Jurnal Geologi dan Sumberdaya Mineral Vol. 23 No. 4 November 2022 hal. 197-203

Geo-Science

Jurnal Geologi dan Sumberdaya Mineral
Journal of Geology and Mineral Resources
Center for Geological Survey, Geological Agency, Ministry of Energy and Mineral Resources
Journal homepage: http://jgsm.geologi.esdm.go.id
ISSN 0853 - 9634, e-ISSN 2549 - 4759

Morphostructure and Hydrogeochemical Analysis of Geothermal Systems in Karaha Bodas and Talaga Bodas Field, West Java

Analisis Morfostruktur dan Hidrogeokimia pada Sistem Panas Bumi di Lapangan Karaha Bodas dan Talaga Bodas, Jawa Barat

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Naskah diterima: 01 November 2021, Revisi terakhir: 30 Agustus 2022, Disetujui: 10 Oktober 2022, Online: 10 Oktober 2022
DOI: http://dx.doi.org/10.33332/jgsm.geologi.v23.4.197-203

Abstract - The Karaha Bodas and Talaga Bodas are two geothermal fields which are located in Tasikmalaya, West Java. The Karaha Bodas and Talaga Bodas fields have geothermal prospects with the discovery of several surface manifestations in the form of hot springs, fumaroles, and acid lakes. The orientation of the structure that developed in the two fields showed a different orientation. However, no research explains the relationship between the geothermal system in the Karaha Bodas field and the Talaga Bodas field, and the potential of Cipacing and Pamoyanan. The survey location is in Garut and Tasikmalaya, West Java. The investigation method used is qualitative (morphostructure analysis) and quantitative (hydrogeochemical analysis) methods. Data processing using DEM (Digital Elevation Model) for morphostructure analysis, and water chemistry from the Karaha Bodas, Talaga Bodas, and Cipacing fields for hydrogeochemical analysis. The analysis shows that the relationship between the Karaha Bodas and Talaga Bodas geothermal systems is typical a geothermal system, with having two different heat sources, the Talaga Bodas field as an upflow zone, and the Karaha Bodas field with Cipacing and Pamoyanan potentials as an outflow zone.

Keywords: Conceptual model, geothermal system, hydrogeochemical, Karaha Bodas, morphostructure, Talaga Bodas.

***Abstrak** - Daerah Karaha Bodas dan Talaga Bodas merupakan lapangan panas bumi yang lokasinya berdekatan di Tasikmalaya, Jawa Barat. Lapangan Karaha Bodas dan Talaga Bodas memiliki prospek panas bumi dengan ditemukannya beberapa manifestasi permukaan berupa mata air panas, fumarol, danau asam. Orientasi struktur yang berkembang di kedua lapangan menunjukkan orientasi yang berbeda. Meskipun begitu, belum ada penelitian yang menjelaskan mengenai hubungan sistem panas bumi lapangan Karaha Bodas dan lapangan Talaga Bodas, dan potensi Cipacing dan Pamoyanan. Lokasi survei berada di Kabupaten Garut dan Kabupaten Tasikmalaya, Jawa Barat. Metode penyelidikan yang dilakukan adalah metode kualitatif (analisis morfostruktur) dan kuantitatif (analisis hidrogeokimia). Pengolahan data dilakukan dengan memakai data citra DEM untuk analisis morfostruktur, dan 3 data kimia air dari lapangan Karaha Bodas, Talaga Bodas, dan potensi Cipacing untuk analisis hidrogeokimia. Hubungan sistem panas bumi Karaha Bodas dan Talaga Bodas berada dalam satu sistem panas bumi, dengan memiliki dua sumber panas yang berbeda, dengan lapangan Talaga Bodas sebagai zona upflow, dan lapangan Karaha Bodas juga potensi Cipacing dan Pamoyanan sebagai zona outflow.*

***Katakunci:** Model konseptual, sistem panas bumi, hidrogeokimia, Karaha Bodas, morfostruktur, Talaga Bodas.*

INTRODUCTION

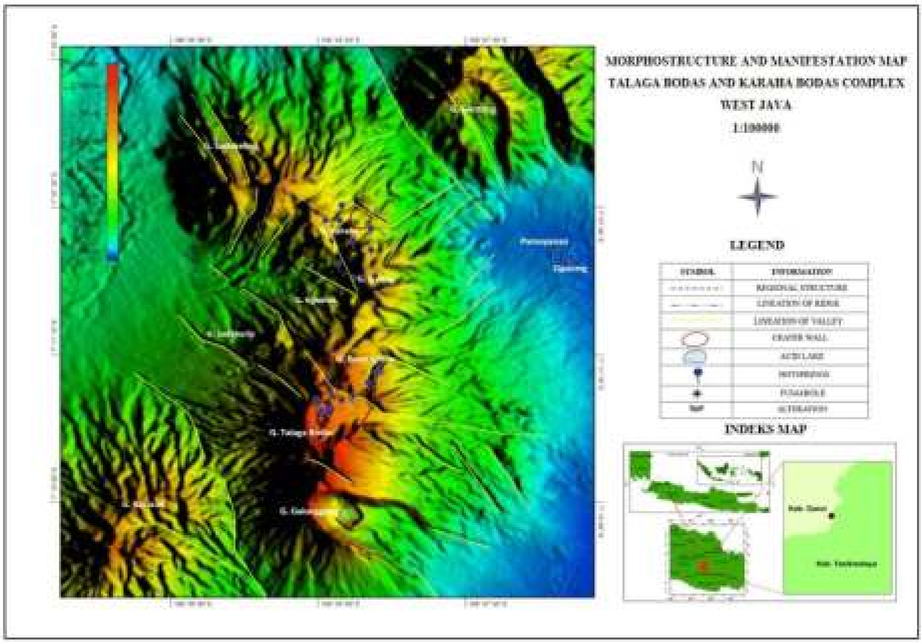
The Karaha Bodas and Talaga Bodas areas are located in the northern area of Mount Galunggung for geothermal prospects with the discovery of manifestations in the form of fumaroles and hot springs (Arisbaya et al., 2018). In addition, there is the potential for hot springs in the Cipacing and Pamoyanan areas which are east of the Karaha Bodas Field (The Directorate of Panas Bumi, 2017). The location of the Karaha Bodas Field or Mount Karaha or known as Gunung Putri is in Kadipaten, Tasikmalaya. Talaga Bodas Field or Mount Talaga is located in Caringin, Garut. While Cipacing is in Pagerageung and Pamoyanan is in Kadipaten.

Based on the structural and morphostratigraphic patterns that developed in the Talaga Bodas and Karaha Bodas fields which are located nearby, it is very likely that the source of the geothermal system in Talaga Bodas Field is different from the Karaha Bodas system. Even the potential areas of Cipacing and Pamoyanan have a relationship related to the influence of the presence of hot springs. This study aims to analyze the description of the relationship between the Karaha Bodas Field, Talaga Bodas Field, and the Cipacing and Pamoyanan Potentials using morphostructure and hydrogeochemical analysis methods.

MORPHOSTRUCTURE ANALYSIS

This study uses a Digital Elevation Model (DEM) image with a scale of 1:100,000 with an azimuth value of 90° irradiation height and uses another angle irradiation height to support morphostructure analysis, and uses a Geological Map of Tasikmalaya (Lembar Tasikmalaya) 1:100,0000 scale by Budhitrisna (1986) which has been modified. The map of the morphology of the Karaha Bodas and Talaga Bodas fields shows several mountains with very diverse heights as seen on the map, namely Mount Sadakeling, Mount Karaha or Mount Putri, Mount Jurang, Mount Ngantuk, Mount Sadahurip, Mount Talaga Bodas, Mount Galunggung, and Mount Karacak (Figure 1).

The straightness orientation of morphostructure of Mount Karaha or Gunung Putri and Mount Sadakeling from lineage data collection with an irradiation height value of 90° indicates the lineament is oriented southwest - northeast. Apart from the stratigraphy that Mount Karaha is composed of rocks produced by Mount Sadakeling (Qtvd), the results of lineage data collection also have similarities between Mount Karaha Bodas and Mount Sadakeling, proving that Mount Karaha Bodas is an isolated hill which may be a breakthrough rock or remnant of a volcanic body from the Mount Sadakeling.



Source: Widiastuti (2021).

Figure 1. Morphostructure and manifestation map of Talaga Bodas and Karaha Bodas Complex, West Java.

The Morphostructure analysis of Mount Jurang and Mount Ngantuk, which are located in the south, shows that from the direction of the 90° irradiation height, it shows the same lineament orientation as Mount Sadakeling and Mount Karaha Bodas. Mount Jurang and Mount Ngantuk are also thought to be the result of volcanic activity from the Mount Sadakeling which is an Old Volcano. The straightness of the structure shown in the rosette diagram of the area around the Karaha Bodas field tends to have a structural orientation that is dominated by a lineament that is oriented southwest-northeast and has a crater wall incision that tends to be north - northeast.

The morphostructure map of Mount Talaga Bodas shows the morphology of remnant large crater, proving that the volcanic activity at Mount Talaga Bodas was very active during the Quaternary age. According to Mulyana (2000 at Haerani et al., 2004), the volcanic activity of Mount Talaga Bodas was a large eruptive activity that forms a large caldera with a diameter of up to 4.5 km, this large caldera forming The mount old Talaga Bodas which is identified in the morphostructure map as an ancient caldera, crater or ancient caldera. It looks like slashed to the North and Northeast. The orientation of the straightness of Mount Talaga Bodas from the DEM image data with the direction of lighting with an irradiation height value of 90° shows the data for the straightness of the ridges and valleys, which are oriented northwest - southeast. In the morphostructure map view of Mount Talaga Bodas, it can be seen that there are small craters in the ancient caldera or large craters at 90° irradiation altitude, the morphological shape of the crater named as Saat, Lebak Jero, and Talaga Bodas.

The morphostructure analysis having a direction of 90° irradiation height represents the same lineaments as regional structures on the Geological Map of the Lake Sheet. One of them is the lineament to the east of Mount Karaha Bodas or Gunung Putri which is a regional structure in Tasikmalaya Sheet (Lembar Tasikmalaya), and similar feature is also found in the area of Mount Gentong. The similarity of the lineament data from the height of the illumination with the regional structure in the lake sheet indicates the lineament is comparable to the regional structure or lineament in the Karaha Bodas and Talaga

HYDROGEOCHEMICAL ANALYSIS

This study uses water chemistry data from the Talaga Bodas field of Nurohman et al. (2016) water chemistry data from the Karaha Bodas field of Powell et al. (2001), and water chemistry data from Cipacing Potential of the Directorate of Panas Bumi et al. (2017) which is contained in Table 1. Hydrogeochemical data processing using calculations in spreadsheets for water geochemistry made by Tom Powell & William (2010).

Talaga Bodas field water chemistry data is 10 samples, 3 samples were taken around the lake and 7 samples were taken in the northern part of Mount Talaga Bodas. Water chemistry data samples from the Karaha Bodas Field are dominated by several samples in the northern part, namely around the crater area and the remaining samples taken in the southern part, which is close to the volcanic dome area or vein area and deep borehole samples. Meanwhile, the Cipacing Potential Sample which is located south of the Karaha Bodas Field is taken from the data of the manifestation of hot springs, 5 samples from the Cipacing and Pamoyanan areas.

Type and Origin of Water

The type of water in the Talaga Bodas field is sulfate water type (volcanic waters) noted as 5 samples and sulfate chloride water type noted as 5 water data samples (Figure 2). The origin of the water in Talaga Bodas Field is based on the type of water that comes from magma on the earth's surface which is relatively shallow and flows laterally. The heat and chemical activity of this field come from volcanic or volcanism sources and this type of water is typically derived from above the upflow zone.

Table 1. Hydrogeochemical analysis of investigation areas

Talaga Bodas Field	Karaha Bodas Field	Cipacing and Pamoyanan
Straightness Orientation		
Northwest - Southeast	Southwest - Northeast	-
Morphology		
• Sadakeling Mount • Karaha or Putri Mount • Jurang Mount • Ngantuk Mount	• Beuti Ganar Mount • Sadahurip Mount • Talaga Bodas Mount	-
Water Type		
• Volcanic waters or Sulfate waters • Sulfate chloride waters	• Volcanic waters or Sulfate waters • Sulfate chloride waters • Mature waters or Clhoride waters	• Peripheral waters
Geotermometer		
• Immature Waters (10 Sample)	• Partial Equilibration (8 Sample) • Immature Waters (2 Sample)	• Immature Waters (5 Sample)
278 °C – 360 °C	249 °C – 352 °C	317 °C – 354 °C
Geoindicator		
Talaga Group	Karaha Group	
Zonation		
Upflow Zone	Outflow Zone	

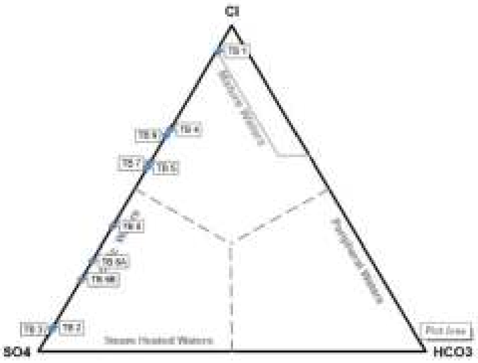


Figure 2. Ternary diagram water type of Talaga Bodas Field.

The type of water in the Karaha Bodas field is sulphate water (volcanic waters) indicated by 2 samples, Chloride sulfate water type is noted as1 sample, and mature waters is noted as 7 samples (Figure 3). The concentration of Cl or chemical chloride in the Karaha Bodas field water is very high. The origin of this field water comes from a mixing of sulfate and chloride water in the outflow zone. Mature waters come from reservoirs that flow to the surface.

Water types of Cipacing and Pamoyanan show the type of dilute-chloride or peripheral waters indicated by all samples (Figure 4). Chloride water flows in the form of hot springs, which flow laterally in the outflow zone. Water type of dilute-chloride or peripheral waters is derived from the dilution of liquid chloride with laterally flowing groundwater or bicarbonate water.

Geothermometer

The Talaga Bodas field geothermometer belongs to the immature waters noted as 10 samples (Figure 5).

The Karaha Bodas field geothermometer was included in partial equilibration noted as 8 samples, and immature waters noted as 2 samples (Figure 6).

The Cipacing and Pamoyanan geothermometers are included in the immature waters noted as 5 samples (Figure 7).

Geoindicators

The Cl/B ratio of the Talaga Bodas, Karaha Bodas, and Cipacing potential fields in Figure 6 can be used to indicate the amount of fluid source in a geothermal system or reservoir. Chloride and boron are conservative elements in geothermal systems that are good for using geoindicators of geothermal systems. Figure 6 shows the ratio of chloride and boron. There is a grouping of sample data which is divided into two different geothermal reservoirs in the study area, namely group 1 which is on the left of the graph composed of Talaga Bodas water chemistry (blue box), Cipacing and Pamoyanan (purple circles), and part of Karaha Bodas (yellow triangle), and group 2 to the right of the graph composed by water chemistry from the Karaha Bodas Field in Figure 6 from which the Karaha Bodas fluid originates. The potential of Cipacing and Pamoyanan hot springs is included in group 1 which has the same fluid origin as the Talaga Bodas reservoir group.

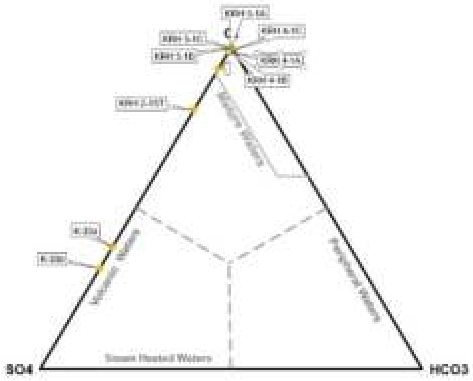


Figure 3. Ternary diagram water type of Karaha Bodas Field.

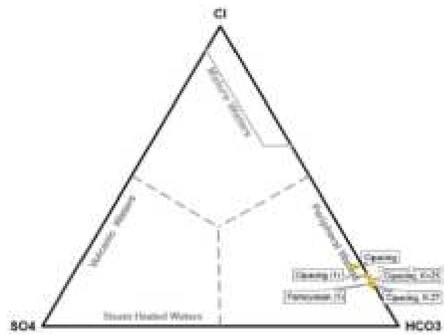


Figure 4. Ternary diagram water type of Cipacing and Pamoyanan Potential.

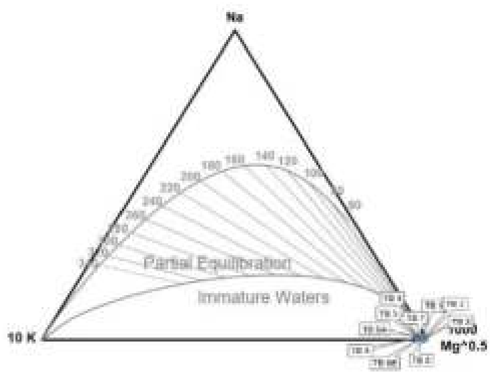


Figure 5. NKM diagram of Talaga Bodas Field.

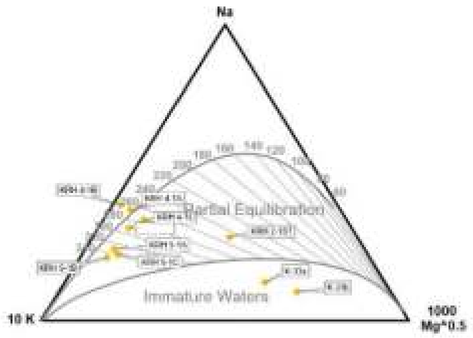


Figure 6. NKM diagram of Karaha Bodas Field.

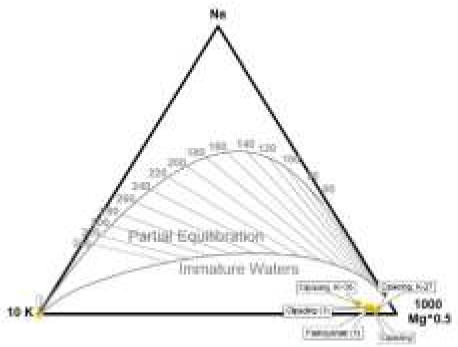


Figure 7. NKM diagram of Cipacing and Pamoyanan Potential.

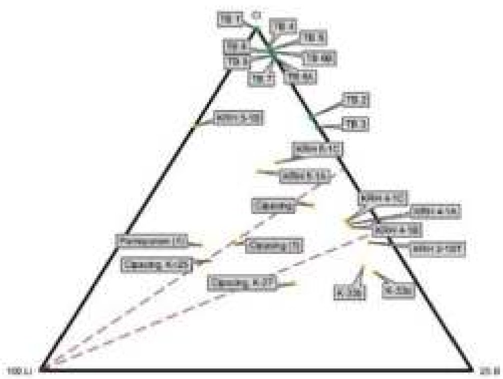


Figure 8. Cl-Li-B diagram of Talaga Bodas Field, Karaha Bodas Field, dan Cipacing Potential.

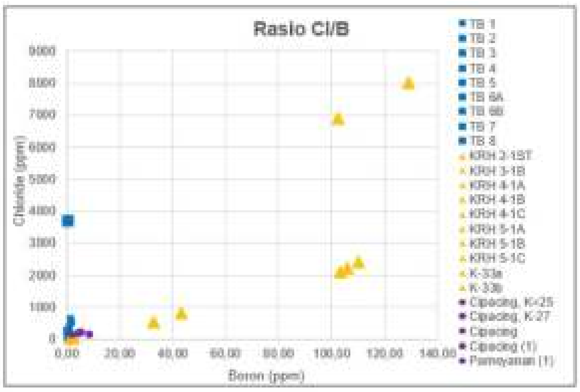


Figure 9. The Cl/B ratio of Talaga Bodas, Karaha Bodas Field, dan Cipacing potential.

DISCUSSION

The straightness of structure located in the area of Mount Karaha Bodas, Mount Talaga Bodas, and its surroundings has the same trendline direction as the previous researcher-Permana et al., (2016). The direction of the structure's straightness of both ridges, and valleys, has an orientation dominated by straightness oriented southwest - southeast. In addition to the straightness of the structure, the direction of the incision of the crater wall from Mount Talaga Bodas tends to the northeast. Although the Mount Talaga Bodas is located next to each other and is still in the same complex as Mount Talaga Bodas and Karaha Bodas and Mount Galunggung, the incisions of the crater wall of Mount Galunggung have a different direction from the incision wall of Talaga Bodas Crater, i.e. northwest - southeast. The lineament orientation of the existing structure in the Talaga Bodas and Karaha Bodas Complexes is parallel to the orientation of the regional structure in the form of three main faults which is almost parallel to the northwest – southeast orientation (The Directorate of Panas Bumi, 2017).

The Talaga Bodas and Karaha Bodas field complexes are two geothermal fields that are located quite close together, which indicates that the source of the geothermal system of these two fields is in the same system. Geothermal manifestations that appear in the Talaga Bodas field are manifestations in the form of solfatara known as Saat Crater, acid lake or crater, and hot springs, while the Karaha Bodas field manifestations are fumaroles, hot soil, mud pools, and hot springs. These two geothermal systems have the same manifestation, namely hot springs as a reflection of the geothermal system fluid. According to Prabata & Berian (2017) even all the manifestations in the Talaga Bodas and Karaha Bodas complexes are controlled by subsurface structures indicating the presence of faults or structures around the manifestation area.

The Talaga Bodas and Karaha Bodas field complexes have two sources of geothermal system groups, namely the Talaga Bodas geothermal system field group and the Karaha Bodas geothermal system field including the Cipacing and Pamoyanan potentials. The fluid samples from the Talaga Bodas field are from an older hydrothermal system which is younger than the old hydrothermal system. The fluid from the Talaga Bodas and Karaha Bodas field areas have two different heat sources and two reservoirs although in one geothermal system. The heat source identified from the geophysical gravity method is a granodiorite intrusion, and the clay cap layer of the geothermal system of the Karaha Bodas and Talaga Bodas complexes are a volcanic breccia and tuff lithology(Nemcok et al., 2007)

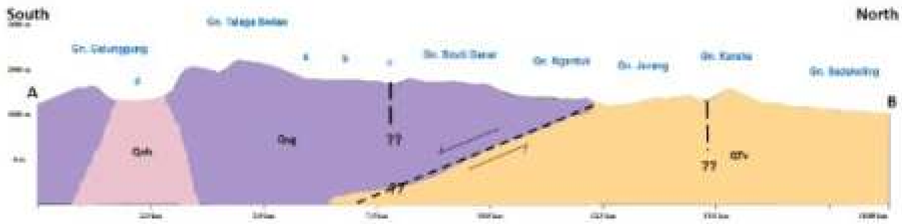
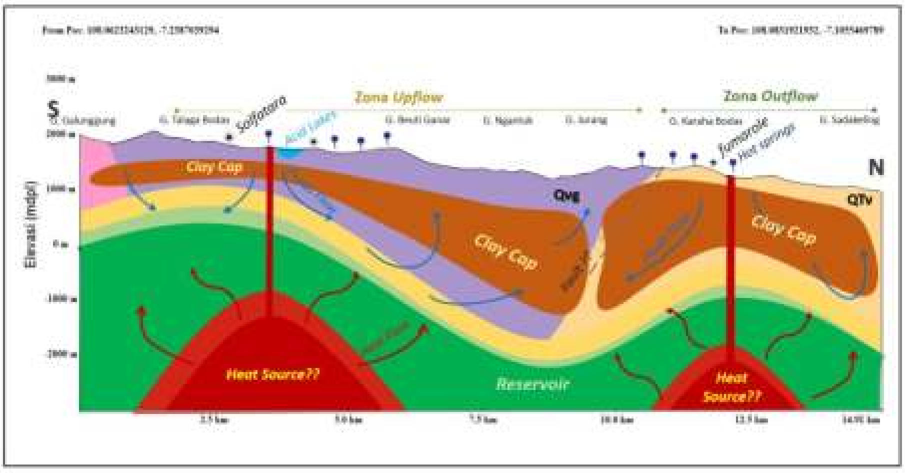


Figure 10 Talaga Bodas Field Geological Section Sketch - Karaha Bodas (Note: a = Saat Crater; b = Lebak Jero Crater; c = Talaga Bodas Crater; dan d = Galunggung Crater)



Source:Modification by Arisbaya et al. (2018) and Yosephin et al. (2019).

Figure 11. Conceptual Model of Geothermal System in Karaha Bodas and Talaga Bodas Fields

However, the type and origin of the water chemistry fluid in the Talaga Bodas field, it is a fluid located in the upflow zone, while the fluid in the Karaha Bodas field is a type of fluid that is often found in the outflow zone. The structure that is around the manifestation has an orientation of almost parallel to the orientation of the regional structure in the Talaga Bodas and Karaha Bodas complexes which is very influential on the appearance of manifestations in the geothermal system of the outflow zone, namely the Karaha Bodas field. The Karaha Bodas and Talaga Bodas field complexes are influenced by the regional structure located in the south of Mount Karaha or Gunung Putri, or more precisely, between Mount Ngantuk and Mount Jurang which is also contained in the conceptual model of Yosephin et al. (2019) identified as one control the discharge of the manifestation making a part of the outflow zone.

The emergence of hot springs in the Cipacing and Pamoyanan areas, which are south of the Karaha Bodas field and have the same fluid origin as Karaha Bodas, has the possibility that Cipacing and Cipanas are also in the same geothermal system as the Talaga Bodas and Karaha Bodas field complexes. The Cipacing and Pamoyanan hot springs flow laterally from the Karaha Bodas field. The discovery of surface manifestations in the form of hot springs in the Cipacing and Pamoyanan areas is influenced by the regional structure and the direction of the flow of water flowing from high to low elevation.

CONCLUSIONS

Talaga Bodas field water types are classified as volcanic waters and sulfate chloride water types. Karaha Bodas field water types are included in the Karaha Bodas field water types, including volcanic waters, sulfate chloride water types, and mature waters types. Meanwhile, Cipacing and Pamoyanan potential water types are included in peripheral waters.

The relationship between the Karaha Bodas and Talaga Bodas fields according to hydrogeochemical data, explains that these two fields are included in one geothermal system with the Talaga Bodas field as an upflow zone and the Karaha Bodas field as an outflow zone with different fluid origins and heat sources or having two heat sources or heat sources.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to Dyah Nindita Sahdarani S.Si., M.Energy as Thesis Supervisor, Sukiato Khurniawan M.Sc and Felix M.H Sihombing S.T., MMinRes as Lecturer for their patient guidance, enthusiastic encouragement, and constructive criticism of this study effort.

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