Physical and Chemical Characteristic of Geothermal Manifestations in Talaga Bodas, West Java, Indonesia

Azy, F.N.[1], Jihadi, L.H[1], and Darana, A.R[1], Oscar A.W[1]

[1] Faculty of Geological Engineering, Universitas Padjadjaran, Jalan Raya Bandung – Sumedang KM 21, 45363, Bandung, Indonesia

fikri11007@student.unpad.ac.id

Keywords: *Geothermal, telagabodas, geochemical, hotspring*

ABSTRACT

As the time goes by, geothermal energy is becoming one of the greatest alternative energy sources in the world. Geothermal systems usually occur in an area which has a lot of volcanic activities, such as Indonesia. One of the areas in Indonesia which has potential is located in Telagabodas, West Java. A geological and geochemical approach is used for this study to determine the characteristics of the geothermal manifestation. Mount Telagabodas has manifestations in the form of mudpools, solfataras and hotsprings. From the physical and chemical data, including the presence of chloride (Cl) water, acid sulphate water (SO_4) bicarbonate water (HCO_3), pH, TDS, and EC, the geothermal manifestations can be characterized as immature, indicating that the water in the geothermal system is mixed or the geothermal system has a shallow ground water source.

1. INTRODUCTION

1.1 Background

Worldwide fossil fuel has become the main energy source used to fulfill energy demand. However, excessive fossil fuel usage is depleting the resources. Therefore, an alternative energy source is required. Geothermal energy could be the solution, because it provides a great amount of energy and is cleaner than fossil fuel. Especially in a country with many volcanic activities, such as Indonesia, the geothermal potential is very high. Indonesia is located in a giant subduction zone where three mayor plates collide. The subduction zone is formed by the collision of the Eurasian Plate, Australian Plate, and Pacific Plate. The Eurasian Plate and the Pacific Plate collide in the northeast of Indonesia, while the Eurasian Plate collide with Pacific Plate and the Australian Plate mostly in the southern part of Indonesia. As a result Indonesia's tectonic structure is very complex especially the structure along the collision zone which includes Fore Arc, Volcanic Arc and Back Arc. So there are a lot of volcanoes that indicate a high potential for geothermal resources. One of the places that could have geothermal potential is located at Talaga Bodas, West Java, Indonesia.

The Talaga Bodas area shows some manifestations of geothermal activity such as solfataras, fumaroles, mud pools and hot springs, and because of these manifestations there is a possibility that the area could be a useful geothermal energy resource. Before any development is started, the geothermal potential must be identified and therefore geothermal exploration is needed.

Geothermal exploration, including geological and geochemical analysis, can help to determine the potential of the Talaga Bodas Area as a geothermal resource. Through exploration and analysis of geological properties, both the chemical and physical characteristics of the water in the manifestations and reservoir properties such as its temperature and fluid type could be identified.

In this study, we focus on geological and geochemical methods for characterising a geothermal area, including measuring the composition of water taken from where the geothermal manifestations and studying geological properties such as: structures, volcanic stratigraphy, and rock types in the research area. From the data, we can determine the type of the reservoir. However, in order to determine the geothermal potential, further analysis and exploration are needed.

1.2 Geological Condition

The research area, Mt. Telagabodas, is a volcanic mountain located in the north to southwest side of Mt. Galunggung. According to Budhitrisna (1986) in the *Geologic Map of Tasikmalaya Quadrangle*, the research area, around the crater of Mt. Telagabodas, consists of rocks resulting from young volcanic mountain activity such as volcanic breccia, laharic rocks, and tuff that is composed of interspersed andesitic-basaltic rocks resulting from eruptions of Mt. Telagabodas. Outcrops in the area show grayish andesitic rock and some rocks which are altered heavily.

Petrographic tests show that the andesitic-basaltic rock-type can be categorized as andesitic pyroxene. Also andesitic lava is found around the crater of Mt. Telagabodas (Irianto et al. 2000). Rocks that were generated near the Mt. Telagabodas site consist of cyclical sequence of lava and pyroclast that have intercalated with each other as a result of eruptions at various sites. Based on the investigations of Suhadi et al. (1999), these rocks can be divided into 39 units, i.e.:

A. Telagabodas Lava

It is composed of grayish brown into black andesitic-basaltic rock with porphyritic and massive texture. Also, it consists of pyroxene and plagioclase minerals, vesiculated in some places and also showing in outcrops as boulders.

B. Telagabodas Pyroclastic

This unit is light brown in colour, weathered and solid, and consisting of material sized volcanic ash to lapilli. It forms a bedding plane with a thickness of around 15 to 20 cm and is up to 10 to 20 meters thick when exposed as an outcrop.

C. Sadahurip Lava

It is classified as a product of a side eruption when Mt. Telagabodas erupted. It has the shape of cone, is isolated, and consists of andesitic-basaltic lava with porphyritic and massive texture. Also, it is heavily weathered.

D. Candramerta Lava

Candramerta lava was generated by a side eruption of Mt. Telagabodas. It consists of andesitic-basaltic rocks, grayish to black in color, whose texture is porphyritic and also in a weathered condition

E. Bungbulang Lava

This unit was formed as the result of a volcanic eruption on the side of Mt. Telagabodas and has a cone shaped morphology. On the eastern side a slope was developed, following the slope of Mt. Telagabodas. In general, the rock is heavy weathered with a brown color when weathered and dark gray in the fresh form. It has a massive structure, and is partially formed of boulders or blocks of lava which are affected by geological structures such as faults.

F. Malang Lava

This unit is mostly covered by Bungbulang Lava and is suspected to be the result of the side eruption of Mt. Telagabodas. It spreads around the east to northeast of Mt. Telagabodas and has a cone-shaped appearance. At a certain height, the rock has a dark gray color with a porphyritic texture.

G. Lebakjero Lava

In general, this unit forms an andesitic-basaltic lava which is gray-black with a porphyritic and massive texture. Also some minerals, i.e. pyroxene and plagioclase, can be found in this unit, and in some places there are traces of solfataras.

H. Lebakjero Pyroclastic Flow

This unit has resulted from pyroclastic flows, and is brown to reddish in appearance. It is composed of andesitic-basaltic components whose size is between pebbles to boulders. It is also composed of lytic components with an average diameter 3-5 cm which are poorly sorted and sub-angular in shape.

I. Lebakjero Pyroclastic Fall

This unit can be found on the western slopes of Mt. Telagabodas. It covers most of the Lebakjero Pyroclastic Flow and Telagabodas Lava. It is brown to blackish in colour and is composed of volcanic material whose size is ash to lapilli.

J. Masigit Lava

Masigit Lava spreads around the Masigit Crater, forming the wall and floor of the crater. The cooled lava created andesitic-basaltic rocks which are blackish gray, weathered and altered by solfataras.

K. Patrol Lava Dome

This unit iss located at the north of Mt. Telagabodas, spreading along and creating a dome morphology which is very rounded. It is composed of andesitic-basaltic lava rocks which are blackish gray with a porphyritic texture.

L. Tegalsaat Piroclastic Fall

This unit spreads along northwest side of the Patrol Lava Dome in a cone-shaped morphology. It is composed of foliated blackish gray ash-lapilli volcanic rocks.

M. Masigit Piroclastic Fall

Masigit Pyroclastic Fall covers a part of Lebakrejo Lava unit. It has a brownish black appearance and is composed of ash, sand, and lapilli bedding.

N. Masigit Pyroclastic Flow

This unit covers the Masigit Pyroclastic Fall. It is composed of yellowish weathered and altered andesitic-basaltic igneous rock.

O. Lahar (Lh)

This unit is located near the northeast side of the foot of Mt. Telagabodas and forms a rather flat landscape that is used by people for farming or rice fields. It is composed of ash, sand and igneous components, poorly sorted and weathered.

According to Suhadi, D et al. (1999), there are a few structures that have been generated in the area near Mt. Telagabodas, i.e.: Candramerta Fault, Sadahurip Fault, Bungbulang Fault, Pasir Sigung Fault, Cibodas Fault and Ciparay Fault. Also there are some structures in the main crater. The presence of these structural faults has produced the geothermal manifestations around the study area, including fissures in the groundwater aquifers that have caused the hot springs to occur.

2. METHOD

This research is based on the geological mapping procedure discussed by Zakaria (2013). Based on remote sensing, a mapping track is prepared, so all the required spatial data can be gathered. The spatial data are gathered has to representative of the area. The spatial data includes geological and morphological aspects that will be used to describe the properties of each locality.

The hot springs were described as part of the geological study. The physical properties of the water in the hot springs is measured using a multi-tester water device, while chemical properties are measured in a laboratory. The water samples were taken at all the hot springs across the study area, and put into labeled plastic bottles. The analyses of the data are discussed below. The geochemistry is used to characterise the geothermal manifestations in the study area.

3. RESULT AND DISCUSSION

3.1 Geothermal Manifestation

One of the geothermal manifestations that can be found around the crater of Mt. Telagabodas is a mud pool located alongside of the crater, exactly at its east side. The mud pool has a diameter of 1.5 m with very active hot mud that comes out from underground (Fig. 3.1.2). At a distance of 5 to 8 m from the mud pool, there are active fumaroles emitting sulfuric gases which can be identified as solfataras. The solfataras produce very thick sulfuric gases, abundant enough to make it hard for humans to breathe.

A hot spring site that is sampled, Telagabodas-2 (Tlb-2), is located near the mud pool and solfataras. The hot spring produces bubbles, and its water is very acid (Table 3.2.1 and Table 3.2.2). Another hot spring near Tlb-2, on its south side, is used as a bath area by locals. A sample was also taken here and was labeled as Telagabodas-1 (Tlb-1). Around the Tlb-1 spring, many outcrops show heavily altered andesitic-basaltic rocks.

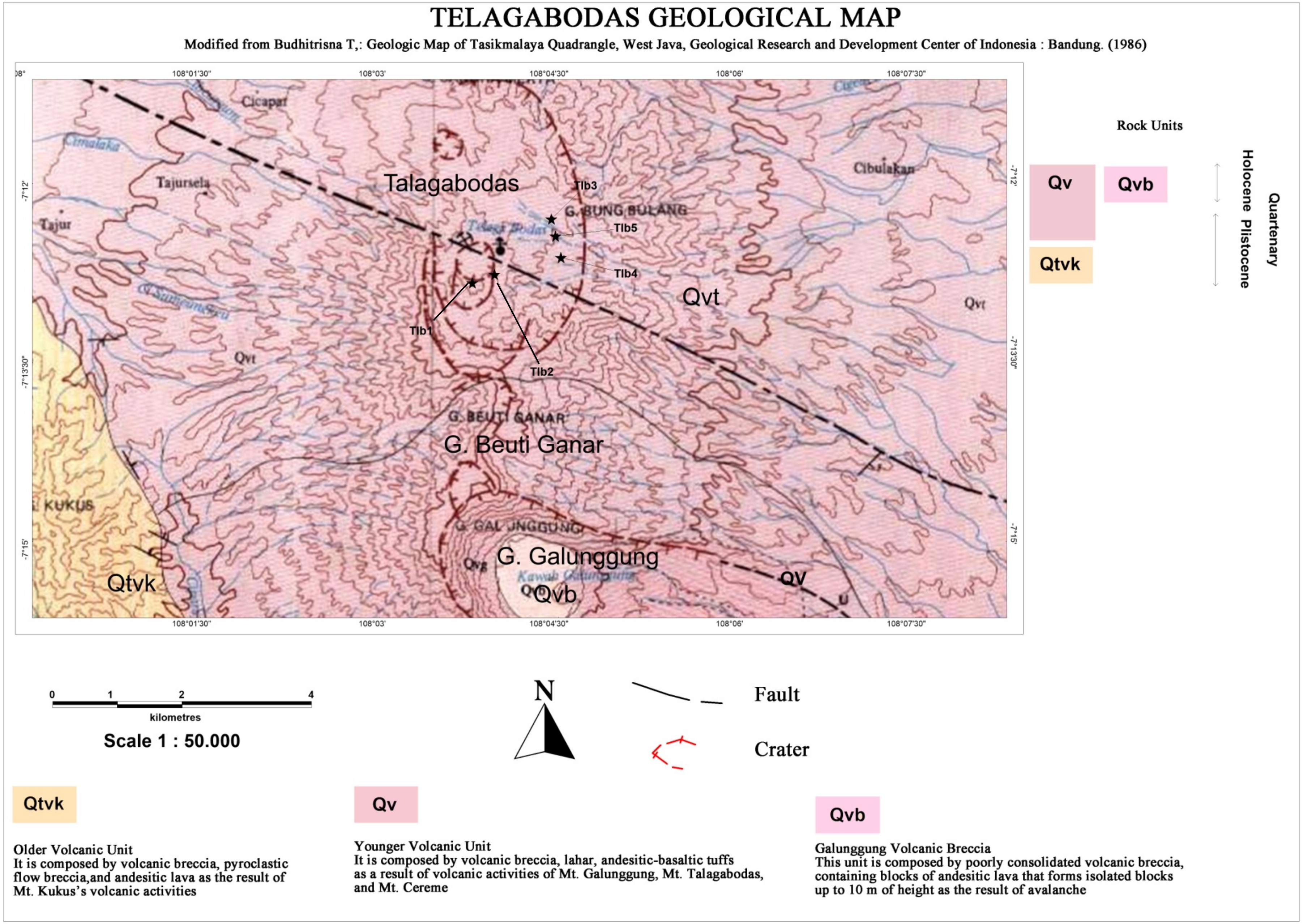

Fig 3.1.1 Telagabodas Geological Map

Fig. 3.1.2 Geothermal manifestation, showing a mud pool with a solfatara on its side

Other sites at which water was sampled were located around the hot spring area, at the eastern side, 1 km from Mt. Telagabodas crater. Also this hot spring area is used as public bath by the locals. The following hot springs are in this area:

A. Cienggang Hot spring

It is located near the access road that connects the Telagabodas area with Tasikmalaya city. The hot spring produces sulfuric bubbles, as shown from the sulphurous smell and withered residue that can be seen below the water. A sample was taken at the site, close to where the bubbles come from.

B. Cikajayan Hot spring

It is located at the end of the public bath, at the southern side of Cienggang hot spring. The hot spring forms a warm steam. This hot spring also has a sulphurous smell, but the smell is not as bad as at the Cienggang hot spring. Some bubbles can be found in the hot spring with a yellowish residue.

C. Ciateul Hot spring

Ciateul Hotspring can be found between Cienggang and Cikajayaan hot springs. Here, greenish residue has accumulated below the water. Bubbles of gas are coming out to the surface along with steam.

3.2 Water Characteristics

The water characteristics can be divided into chemical characteristics and physical characteristics. Physical characteristics are measured at the field. The measurements include pH, temperature, and TDS/EC. The chemical characteristics are measured in the lab, and include determining the concentration of components such as Na, K, Mg, Cl, SO_4, and HCO_3. The results of measurements of both physical and chemical properties can be seen in the tables (Table 3.2.1 and Table 3.2.2).

Tabel 3.2.1. Measurements of chemical characteristics

Element (mg/L)	Telagabodas 1 (Tlb-1)	Telagabodas 2 (Tlb-2)	Cienggang (Tlb-3)	Cikajayan (Tlb-4)	Ciateul (Tlb-5)
	S 7^0 12’ 46.6”	S 7^0 12’ 45.8	S 7^0 12’ 19.3”	S 7^0 12’ 37.0”	S 7^0 12’ 26.2”
	E 108^0 03’ 50.3”	E 108^0 03’ 56.3”	E 108^0 04’ 25.3”	E 108^0 04’ 29.2”	E 108^0 04’ '27.0”
Na	11,6	8,7	23,5	34,9	14,3
K	<0,1	<0,1	2,0	20,3	1,1
Mg	20,4	29,0	60,0	75,4	31,6
Cl	67,5	312,5	274,2	407,5	579,2
SO_4	300	545	465	435	315
HCO_3	112,0	106,0	104,2	417,0	121,6

Table 3.2.2. Measurement of physical characteristics

Physical Characteristic	Telagabodas 1 (Tlb-1)	Telagabodas 2 (Tlb-2)	Cienggang (Tlb-3)	Cikajayan (Tlb-4)	Ciateul (Tlb-5)
	S 7^0 12' 46.6"	S 7^0 12' 45.8	S 7^0 12' 19.3"	S 7^0 12' 37.0"	S 7^0 12' 26.2"
	E 108^0 03' 50.3"	E 108^0 03' 56.3"	E 108^0 04' 25.3"	E 108^0 04' 29.2"	E 108^0 04' '27.0"
pH	4,4	1,4	2,8	1,6	2,3
Temperature (^{0}c)	37,5	36,7	49,4	45,2	41,2
EC (μs/cm)	780	6700	1650	7200	2190
TDS (mg/L)	370	3600	810	3860	1080

3.3 Analysis of Surface Geothermal Manifestation

Geothermal manifestations occur as a result of geothermal activity below the surface. A geothermal system in general consists of components such as fluids, heat source, and reservoir (Goff and Janik, 2000). The components which create the geothermal system also trigger rock alteration, as the high temperature magmatic and meteoric water percolate through the rock around the geothermal system. According to characteristic that can be seen in the field, the geothermal manifestations at Telagabodas result from a volcanogenetic geothermal system which is strongly affected by magmatic heat. Also, the manifestations may be affected by structural faults (Fig 3.2.1). For example there is a structural fault alongside the crater of Mt. Telagabodas.

3.4 Analysis of Physical and Chemical Characteristic

Based on the work of Nicholson (1993), the temperature in a geothermal system can be predicted using a geo-thermometer based on minerals in the water and its chemical components. The geo-thermometer can be applied to geothermal manifestations such as natural hot springs and also the hot discharge that comes out from drilling a well. The geo-thermometer is based on mineral solubility (silica) and the ion exchange reaction (Na-K, Na-K-Ca).

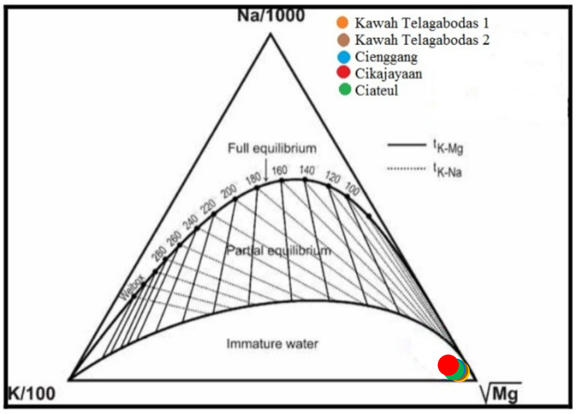

Fig 3.4.1 Comparison of Na – K – Mg in water in hot springs around the study area showing that water is immature (Giggenbach, 1988 in Nicholson, 1993)

The fluid in hot springs around the study area is very high in Mg, much higher than in Na and K (Fig 3.4.1). The figure shows that water is immature. This condition means that the water in the geothermal system could be mixed or that the geothermal system contains shallow groundwater.

Generally, the water type in a hot spring can be classified as chloride (Cl), sulfate (SO_4), and bicarbonate (HCO_3) based on the relative content of Cl, SO_4, and HCO_3 anions. Chloride water is dominated by the Cl anion with concentrations exceeding 10000 mg/Kg (Nicholson, 1993). Chloride water manifestations usually have a greenish residue below the water. Sulfate water type is usually found in areas where the groundwater is near the surface (<100 m) and the type of manifestation found is a mud pool. The sulfate water results from oxidation reaction between H_2S and steam creating H_2SO_4. The bicarbonate water is dominated by HCO_3, resulting in a travertine residue near the surface if the Ca content is high (Nicholson, 1993).

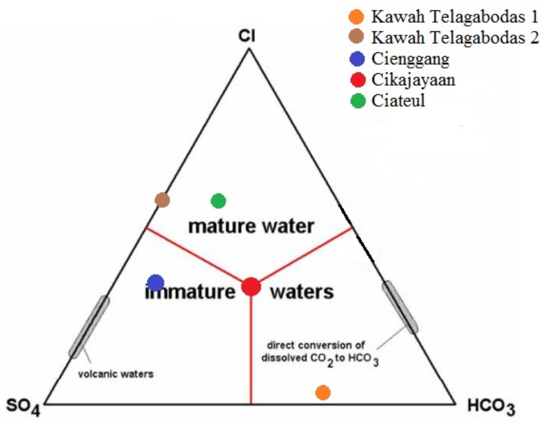

Fig 3.4.2 The diagram shows a comparison between anions of chlorida (Cl), sulfate (SO_4), and bicarbonate (HCO_3), indicating the water type at each site.

According to the diagram (Fig 3.4.2), the study area has a range of water types, including: bicarbonate, chloride-sulfate-bicarbonate, chloride, and sulfate. Talagabodas-1 (Tlb-1) is bicarbonate with high concentrations of the HCO_3 anion, which is expected as it is a seepage water that occurs around the crater of Mt. Telagabodas. Talagabodas-2 (Tlb-

2) and Ciateul (Tlb-5) are categorized as chloride water type, dominated by the Cl anion. For Tlb-2 and Tlb-5 it seems that the water comes from reservoir of the geothermal system, below the surface. Cienggang (Tlb-3) is categorized as sulfate water and it could be caused by an oxidation reaction of H_2S into H_2SO_4 that occurs near the hot spring. The last sample Cikajayaan (Tlb-4) has a unique state where all the anions (chloride-sulfate-bicarbonate) are nearly in balance, perhaps caused by mixing of water as the surface as the sample was taken near a hot stream.

4. CONCLUSION

Based on this study, the Telagabodas area appears to have a geothermal system which is volcanogenetic. The geothermal system occurs as the result of the volcanic activity of Mt. Telagabodas, but approximately immature water, indicates that the water in the geothermal system is mixed or the geothermal system contains shallow groundwater. This can be explained by the manifestations in that area. The manifestiations are: mudpools, solfataras and hot springs. Geological investigations showed that the area contains altered andesitic-basaltic rock including andesitic pyroxene and piroclastics rocks, while the geochemical analysis showed that the water in the manifestations is immature.

ACKNOWLEDGEMENTS

We really appreciate the help from the Hydrogeology and Geo-environment Laboratory of the Faculty of Engineering Geology, and the Physical Chemistry Laboratory of the Faculty of Mathematics and Sciences, in the University of Padjadjaran. Also, we are really grateful for the cooperation with the Chemistry and Environment Laboratory of PT. Ubar Jalindo was supervised by Dr. Solihudin, We are really grateful for the support given by Mr. Zufialdi Zakaria and Mr. Johannes Hutabarat, who kindly guided us in the process of this study.

REFERENCES

Budhitrisna T,: *Geologic Map of Tasikmalaya Quadrangle, West Java*, Geological Research and Development Center of Indonesia : Bandung. (1986)

Irianto, Pribadi, A., Suherman, W., Tripambudi, A.S. : *Laporan Penyelidikan Petrokimia Batuan Gunungapi Telaga Bodas, Jawa Barat,* Badan Geologi : Bandung. (2000).

Suhadi, D., Kusdaryanto, Mudjiman, Y., : *Pemetaan Geologi Foto Gunungapi Telaga Bodas, Kabupaten Garut dan Tasikmalaya,* Direktorat Vulkanologi : Bandung. (1999).

Goff, F. and Janik, C.J, : *Geothermal Systems. In Encyclopedia of Volcanoes* (editor: Sirgudsson, H., Houghton, B., McNutt, S. R., Rymer, H., Stix, J.), Academic Press, San Diego. (2000)

Nicholson, K., : *Geothermal Fluids Chemistry and Exploration Techniques*, Springer Verlag, Jerman. (1993)

Zakaria Z : Management of Geological Mapping, 220 pp. Faculty of Geology, University of Padjadjaran: Jatinangor (2013)