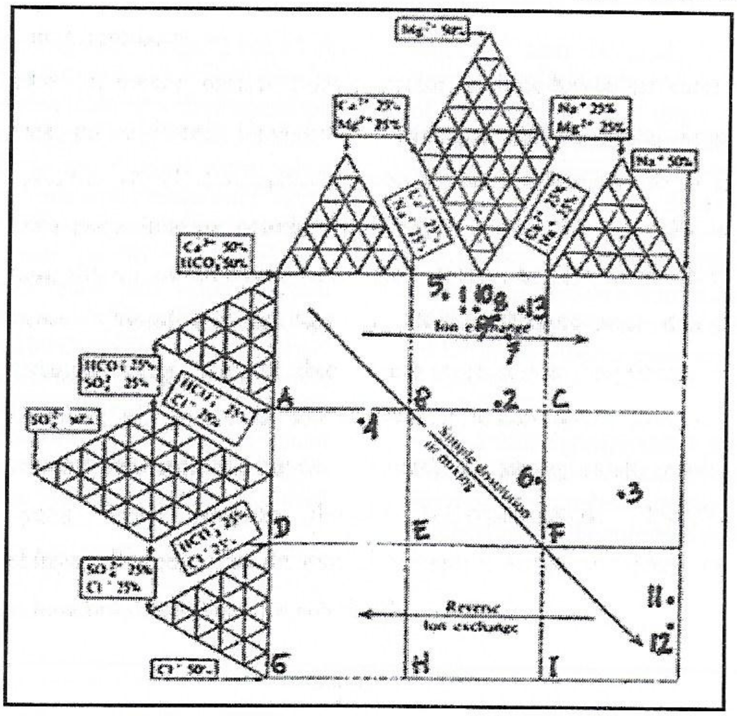

Figure 5. Data plotting in Durov diagram.

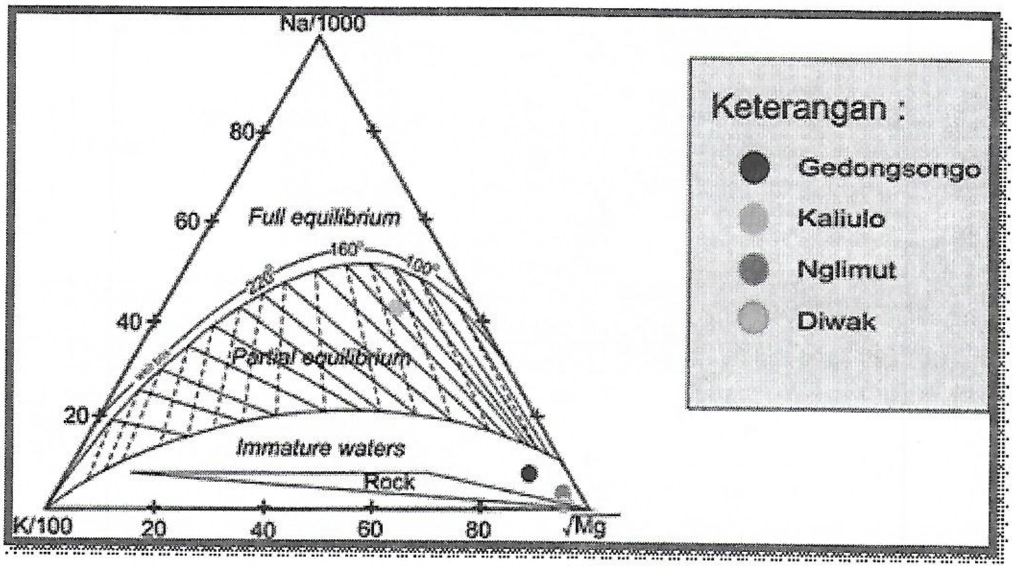

Figure 6. Data plotting in Gigenbach diagram of Na-K-Mg.

The data plotting in SO_4-Cl-HCO_3 diagram show that water from Nglimut, Diwak and Kendalisodo fall in peripheral waters position. Whereas, Gedongsongo spring indicate steam heated waters, and Kaliulo spring include in mature waters (Figure 7). So far, water from Gedongsongo and Kaliulo also show as part of volcanic waters.

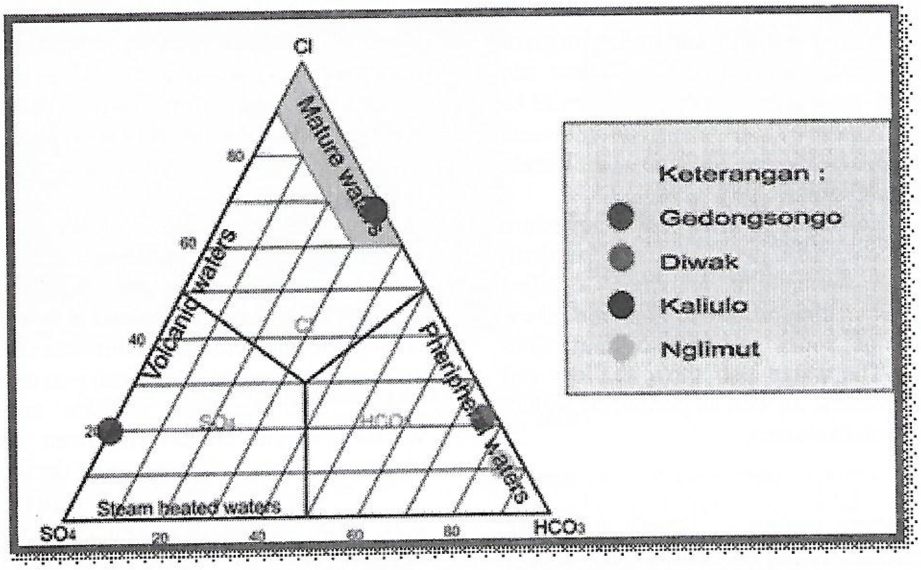

Figure 7. Data plotting in Gigenbach diagram of Cl-SO_4-HCO_3.

DISCUSSION

Geothermal manifestation of Ungaran prospect area found mainly as hot/warm spring located at the southern part of the mountain (Gedongsongo), at the north (Nglimut) and east (Diwak, Kendalisodo and Kaliulo). Each spring show certain hydrochemical characteristic explained as follows.

a. Gedongsongo

The geothermal manifestation here show fumarole indicate magmatic gas, where CO_2 was the dominant gas. High ratio of H_2S to CO_2 show that steam have been come from the deep area. Sulfate enrichment occurred in steam flown from brine reservoir of Ungaran Mt. geothermal.

The water show mixing and simple dissolution where lava influence in local recharge. Ion exchange may be supported by clay minerals or claystone of Merawu Member (claystone) and Penyatan Member (marly claystone) of Kerek Formation; Cipluk and Kalibiuk Member of Kalibeng Formation which have clayey marl. Beside that, the gradation from Kalibiuk Member to Damar Formation also show black clay.

The water of Gedongsongo spring show less cloudiness, and strong acid pH. The chemical composition show sodium sulfate, calcium bicarbonate sulfate, calcium bicarbonate and sodium magnesium sulfate. This sulfate type indicate steam heated meteoric water. This fact is supported by shallow waters position in Gigenbach Diagrams. The high silica show reaction between rocks and hydrothermal fluid. The water also acts as immature waters and volcanic waters, indicate that it's influenced by Ungaran volcanic activity.

b. Nglimut

Two springs existed at Nglimut, lied at northern slope of Ungaran Mt. The springs exposed from volcanic breccia, show clear water, with temperature 46°C, debit 2 l/s, neutral pH and produced both of ferry oxide and travertine deposits.

The warm water show earth alkali more than alkali content, weak acid more dominant than strong acid, and high enough of carbonate hardness. The HCO_3, Ca and Mg dominantly show that ion exchange would be dominant processes. This hydrochemical process supported by clayey minerals of Kerek, Kalibeng and Damar Formation.

The water show calcium magnesium bicarbonate and sodium magnesium bicarbonate types with numbers of silica content. The high enough of silica show influence of rocks – hydrothermal fluid reactions. The water also show shallow and immature waters, as well as peripheral waters in Gigenbach Diagrams.

c. Diwak

Warm springs in Diwak area have temperature 36 – 40°C, neutral pH (6,38 – 8,69), debit 2 – 10 l/s, clear – cloud enough water with constant bubble gas. The springs existed from volcanic breccia. Their types are sodium magnesium bicarbonate and sodium calcium magnesium bicarbonate, with 73,5 – 118 ppm silica content. The water also show shallow, immature and peripheral waters in Gigenbach Diagrams.

a. Kendalisodo

Warm water of Kendalisodo have similar characteristics with Diwak ones. The water show soil alkali more than alkali content, weak acid more than strong acid and it's bearing high enough of carbonate hardness. The dominant of HCO_3, Ca and Mg indicate the dominant ion exchange. The water also show neutral pH, have 150 ppm silica content and sodium magnesium bicarbonate type.

b. Kaliulo

The spring water at Kaliulo on the other hand, show different characteristic compared with the other ones. The warm water samples here show alkali more than soil alkali content, strong acid more dominant than weak acid, and its bearing high alkali non carbonate. Theses characteristics indicate end point waters , might be derived from chemical evolution as long as its way under depth.

The water show neutral pH (7,22 – 7,3), with sodium bicarbonate chloride and sodium chloride types. The only small concentration of silica content (40 – 52,08 ppm) indicate that chemical evolution is not long enough. The high content of Na (5300 ppm), Cl (5900 ppm), HCO_3 (4500 ppm) and B (250 ppm) indicate connate water trapped in marine Tertiary sediments (Trend Team Jawa – IBT, 1997). Whereas, STTNAS and Dinas P & E (2004) also supported with high Na (5483,87

Figure 8. Geothermal warm spring at Diwak, east of Ungaran Mt.

Figure 9. Warm spring manifestation at Kaliulo, located at east of Ungaran Mt. (STTNAS and Dinas P & E Jateng, 2004).

ppm), HCO_3 (3256,81 ppm) and Cl (5799,48 ppm) data. The travertine also shown at the outcrop around the spring. This limestone may be gave strong influence to water composition.

Warm water from Kaliulo is plotted as partial equilibrium dilution or mixing water, mature and volcanic waters in Gigenbach diagram. So, the chemical evolution of groundwater influenced by both of Tertiary limestone and volcanic materials.

As explained before, hot water from Gedongsongo is steam heated meteoric water, but the other location (Diwak, Nglimut, Kendalisodo) might be came from dilution water as long as its flowing from Ungaran reservoir. Whereas, warm water from Kaliulo is mature waters under influence of volcanic materials and connate water. The variety of chemical characteristics of hot/warm water in Ungaran geothermal prospect area can be drawn schematically in geothermal model shown at Figure 10 below.

CONCLUSIONS

Hot water of Gedongsongo springs are acid, with sodium sulfate, calcium bicarbonate sulfate and sodium magnesium sulfate types. The water is belongs to steam heated meteoric waters or acid condensate waters with some hydrochemical processes such as simple dissolution or mixing. Sulfate enrichment occurred in steam flown from brine reservoir of Ungaran Mt. geothermal.

The water of Nglimut, Diwak and Kendalisodo springs are neutral water, mainly composed of sodium, calcium magnesium bicarbonate. The water were dilute / mixed meteoric condensate waters. Ion exchange is the dominant hydrochemical process. This process might be supported by clay minerals or claystone of Kerek, Kalibeng and Damar Formation.

Lastly, warm/hot water of Kaliulo show neutral characteristic, with major composition as sodium bicarbonate chloride and sodium chloride. This characteristics indicate influence of volcanic activity and connate water. Simple dissolution or mixing also influenced the chemical composition of the water.

ACKNOWLEDGMENTS

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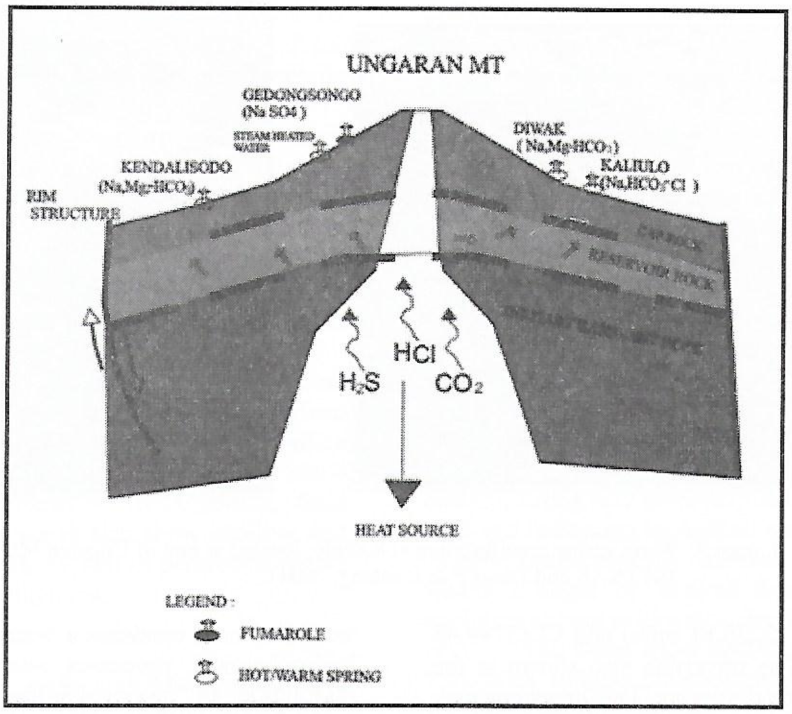

Figure 10. Ungaran prospect geothermal model scheme at south west – north east direction.

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