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Hydrogeochemical Study Of Ciseeng Thermal Springs, West Java Province, Indonesia

Izzuddin Azzam, Fajar Hendrasto and Untung Sumotarto

Geological Engineering Dept., Faculty of Earth Technology and Energy, Trisakti University, Jakarta, Indonesia

Izzuddinazzam96@gmail.com

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ABSTRACT

Indonesia is a country that has considerable geothermal potential either associated with volcanism or non-volcanism. Due to complexity of geological feature in Java Island there is a geothermal manifestation that located in Ciseeng Area, Bogor Regency, West Java Province, Indonesia. Regionally, the geological condition of Ciseeng is composed of Bojongmanik Formation, Young Volcanic Formation and Alluvial Formation and locally composed of Limestone Unit, Andesite Fragment Breccia Unit, Alluvial Deposit and Travertine unit. There are three geothermal manifestations that spread over in three locations, namely Gunung Panjang, Gunung Peyek and Gunung Kapur. All of the manifestations consist of warm spring, warm pools and Travertine hills. Ciseeng geothermal area is classified as volcanogenic low relief type with several geochemical characteristics such as having a chloride water type, based on the geochemical plotting has one reservoir source, fluid condition in partial equilibrium. The estimation of reservoir temperature by using cation geothermometers is in the range of 153°C-184°C. According to isotope analysis from four samples that spreaded in three geothermal manifestations located in mixing zone.

1. INTRODUCTION

Geothermal is a source of heat energy contained in hot water, water vapor, and rocks along with associated minerals and other gases that are genetically inseparable in a geothermal system, Law of Republic Indonesia article 1 section 1 No.21 (2014). The geothermal system is a heat transfer system in the upper mantle and the earth's crust where heat is delivered from a heat source to a heat sink where the heat source travels to the earth surface. The hydrothermal system is a type of geothermal system in which heat transfer from a heat source to a surface involving "meteoric" fluid with or without magmatic fluid marks. The liquid coming out near the surface is replenished by "meteoric" water from outside (recharge zone). The hydrothermal system consists of heat sources, reservoirs with thermal fluids, recharge zones and discharge zones in the form of surface manifestations Hochstein and Browne (2000).

The process of geothermal exploration through several stages including analysis of satellite imagery to obtain a general description of the research area, geological mapping to find out the rock features that fill the research area, geochemical analysis to find out the water type, origin of water, geothermometer, geo-indicator ratio, isotope analysis, reservoir depth to determine the configuration below the surface. Observing energy problems in Indonesia along with the high appearance of geothermal energy activities in Indonesia, the author intends to conduct a study on "Hydrogeochemical Study of Ciseeng Thermal Springs, West Java Province, Indonesia". By conducting this research, it is expected that an understanding of the geothermal processes that will take place in this region is expected.

2. METHODOLOGY

Ciseeng geothermal region is a complex of several geothermal manifestations by the form of several warm springs that contain Travertine deposit that created several hills namely: Gunung Panjang (GPJ), Gunung Peyek (GPY) and (GK) where in each of this manifestations become the subject of this research. During sampling we are using basic method where we are using HDPE bottle to be the sample collect, thermometer for measuring the temperature and etc.

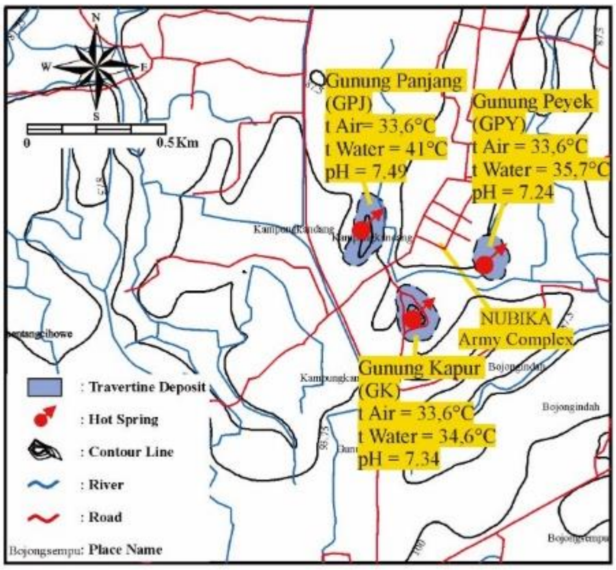


Figure 1: Map of around Ciseeng geothermal region

No	Manifestation	Coordinate		Elevation	Air Temp	Water Temp	Debit	pH	Date	Note
		m	m	(m)	(°C)	(°C)	(L/s)			
1	Gunung Peyek (GPY)	S6° 25' 47.3"	E106° 41' 59.8"	107 m	33,6°C	35,7°C	0,1	7,24	30/3/18	There is 1 pool of hot spring tahat has a diameter of 1m, a temperature of 35.7°C, alkaline pH, has a sulfur odor, clear water, the rate of gas every second, around it there are travertine deposits. Then around this pool are small pools of 15cm in diameter that emit gas.

Photo

No	Manifestation	Koordinat		Elevation	Air Temp	Water Temp	Debit	pH	Date	Note
		m	m	(m)	(°C)	(°C)	(L/s)			
3	Gunung Kapur (GK)	S6° 25' 56.6"	E106° 41' 47.3"	111 m	33,6°C	34,6°C	-	7,34	3/4/18	There is 1 pool of hot spring with unnatural conditions in this case the shape of an artificial concrete tub has a length of 2 meters and a width of 1 meter, a temperature of 34.6°C, alkaline pH, has a sulfur odor, turbid water, emit gas every second, around it there are travertine deposits.

Photo

No	Manifestation	Coordinate		Elevatiom	Air Temp	Water Temp	Debit	pH	Date	Note
		m	m	(m)	(°C)	(°C)	(L/s)			
1	Gunung Panjang (GPJ)	S6° 25' 48.1"	E106° 41' 41.6"	117 m	33,6°C	41,3°C	0,1	7,49	30/3/18	1 hot spring with a diameter of 40 cm, temperature 41°C, alkaline pH, sulfur odor, clear water, gas rate once every 8 seconds, carbonate deposits, algae (?)

Photo

Figure 2: Data of each warm spring in Ciseeng geothermal region

2.1 Ion Balance

Calculation of ion balance is done by converting the concentration of all charged elements from (mg/kg) to meq, and summing the value of milliequivalents from anions and cations (2).

$$\text{meq}=\left(\frac{\text{(mg/kg)}}{\text{atom mass}}\right)\times\text{elemental oxidation number} \tag{1}$$

$$\%\ \text{Balance}=\left[\frac{(\sum\text{anions}-\sum\text{cations})}{(\sum\text{anions}+\sum\text{cations})}\right]\times 100\% \tag{2}$$

2.2 Water Type

Determination of water type is a method carried out in geothermal exploration because water in the geothermal system has a diverse composition and its formation is controlled by the chemical process between the water itself and the rock it passes through. For determining the type of geothermal water, the relative content of Chloride (Cl), Bicarbonate, (HCO_3) and Sulphate (SO_4) are needed. Determination of water type was carried out by plotting the data of the three chemical contents into the ternary triangle diagram Cl-SO_4-HCO_3 Giggenbach (1988).

2.3 Water Origin and Condition

The origin and condition of water is obtained from the results of the Cl-Li-B plotting diagram. Water origin is an analysis using several elements like Cl, Li and B that are conservative elements (not easy to react) in the geothermal system and include as dissolved elements which can be used to determine the origin (reservoir) of geothermal fluid. The water condition is an analysis to find out the condition of subsurface fluid with Na-K-Mg elements where the results of immature water indicate that fluid has not been heated for a long time and gradually heated in mature water.

2.4 Silica Geothermometer

In most geothermal systems, subsurface solutions are generally at >180°C which is in equilibrium with quartz, quartz itself can be stable up to 250°C and has the lowest solubility compared to other polymorphic silica types. Polymorphic silica with an irregular crystal structure (ie chalcedony, CT opal, cristobalite) has a higher solubility than quartz and forms at colder temperatures <180°C. On the basis of the high silica content indicates the possibility that the fluid is directly from the reservoir, this is what makes the silica geothermometer considered able to calculate the subsurface temperature where the equation is as follows.

Quartz No Steam Loss

$$t(°C)=\frac{1309}{5,19\text{-}LogSiO^2} - 273,15 \quad (3)$$

Quartz Max Steam Loss

$$t(°C)=\frac{1522}{5,75\text{-}LogSiO^2}-273,15$$

Quartz max steam loss is used if during sampling, the manifestation is in a boiling condition (± 100 ° C) which indicates that no heat is lost when the water rises to the surface where this type is used to calculate the temperature of boiling manifestation data and well data. Quartz no steam loss is used if during sampling, the manifestation is not in a boiling condition which indicates that there is a heat release process.

2.5 Na/K Geothermometer

The use of this geothermometer is based on the assumption that there is a balance between sodium feldspar (Na) and potassium feldspar (K). The solution of a high-temperature reservoir (180°C) with a type of chloride water is suitable for this geothermometer. For lower temperature reservoirs where the fluid has a long residence time, a Na-K geothermometer may in some cases be applied. The advantage of this geothermometer is that with the geothermometer Na/K the value produced is not affected by dilution or steam loss.

Fournier (1979)

$$t(°C)=\frac{1217}{1,458+\log(Na/K)}-273,15 \quad (4)$$

Giggenbach (1988)

$$t(°C)=\frac{1390}{1,75+\log(Na/K)}-273,15 \quad (5)$$

2.6 K/Mg Geothermometer

The K/Mg geothermometer is based on the comparison between K and Mg concentrations where shallow water has a higher Mg concentration than deeper water. The K/Mg ratio represents the final state of the reaction between the fluid and wall-rock reaction before rising to the surface. The concentration of Mg will decrease if the temperature of the fluid rises. If the concentration of Mg increases it can be assumed that the fluid has been mixed with a low temperature fluid close to the surface. This geothermometer is valid up to 300°C.

Giggenbach et al. (1983)

$$t(°C)=\frac{4410}{13,95+\log(K^2/Mg)}-273,15 \quad (6)$$

2.7 Na/K/Ca Geothermometer

Geothermometer Na-K-Ca is a type of geothermometer developed by Fournier and Truesdell (1973), for the application of fluids with high calcium concentrations where the element Ca in the geothermometer is a correction factor. This is evidenced by the use of calculation indicators where before entering the main formula first calculate the value of {log (Ca1/2/Na) + 2.06} if positive results are obtained then using β = 4/3 if negative then using β = 1/3. If the calculated temperature is <100°C, then this temperature is appropriate. The main advantage of the Na-K-Ca geothermometer compared to quartz Geothermometers and especially the Na/K geothermometer, is that the results of the application of this geothermometer do not give too high (over) and "misleading" results for the observation of geothermal fluid in cold water with conditions non-equilibrium.

Fournier and Trusdell (1973)

$$t(°C)=\frac{1647}{\left\{Log\left(\frac{Na}{K}\right)\right\}+\beta\left[Log\left(\frac{\sqrt{Ca}}{Na}\right)+2{,}06\right]+2{,}47}-273{,}15 \quad (7)$$

2.8 Ratio Map

Geoindicator analysis is an analysis carried out by comparing the anions of each existing manifestation to determine the flow pattern in a geothermal system (Nicholson, 1993). There are several water geo-indicator ratios that can be used to determine hydrogeology and geothermal zoning, namely the B/Li ratio, the Na/K ratio, the HCO_3/SO_4 ratio, the Cl/B ratio and also the Cl/F ratio. Where in the B/Li, Na/K and HCO_3/SO_4 geo-indicators, the smaller the value of the ratio, the more it shows that the direction of the flow leads to fracture upflow directly from the reservoir. Whereas the Cl/B and Cl/F geoindicators show that the smaller the ratio, the more it shows that the direction of flow towards the fracture outflow is not directly from the reservoir (flanking).

2.9 Isotope Analysis

Isotope analysis is a method that using natural isotope with stable isotopes, namely Deuterium (^2H) and oxygen-18 (^{18}O), the use of this type of isotope is because it is stable and does not change easily so it is relevant to use. Its use in estimating fluid origin is by plotting the isotope graph where there are three zones, namely the meteoric zone, mixed zone (mixing) and magmatic zone (andesitic).

2.10 Depth of Reservoir

Calculation of reservoir depth was carried out using equations based on statistical data from geothermal area wells that had previously been examined by Hochstein and Sudarman (2008) where the following equations were obtained. X in the equation is the amount of temperature from the geothermometer.

Iqbal (2014)

$$y = -12{,}4x + 1.583;\ R2=0{,}74 \quad (8)$$

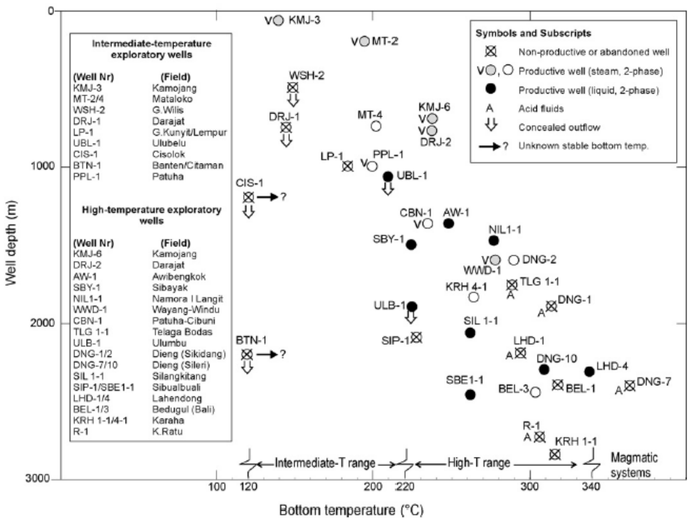


Figure 3:Subsurface temperature curves for reservoir depth Hochstein and Sudarman (2008).

3. RESULTS AND DISCUSSION

3.1 Ion Balance

Ion balance analysis is an analysis carried out to determine the equilibrium level between positive ions (cations) and negative ions (anions) of the three existing manifestations. A result of ion equilibrium analysis is said to be feasible if not more than 5%.

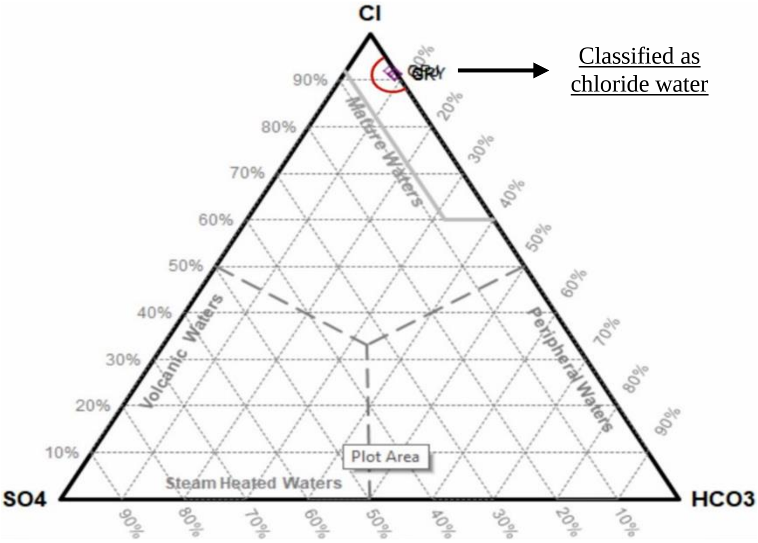
Table 1: Conditions of geothermal fluid Ciseeng

No.	Sampel	Na (ppm)	K (ppm)	Ca (ppm)	Mg (ppm)	Cl (ppm)	HCO3 (ppm)	SO4 (ppm)
1	Gunung Panjang (GPJ)	6391.33	281.39	788.45	126.44	10307.07	834.59	60.93
2	Gunung Peyek (GPY)	7638.63	395.66	1030.12	110.14	14908.88	1365.12	28.21
3	Gunung Kapur (GK)	6671.90	205.59	1178.36	127.52	12964.70	1203.82	39.40

No.	Sampel	Li (ppm)	NH4 (ppm)	F (ppm)	pH	SiO2 (ppm)	B (ppm)	Sum Cation	Sum Anion	Ion Balance
1	Gunung Panjang (GPJ)	11.55	40.57	7.48	7.49	13.7	15.8	338,88	306,10	5%
2	Gunung Peyek (GPY)	18.32	44.55	2.02	7.24	17.7	57.9	407,97	403,65	-4%
3	Gunung Kapur (GK)	16.69	58.54	2.02	7.34	22.3	49.4	370,43	386,39	-2%

3.2 Water Type

Based on the high Cl concentration and the results of the triangular diagram plot of using Cl-SO_4-HCO_3 geoindicator, the type of geothermal water in the study area in this case Gunung Panjang, Gunung Peyek and Gunung Kapur consists of one type of water namely chloride water.

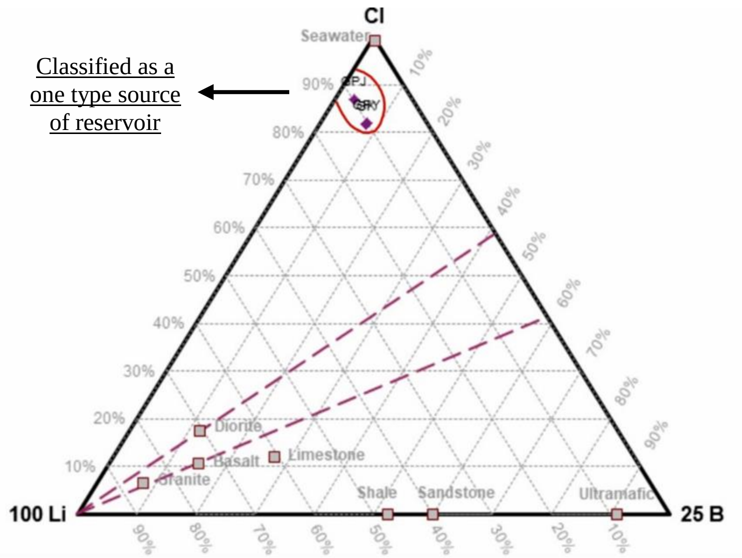


No	Sample Name	Cl (ppm)	SO4 (ppm)	HCO3 (ppm)	Total	%Cl	%SO4	HCO3
1.	Gunung Panjang (GPJ)	10307,07	60,93	834,59	11202,59	92,00 %	0,54 %	7,44 %
2.	Gunung Peyek (GPY)	14908,88	28,21	1365,12	16302,21	91,45 %	0,17 %	8,37 %
3.	Gunung Kapur (GK)	12964,70	39,40	1203,82	14207,92	91,24 %	0,27 %	8,47 %

Figure 4: Water type of research area based on Cl-SO_4-HCO_3 Giggenbach (1991) in Powell and Cumming (2010)

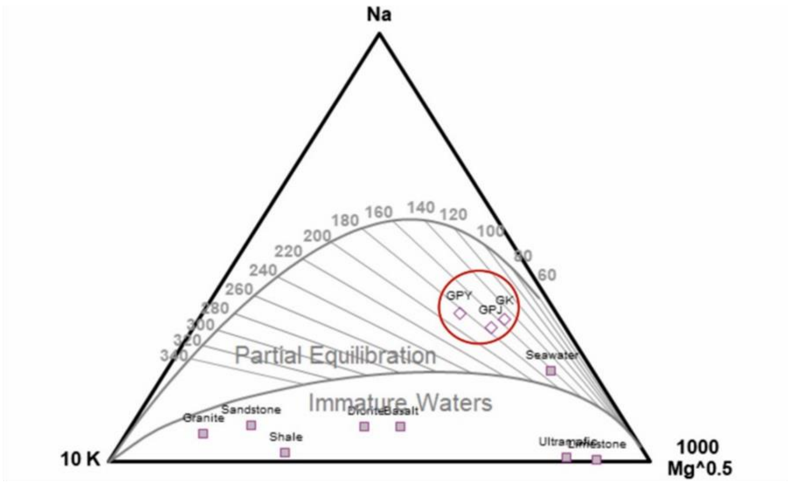
3.3 Origin and Water Conditions

Based on the analysis using the Cl-Li-B geoindicator triangle diagram as shown, it can be interpreted that the origin of water from the three manifestations in the Ciseeng geothermal region originates from one type of reservoir indicated by the results of plotting points adjacent to one zone. Based on the triangular diagram of Na-K-Mg geoindicator, a fluid condition is located in the partial equilibrium zone which indicates that the water has been mixed and has been warming for a long time in the reservoir.



No	Sample Name	Cl (ppm)	Li (ppm)	B (ppm)	100Li	25B	Total	%Cl	%Li	%B
1.	Gunung Panjang (GPJ)	10307,07	11,55	13,7	1155	342,5	11829,82	87,12 %	9,76 %	2,89 %
2.	Gunung Peyek (GPY)	14908,88	18,32	57,9	1832	1147,5	17964,6	82,99 %	10,19 %	6,38 %
3.	Gunung Kapur (GK)	12964,70	16,69	49,4	1669	1235	15934,79	81,36 %	10,47 %	7,75 %

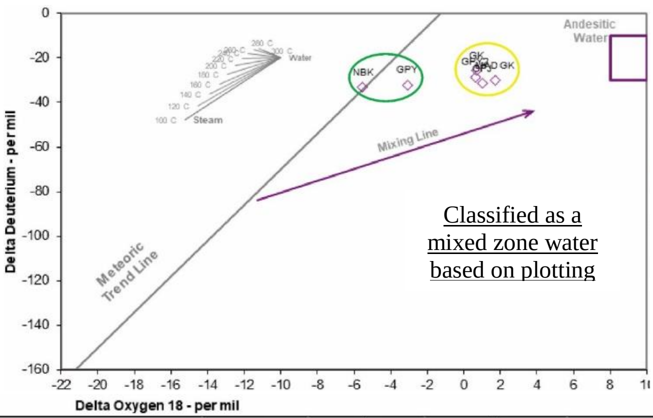
Figure 5: Origin of Ciseeng geothermal region based on Cl-Li-B geoindicator Giggenbach (1991) in Powell and Cumming (2010)



No	Sample Name	Na (ppm)	K (ppm)	Mg (ppm)	10K	1000(Mg)^0,5	Total	%Na	%K	%Mg
1	Gunung Panjang (GPJ)	6391,33	281,39	126,44	2813,9	11244,55	20576,22	31,06 %	13,67 %	54,64 %
2	Gunung Peyek (GPY)	7638,63	395,55	110,14	3956,6	10494,76	22200,13	34,40 %	17,82 %	47,27 %
3	Gunung Kapur (GK)	6671,90	205,59	127,52	2055,9	11292,47	20147,79	33,11 %	10,20 %	56,04 %

Figure 6: Fluid condition of the Ciseeng geothermal region based on Na-K-Mg geoindicator Giggenbach (1991) in Powell and Cumming (2010)

In this study isotope data also obtained using secondary data that had previously been studied by Sembiring (2017) where the previous researcher conducted research on interconnection studies of Ciseeng warm springs and groundwater around manifestations that only carried out isotope tests on warm springs of Gunung Peyek and cold springs wells around one of the manifestations at the NUBIKA Army Complex. Then the next data is the primary data that has taken and then tested for the isotope level in BATAN Isotope Laboratory Jakarta.



No	Sample Name	Code	d^2H	$d^{18}O$	Type
1	NUBIKA Army Complex	NBK	-33,02	-5,53	Cold Water Well
2	Gunung Peyek	GPY	-32,08	-3,06	Hot Spring
3	Gunung Peyek 2	GPY 2	-28.5	0.63	Hot Spring
4	Gunung Panjang	GPJ	-31.3	1.01	Hot Spring
5	Gunung Kapur	GK	-25.6	0.67	Hot Spring
6	Gunung Kapur 2	MAD GK	-30.1	1.71	Cold Spring

INFORMATION : Secondary Data (green); Primary Data (yellow)

Figure 7: Isotopes of the Ciseeng Giggenbach (1992) in Cumming and Powell (2010)

Based on the plotting process using secondary data in this case according to Sembiring (2017) the results show that the Gunung Peyek warm spring has a tendency to meteoric water patterns, it is also found with cold springs, the NUBIKA Complex of the Army which is also meteoric, but if based on primary data processed in BATAN found that Gunung Peyek, Gunung Kapur and Gunung Panjang are in the mixed zone so that it can be concluded that the geothermal solution in the process towards the surface has been mixed.

3.4 Geothermometer

Based on different type of geothermometers we believe that Geothermometer Na/K by Giggenbach (1988) is the most suitable geothermometer to be applied in Ciseeng because previously based on geoindicator Cl-Li-B the result is Ciseeng classified as a chloride water. According to Karingithi (2013) waters from high temperature reservoirs (180°C) of chloride waters are suitable for Na/K geothermometer.

Table 2:Geotherometers of Ciseeng

No	Sample Name	Fournier (1977)	Giggenbach et al. (1988)
1	Gunung Panjang	49,79°C	174,33°C
2	Gunung Peyek	58,91°C	184,75°C
3	Gunung Kapur	67,58°C	153,07°C
No	**Sample Name**	**Fournier (1979)**	**Giggenbach et al. (1983)**
1	Gunung Panjang	162,38°C	122,24°C
2	Gunung Peyek	173,65°C	135,28°C
3	Gunung Kapur	139,649°C	112,69°C
No	**Sample Name**	**Fournier & Trusdell (1973)**	
1	Gunung Panjang	162,62°C	
2	Gunung Peyek	184,53°C	
3	Gunung Kapur	148,61°C	

Silica Geothermometer

Based on the calculation of silica geothermometer according to Fournier (1977) obtained values from low to high, Gunung Panjang with a temperature of 49.79°C, on Gunung Peyek with temperatures of 58.91°C and on Gunung Kapur with a temperature of 67.58°C.

Geothermometer Na/K

Based on the calculation of the Geothermometer using Na/K according to Fournier (1979) reservoir temperature is obtained from low to high, Gunung Kapur 139,64°C, Gunung Panjang 162,38°C and Gunung Peyek 173,65°C. Then based on Giggenbach (1988) reservoir temperature was obtained from low to high, namely Gunung Kapur 153,07°C, Gunung Panjang 174,33°C and Gunung Peyek 184,75°C.

K/Mg Geothermometer

Based on the calculation of the geothermometer using K/Mg by Giggenbach et al. (1983) reservoir temperature from low to high was obtained, namely Gunung Kapur 112.69°C, Gunung Panjang 122.24°C and Gunung Peyek 135.28°C.

Na-K-Ca Geothermometer

Based on the calculation of the Geothermometer using Na-K-Ca by Fournier and Trusdell (1973) reservoir temperature was obtained from low to high namely Gunung Kapur 148.61°C, Gunung Panjang 162.62°C and Gunung Peyek 184.53°C.

3.5 Geoindicator Ratio Map

Based on the calculation of the geoindicator ratio B/Li, Na/K ratio, HCO_3/SO_4 ratio, Cl/B ratio and also the Cl/F ratio will be obtained the location distribution then the calculation value of the geo-indicator is plotted to the existing manifestation coordinates on topographic maps. Of the five geoindicators, the dominant outflow and upflow patterns are obtained from HCO_3/SO_4 ratio, Cl/B ratio and Cl/F, where the outflow zone is found in the eastern part of the manifestation and the upflow is in the western part of the manifestation.

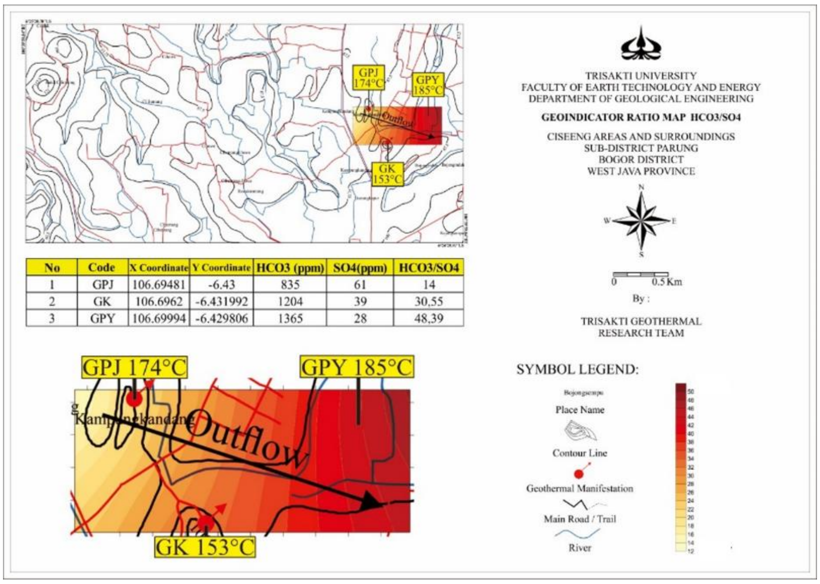
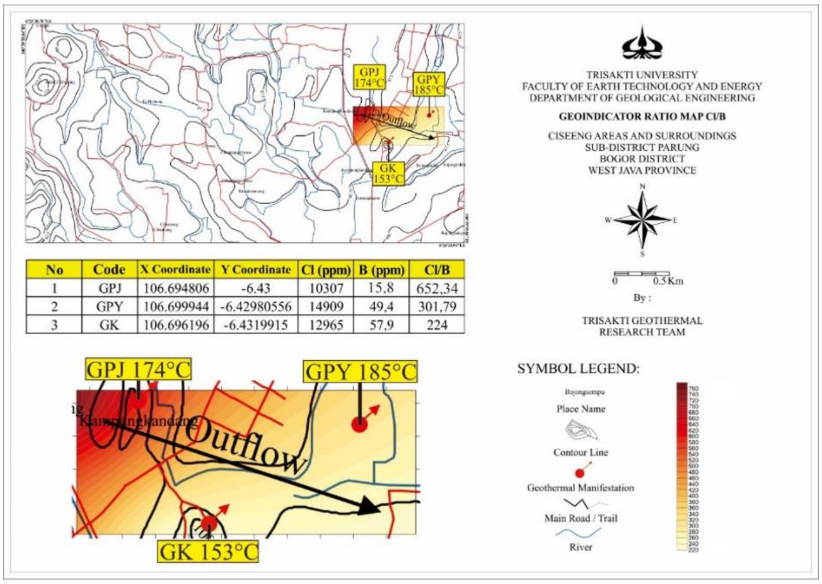
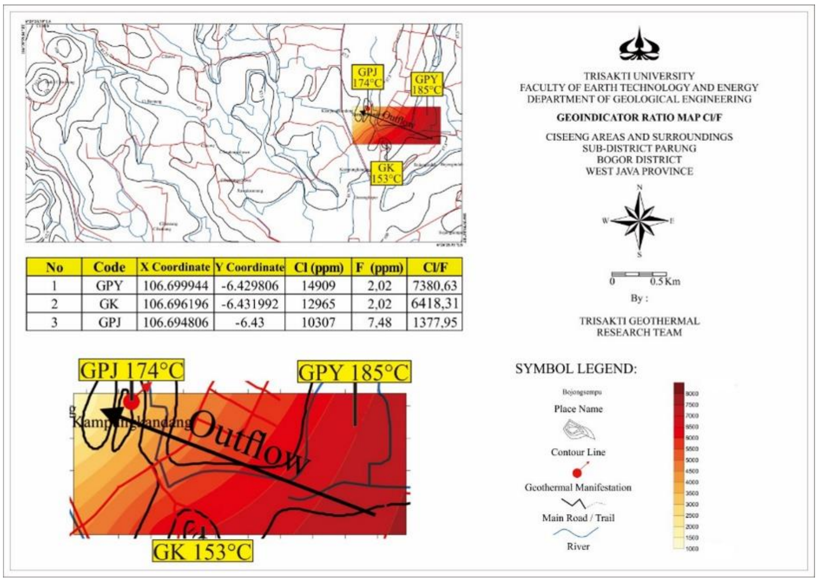


Figure 8: HCO_3/SO_4 geoindicator ratio map



No	Code	X Coordinate	Y Coordinate	Cl (ppm)	B (ppm)	Cl/B
1	GPJ	106.694806	-6.43	10307	15,8	652,34
2	GPY	106.699944	-6.42980556	14909	49,4	301,79
3	GK	106.696196	-6.4319915	12965	57,9	224

Figure 9: Cl/B geoindicator ratio map



No	Code	X Coordinate	Y Coordinate	Cl (ppm)	F (ppm)	Cl/F
1	GPY	106.699944	-6.429806	14909	2,02	7380,63
2	GK	106.696196	-6.431992	12965	2,02	6418,31
3	GPJ	106.694806	-6.43	10307	7,48	1377,95

Figure 10: Cl/F geo-indicator ratio map

3.6 Reservoir Depth

Calculation of reservoir depth was carried out using equations based on statistical data had previously been studied by Iqbal (2004) and plotted using Hochstein and Sudarman (2008) geothermal wells data. The result of the calculation using the isotope equation is that Gunung Panjang shows results at a depth of -578m, Gunung Kapur shows results at -315m while Gunung Peyek shows a depth of -707m where the temperature curve line according to the subsurface moves straight according to the results of each manifestation.

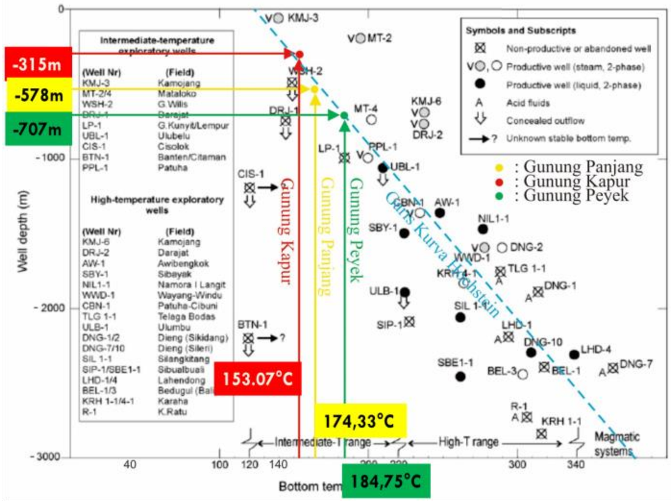


Figure 11:Plotting of depth vs temperature using geothermometer data Hochstein and Sudarman (2008)

3.7 Geochemical Modeling

Based on the previous data obtained from this case, the geological features are as follows: 4 units namely Limestone Unit, Andesite Fragment Breccia Unit, Alluvial Deposition and Travertine. From the geothermal aspect the Ciseeng geothermal area has three manifestations, namely Gunung Panjang, Gunung Peyek and Gunung Kapur, which are three in low contours so that Ciseeng's geothermal area is included as a volcanogenic low relief system.

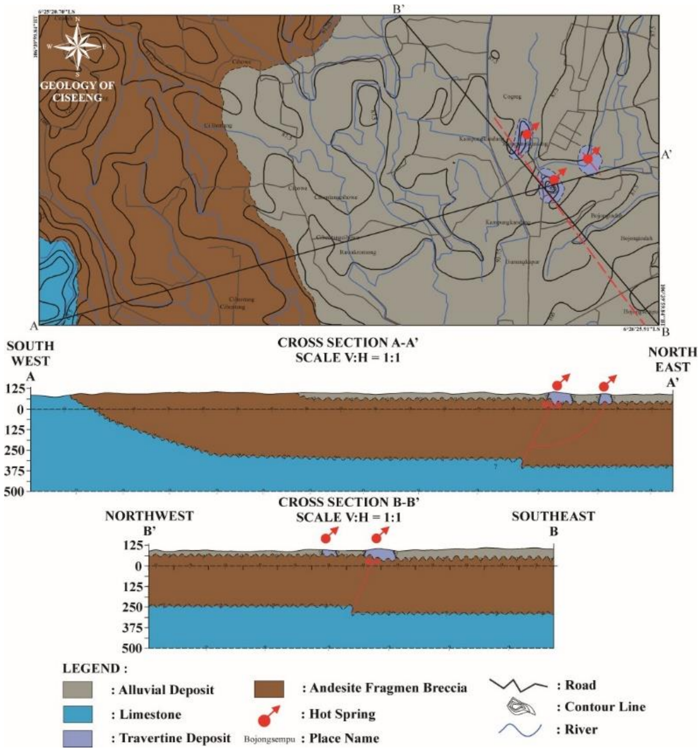


Figure 12: Geological conditions of the study area

The geothermal system in Ciseeng is triggered by the presence of a geological structure in the form of an oblique fault rising under the Alluvial Deposition Unit so that it opens a gap for the geothermal fluid to rise to the surface to form Travertine layered horizontally (bedded Travertine) and vertical gap (banded Travertine). Based on the geochemical analysis of water types including chloride water and including mature water, this indicates that geothermal fluid flowed directly from the reservoir data obtained from the estimated temperature in the Ciseeng geothermal region ranged from 153 ° C-184 ° C (Table 3).

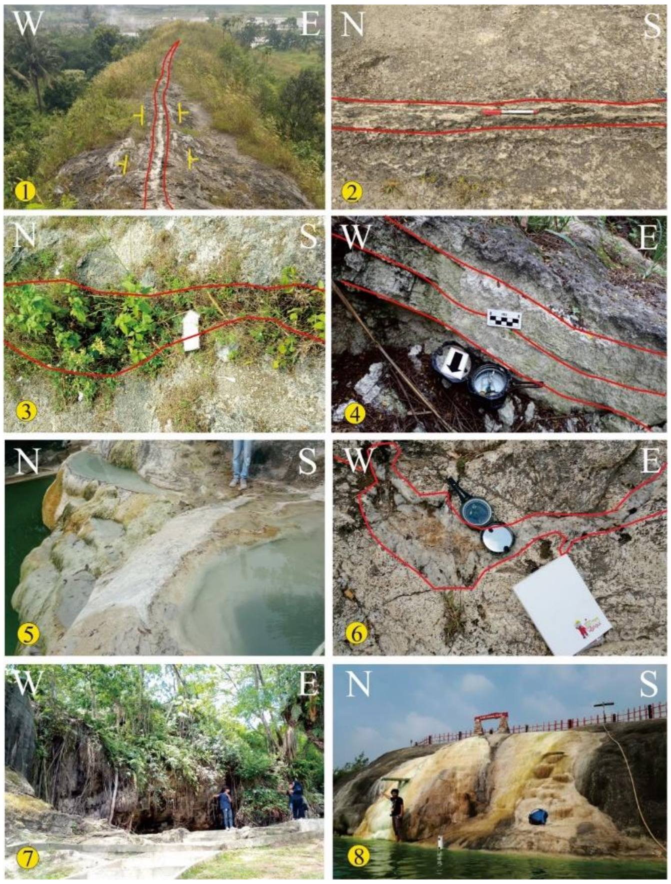


Figure 13: (1) Open fracture of Gunung Panjang, (2) Banded Travertine filled with Travertine deposits of Gunung Panjang (3) Open fracture that has not been clogged in Gunung Panjang (4) Bedded Travertine of Gunung Panjang (5) Travertine deposits form a terrace in Gunung Panjang (6) Calcite veins found at the top of Gunung Kapur (7) Travertine cave in Gunung Kapur (8) Travertine hill of Gunung Peyek

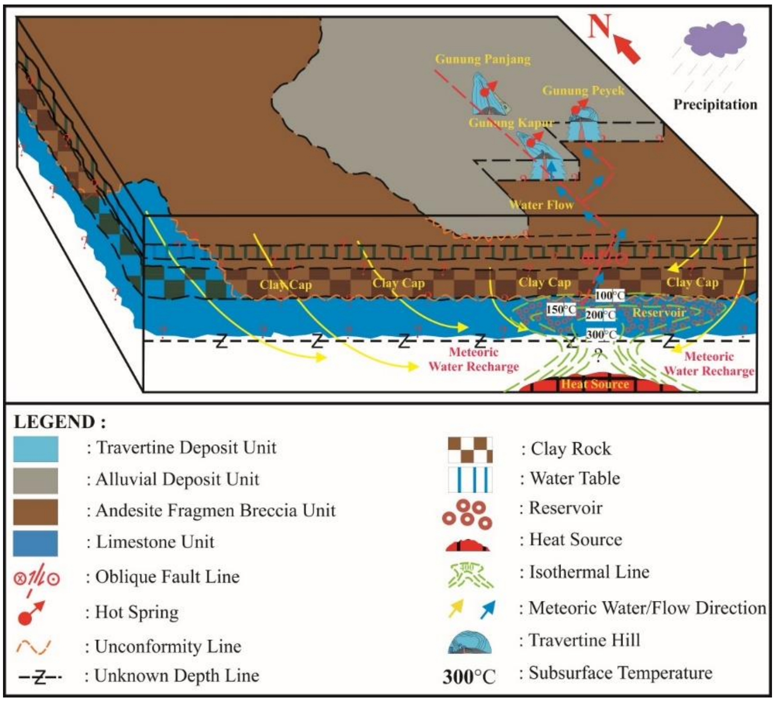


Figure 14:Tentative models of the Ciseeng geothermal region

Based on the isotope analysis, the results showed that the type of water shows the type of mixing that shows the control of meteoric water from groundwater around the reservoir mixed manifestations. Calculation of ratios shows that the overall manifestation is the area of outflow found on Gunung Peyek (east of the geothermal manifestation area) then the upflow area is located on Gunung Panjang (west of the geothermal manifestation area).

Figure 15: Gas bubble in Gunung Peyek

The components of the geothermal system that comprise the Ciseeng geothermal region are heat sources which are magmas this is because there are high appearance of gas bubbles with a high aroma of sulfur that adds to the assumption that there is a heat source related with magma which then heat the rocks above them which are far below the surface. Then the reservoir is located in Limestone lithology units due to the emergence of Travertine which has a large volume where reservoir depth data obtained based on statistical tests show the results of the Gunung Panjang reservoir showed results at a depth of -578m, Gunung Kapur showed results at -315m while Gunung Peyek showed -707m depth.

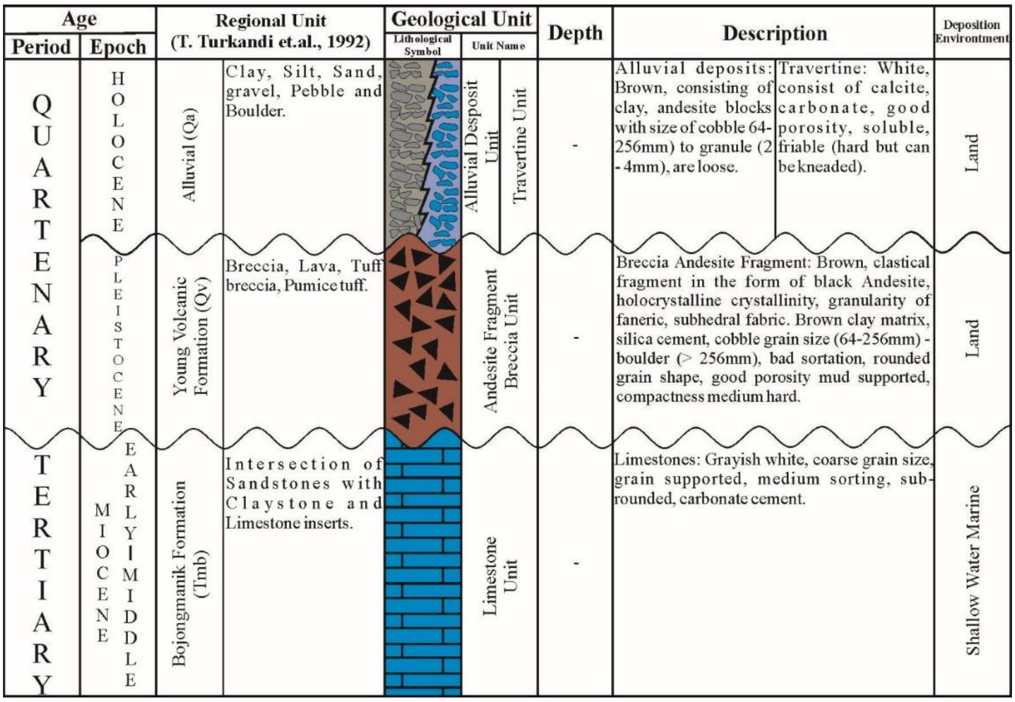


Figure 16: Stratigraphic column of the research area

The clay cap in the Ciseeng geothermal area is in the Andesite Fragment Breccia lithology unit so that based on these data an understanding of what surface conditions can be found in the Ciseeng geothermal region.

The formation genesis of the Travertine Unit is caused by a process where meteoric water which is then heated into the reservoir zone is composed of limestone lithology. The meeting between the geothermal solution and the surrounding lithology causes a contact process so that the walls of the Limestone unit are eroded by a heated and eroded geothermal solution causing changes in physical and chemical elements so that a deposit of Travertine is formed which then increases pressure and temperature causing the geothermal solution to rise towards the surface through cracks either faults or fractures carrying the Travertine deposit that had previously been formed.

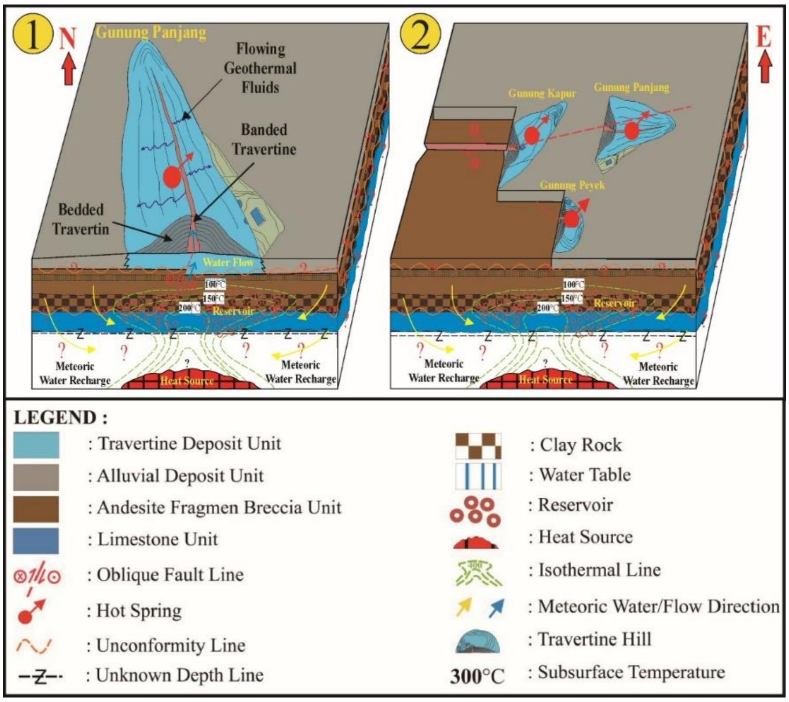


Figure 17: (1) Close-up of the manifestation of Gunung Panjang, (2) Tentative modeling around visible manifestations of east-west

When the geothermal solution comes out on the surface a process occurs where the geothermal solution undergoes evaporation and leaves the Travertine deposit on the surface which can be classified as Travertine Unit where the sediment settles gradually layer by layer called bedded Travertine then when a Travertine body grows well widens or rising will form a banded Travertine which can be blocked at any time by the Travertine deposit itself.

IV. CONCLUSION

Based on field research including mapping and geothermal surveys and geochemical analysis conclusions of geothermal models were obtained based on the following understandings. The results of field identification were four units namely Limestone Unit, Andesite Fragment Breccia Unit, Alluvial Deposition Unit, Travertine Unit. Geothermal manifestations located in the eastern part of the research plots are characterized by lithology in the form of Travertine which is formed by the presence of faults under the surface in this case the oblique fault which then opens the fracture for the geothermal fluid towards the surface.

The geochemical characteristics of water chloride type (mature water based on plotting on Cl-SO4-HCO3 Giggenbach (1991)) water have one origin of water with a partial equilibrium condition where water has been mixed and has warmed up long enough in the reservoir. Geothermometer measurements show the value of subsurface temperatures ranging from 153°C-184°C which is an enthalphy intermediate. Geoindicator shows the pattern of moving outflow zones from the east namely Gunung Peyek towards upflow in the west, namely Gunung Panjang. The isotope analysis of the Ciseeng geothermal region is located in the mixing zone where the geothermal solution in the process toward the surface has been mixed with the type of reservoir fluid, where heat source is magma which then heats the rock above it which is located far below the surface.

Geothermal modeling obtained from an understanding of geochemistry yields the results of a tentative model with a low-relief volcanogenic type system.

REFERENCES

Fournier, R.O., Truesdell, A.H.: An Empirical Na-K-Ca Geothermometer for Natural Water, Geochimica Cosmochimica Acta, vol.37, Pp.1255-1275, (1973).

Founier, R.O.: Chemical Geothermometer and Mixing Models for Geothermal Systems, Geothermics, (1977).

Fournier, R.O.: A revised equation for the Na/K Geothermometer, Geothermal Resource, Council Transaction, (1979), vol.3, Pp.221-224.

Giggenbach, W.F., Gonfiantini, R., Jangi, B.L. and Truesdell, A.H.: Isotopic and chemical composition of Parbati valley geothermal discharges, NW-Himalaya, India, Geothermics, (1983), 12: 199-222.

Giggenbach, W. F.: Geothermal solute equilibria. Derivation of Na-K-Mg geoindicators. Geochemica et Cosmochimica Acta, (1988), 2749-2765.

Giggenbach, W.F.: Chemical techniques in geothermal exploration in UNITAR/UNDP Guidebook: Application of geochemistry in resources development, (1991), 119-144.

Giggenbach, W.F.: Isotopic shifts in waters from geothermal and volcanic systems along convergent plate boundaries and their origin, EPSL 113, (1992), 495-510.

Hochstein, M. P.: Classification and Assessment of Geothermal Resources. Small Geothermal Resources, Rome, Italy, (1990).

Hochstein, M. P.: Classification of Surface Discharge Features and Heat Loss Surveys, University of Auckland, Auckland, (1994).

Hochstein, M.P. and Browne, P.R.L.: Surface manifestations of geothermal systems with volcanic heat sources. Encyclopedia of Volcanoes, Academic Press. (2000).

Hochstein, M.P., Sudarman, S.: History of Geothermal Exploration in Indonesia from 1997 to 2000, Geothermics, (2008), Vol. 37 No. 3.

House Of Representative of Republic Indonesia., President Of The Republic Of Indonesia.: Geothermal, Law of Republic Indonesia No.21 (2014)

Karingithi, C. W.: Chemical Geotermometers For Geothermal Exploration. Kenya Electricity Generating Company Ltd. (KenGen). Naivasha, Kenya. (2013).

Mochamad. I.: Geology and Geochemistry of Geothermal Fluid in Rana Masak Area and Surroundings, Borong District, East Manggarai Regency, Flores, East Nusa Tenggara, Geology Engineering, Bandung Institute of Technology. (2014).

Nicholson, K.: Geothermal Fluids - Chemistry and Exploration Techniques, Berlin: Springer-Verlag Berlin Heidelberg, (1993).

Powell T., Cumming W.: Spreadsheets For Geothermal Water And Gas Geochemistry, Mighty River Power: Hamilton, New Zealand, (2010).

Richards, M., Blackwell, D.: The Nevada Story: Turning a Loss into a Gain. Geothermal Resources Bulletin, (2002), 31.

Sembiring., G., C.: Ciseeng Warm spring Interconnection Study in Bogor Regency with Surrounding Groundwater Using Natural Isotopes (2H, 18O, 222Rn) and Water Chemistry, Gadjah Mada University, Yogyakarta, (2017).

Turkandi, T., Sidarto., Agustiyanto, D.A., and Purbo, H.M.M.: "Regional Geological Maps of Jakarta and Thousand Islands", (1992).