http://journal.uir.ac.id/index.php/JGEET

E-ISSN : 2541-5794
P-ISSN :2503-216X

Journal of Geoscience,
Engineering, Environment, and Technology
Vol 5 No 4 2020

RESEARCH ARTICLE

Origin of Geothermal Water Around Slamet Volcano, Paguyangan, Cipari, Central Java, Indonesia

Sachrul Iswahyudi[1*], Indra Permanajati[1], Rachmad Setijadi[1], Januar Aziz Zaenurrohman[1], Muhamad Afirudin Pamungkas[1]

[1]*Department of Geological Engineering, Jenderal Soedirman University, Purwokerto, Indonesia.*

* Corresponding author : sachrul.iswahyudi@unsoed.ac.id
Tel.:+62-81392331997
Received: Nov 25, 2019; Accepted: Nov 18, 2020.
DOI 10.25299/jgeet.2020.5.4.4112

Abstract

The existences of several hot springs between Slamet volcano, Paguyangan, and Cipari Districts raised questions regarding their origin. Several studies have been conducted related to the hydrothermal system at the location. Subsequent studies are needed to understand the hydrothermal system at the research site for the sustainability and conservation of geothermal natural resources. This research has reviewed several previous studies plus the latest information on the origin of hot spring water with the help of deuterium (^{2}H) and ^{18}O isotopes. This study used geochemical analysis of hot springs (geothermal) and local meteoric water to obtain information on isotope values. This was used for the interpretation of the origin of geothermal water. This study also used regional geological analysis methods for the interpretation of the mechanism for the emergence of these hot springs. The results of the analysis informed that the origin of hot water was local meteoric water. The geological structure was weak enough to allow water from the geothermal reservoir to reach the surface and meteoric water into the reservoir.

Keywords: Slamet volcano, Paguyangan, Cipari, Geothermal water

1. Introduction

1.1 Background

There are several hot springs in the area between Slamet Vulcano, Paguyangan and Cipari Central Java. The distribution of these hot springs raises the question: what is the origin of the geothermal springs at this location? It is important to understand more about the possibility of the existence of several geothermal systems that control the distribution of some of these hot springs.

Several studies on hot springs at the research sites have been carried out previously with several different research methods (Juhri and Harijoko, 2016; Sumaryadi, 2014; Permana dan Mulyadi, 2018; Kastowo, 1975). Further studies need to be carried out continuously to get more complete information about the developing hydrothermal system. It is expected to be able to provide more useful information for the management and development of geothermal and renewable energy.

1.2. Literature Reviews

Regional Geology : The geological conditions of the study area can be seen from several aspects such as the stratigraphic arrangement and control of geological structures. From old to young, the stratigraphy of the study area is composed of 5 different rock formations. The first formation of the Miocene age is the Pemali Formation which is composed of marl with the insertion of tufan sandstones and limestones. The second formation formed is the Rambatan Formation with the dominance of sandstones in it. Above the Rambatan Formation there is the Halang Formation which is composed of tuffaceous sandstones, conglomerates, marl and claystone (Kastowo, 1975). On top of the three formations of tertiary ages, there are two rock formations which are the result of the eruption of Slamet Volcano, namely Slamet Compacted Volcanic Rock and Lava of Slamet Volcano (Djuri et al, 1996). The existence of a geological structure in the form of a fault that extends from the northwest to the southeast represents control of the geological structure in the study area.The fault structure that controls Slamet Volcano geothermal System consists of one main normal fault and three strike-slip faults. The main normal fault of Slamet is very influential in the appearance of the volcanic cone of the Slamet Muda Volcano. The presence of a normal fault is very important as a controller of rock permeability in the reservoir (Direktorat Panas Bumi, 2017).

Geothermal Water : Water in geothermal systems come from several sources, including surface (meteoric) water, formation water (connate waters), metamorphic waters and juvenile waters (Nicholson, 1993). Ellis and Mahon (1967) also explained that geothermal fluids can be produced from reactions between meteoric groundwater and host rock. Experiments on the origin of water in geothermal water conducted by Craig (1963) stated that geothermal water shows similarities to local meteoric water. This is based on the meteoric waterline model that was also proposed by Craig in 1961.Several studies on the origin of geothermal water have been carried out. Lu et al (2018) used the ^{18}O and ^{2}H methods to determine the origin of geothermal water. The study concluded that geothermal water at the study site came from local meteoric water. Chatterjee et al (2017) also uses isotopes ^{18}O and ^{2}H to determine the origin of geothermal water. This study concludes the origin of geothermal water comes not from meteorics water but formation water that is stored long in rock layers.

1.3. Location

Research location is located in the area around Slamet Volcano, Paguyangan, Bantarkawung, and Cipari, Central Java. The location is limited by the geographical coordinates of

108.70° - 109.26° East Longitude and 7.01° - 7.52° South Latitude, which can be reached from the nearest cities (Purwokerto, Cilacap) using two-wheeled vehicles or four-wheeled vehicles (Fig 1).

Fig 1. Research location

2. Methods

This research was conducted based on geochemical analysis of geothermal isotopes and geological analysis. The first step is to observe geothermal manifestations and then take geothermal and meteoric water samples. Then the obtained water samples were analyzed in the laboratory to obtain information on deuterium (^{2}H) and ^{18}O isotopes of geothermal and meteoric water. The laboratory analysis was carried out for the interpretation of the origin of geothermal water (meteoric, magmatic, or others). Geochemical analysis of geothermal water was carried out on samples from springs and hot spring or geothermal pools from Paguyangan, Buaran, Bantarkawung, Saketi, and Cipari Districts. Geothermal isotope data were obtained from laboratory analysisand from previous research, namely: Pancuran-3, Pancuran-7, Guci, Cahaya, Sigedong (Sumaryadi, 2014). The results of the analysis of deutrium and ^{18}O isotopes were then analyzed for the interpretation of the origin of the geothermal water and hydro geochemical processes that accompanied its appearance on the surface. Geological analysis was carried out to estimate the locations where meteoric water came into the reservoir and where the geothermal water came out to reach the surface.

3. Result and Discussion

3.1. Distribution of Geothermal Manifestations

Manifestations of Geothermal Systems area between Slamet Volcano, Paguyangan, Bantarkawung, and Cipari is spread over a range of more than 50 kilometers from the SlametVolcano crater. In the east, there is a collection of hot spring manifestations around Slamet Volcano, namely the hot springs of Pancuran-3, Pancuran-7, Guci, Cahaya, Sigedong, and Saketi. In the central part of the research location there are several hot springs, namely Paguyangan, Buaran and Bantarkawung hot springs. Whereas in the south-west there are Cipari hot springs (Fig 2).

3.2. Chemistry Data of Hot and Cold Water

Laboratory analysis of water from hot and cold spring samples has been carried out by several previous studies. Observations and sampling that did not have laboratory analysis data were carried out on the manifestations of hot water and cold water at the study site. The water samples were then analyzed to determine the isotopic content of ^{2}H and ^{18}O (Table 1).

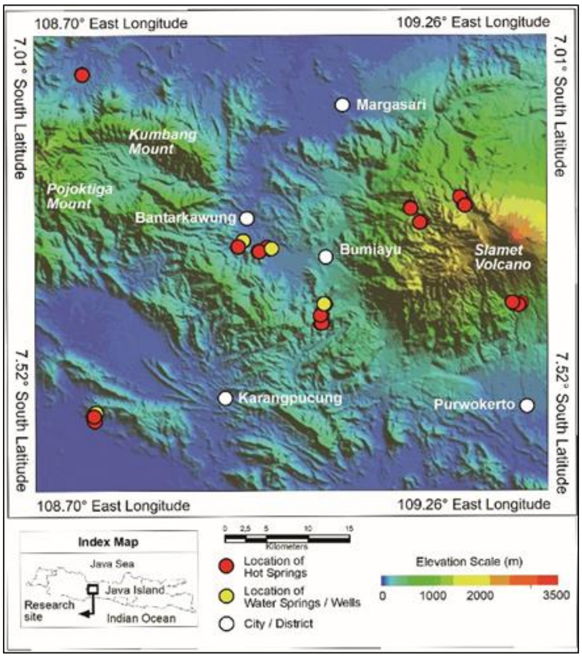

Fig 2. Distribution of hot springs at the study site

3.3. Origin of Geothermal Water

The interpretation of the origin of geothermal water in the study location was based on the calculation and ratio of deutrium and ^{18}O isotope components. Plotting of deutrium and ^{18}O water isotope data laboratory analysis of geothermal and cold water at the study site reveals several trends, namely:

a. Plotting of deutrium and ^{18}O isotopes data of local cold water samples shows consistent with global meteoric water lines. Both the local and global meteoric water lines arealmost coincidental. Variations in local and global deuterium and ^{18}O isotopes values are controlled by temperature, geographic location, rainfall, distance relative to the sea, and elevation.

Table 1. Deutrium And ^{18}O Water Isotopes Analysis Result

No.	Location	Code	del ^{8}O	del D
	Hot springs			
1	Paguyangan	LP1 *	-5,2	-27,5
2	Buaran	LP3 *	-5,8	-31,0
3	Bantarkawung(	LP5 *	-5,4	-30,9
4	Cipari	LP7 *	-3,7	-22,5
5	Pancuran 3	P3 **	-6,4	-39,1
6	Pancuran 7	P7 ****	-7,9	-51,4
7	Guci	GU **	-6,9	-44,7
8	Cahaya	CA **	-6,1	-41,1
9	Sigedong	SI **	-6,6	-41,0
10	Saketi	SA	-	-
11	Cipari	CP2 ***	-3,2	-21,8
	Springs/Wells			
1	Kalipagu	KP **	-7,5	-44,3
2	Sigedong	SG **	-7,8	-48,0
3	Cipari	LP8 *	-5,8	-33,7
4	Bantarkawung	LP6 *	-5,8	-35,7
5	Paguyangan	LP2 *	-5,3	-30,6
6	Buaran	LP4 *	-6,5	-38,9

Notes:
* : Laboratory analyses
** : Sumaryadi (2014)
*** : Permana dan Mulyadi (2018)
**** : Iswahyudi, et al (2015)

b. Plotting of deutrium and ^{18}O isotopes hot water samples data generally similiar to global and local meteoric water lines even though there are varied deviations in each plotting point in all locations of hot water manifestations.

Deviation in the values of deutrium and ^{18}O values (shift) are interpreted to occurs because of the enrichment of these isotopes, and related processes of interaction of geothermal water and rocks (enrichment of ^{18}O) and evaporation on the surface (enrichment of deutrium).

c. Plotting data on samples of hot and cold water in the Bantarkawung area almost coincided at the same point. It is interpreted that, the origin of Bantarkawung geothermal water came from a relatively very close location. The similarity of plotting can also be caused by the close circulation of meteoric and geothermal fluids that have reached a relatively perfect balance.
d. In general, the geothermal water of the study site came from the local meteoric water. This is indicated by the position of plotting data of deutrium and ^{18}O isotopes which tend to correspond to local and global meteoric water lines even though there are enrichments of both of these water isotopes.

The analysis of the origin of the geothermal water described above is shown in Fig 3 below.

3.4. Hot springs Existence Mechanism Interpretation

The emergence of hot springs is closely related to existing geological conditions. Based on the geological map data around the study site, the lithology consists of tertiary-aged sedimentary rocks and quarter-age volcanic rocks (Fig 4).

Tertiary-aged sedimentary rocks are folded, fractured and faulted in several places. Those places are weak zones that allow geothermal water from the reservoir to reach the surface or close to the surface. It is confirmed that almost all hot springs that appear on tertiary sedimentary rocks are located in the fracture or fault zones. These fractures and faults also allow meteoric water to enter into geothermal and heated reservoirs (Fig 4).

Some hot springs appear in quarter-age volcanic rocks that do not have fracture or fracture indications. It was interpreted that the appearance of several hot springs was also caused by geological structures in the form of fractures or faults covered by volcanic lithology from quater-age volcanic eruptions (Fig 4).

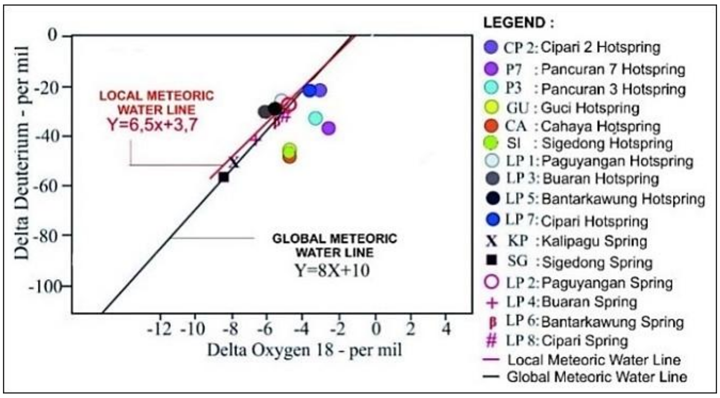

Fig 3. Interpretation of the origin of geothermal water at the study site.

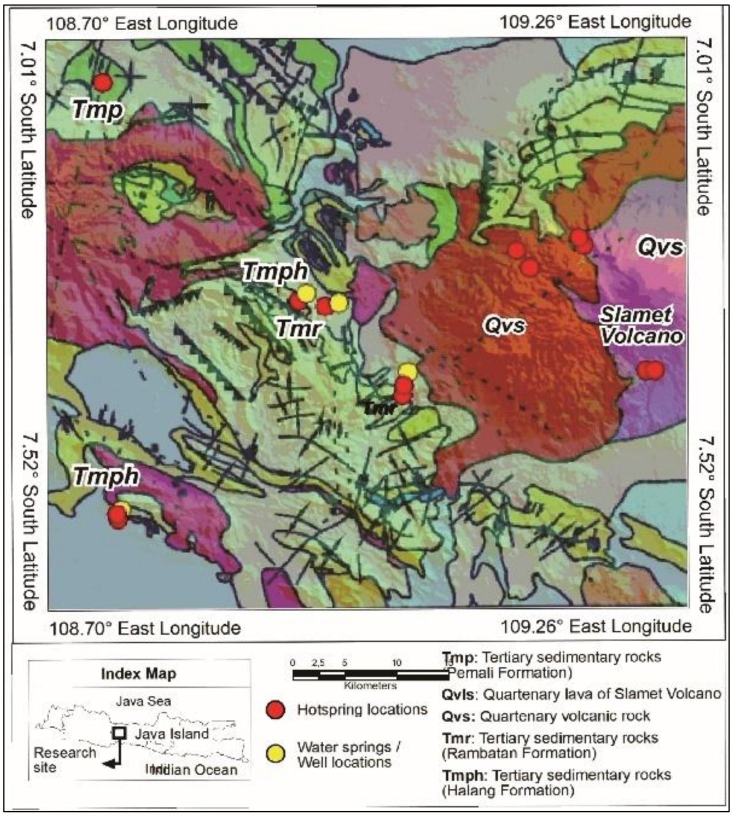

Fig 4. Geological map that shows the geological structure density (fracture or fracture) of the research location (Kastowo, 1975).

4. Conclusion

Geothermal water from samples of Paguyangan, Buaran, Bantarkawung, Cipari, Pancuran 3, Pancuran 7, Guci, Cahaya, Sigedong, Saketi, Cipari comes from local meteoric water. In general, enrichment values of ^{18}O and ^{2}H occur in geothermal water from values of ^{18}O and ^{2}H of local meteoric water. This is interpreted because of interaction of geothermal water and rock and surface evaporation. The enrichment of the value of ^{18}O geothermal water from the Sigedong, Cahaya, Pancuran 3 and Pancuran 7 regions indicates more intensive processes of geothermal water rock interactions than those that occur in other regions. Differences of the local meteoric water lines of the study area and global meteoric water line occur because of differences in geographical latitude and distance from the sea where the water samples are taken. Hot springs at the study site coincide with the locations of geological structures in the form of faults, fractures and folds. It is interpreted that, these locations are weak zones that allow geothermal water from the reservoir to reach the surface and meteoric water can enter the reservoir.

Acknowledgements

Our gratitude goes to the Research and Community Service Institute (LPPM) - Jenderal Soedirman University, Geological Engineering teaching staff and those who helped provide support and assistance so that this paper was published.

References

Natasia, N., Syafri, I., Alfadli, M.K., Arfiansyah, K., 2016. Stratigraphy Seismic and sedimentation Development of Middle Baong Sand , Aru Field , North Sumatera Basin. J. Geoscience, Engineering, Environment, and Technology 1, 51–58.

Chatterjee, S., Ansari, M. A., Deodhar, A. S., Sinha, U. K., & Dash, A. 2017. A Multi-Isotope Approach (O, H, C, S, B and Sr) to Understand The Source of Water and Solutes in Some The Thermal Springs from West Coast Geothermal Area, India. Arabian Journal of Geosciences, 10(11). https://doi.org/10.1007/s12517-017-3022-0.

Craig, H. 1963. The Isotopic Geochemistry ofWater and Carbon in Geothermal Areas, In: Tongiorgi, E. (ed.), Nuclear Geology in Geothermal Areas, Spoleto, 1963, Consiglio Nazional Delle Richerche, Laboratorio de Geologia Nucleare, 17-53.

Craig, H., 1961. Isotopic Variations in Meteoric Waters. Science, 133(3465), 1702–1703. doi:10.1126/science.133.3465.1702.

Direktorat Panas Bumi EBTKE., 2017. Potensi Panas Bumi Indonesia (1 ed.) (Vol. 1). Kementerian Energi dan Sumber Daya Mineral, Republik Indonesia, Jakarta http://ebtke.esdm.go.id/post/2017/09/25/1751/buku.potensi.panas.bumi.2017.

Djuri, M., Samodra, H., Amin, T.C., Gafoer, S. 1996. Peta Geologi Lembar PurwokertoTegal, Jawa. Pusat Penelitian dan Pengembangan Geologi.

Ellis, A.J and Mahon, W.A.J. 1967. Natural Hydrothermal Systems and Experimental Hot-Water/Rock Interactions (Part II). Geochim. Cosmochim. Acta, 31, 519-538.

Iswahyudi, S., Widagdo, A., Siswandi, Candra, A., Setijadi, R., Purwasatriya, E.B. 2015. Analisis Isotop ^{2}H dan ^{18}O Air Panas Pancuran-7 Baturaden Untuk Mengetahui Asal Air Panasbumi Gunungapi Slamet. Proceeding Seminar Nasional Ke-8. 15-16 October 2015. Universitas Gadjah Mada.

Juhri S., Harijoko, A. 2016. Karakteristik Geokimia Sekitar Gunung Slamet. Proceeding Seminar Nasional Kebumian Ke-9. Peran Penelitian Ilmu Kebumian Dalam Pemberdayaan Masyarakat. 6 - 7 October 2016. Universitas Gajah Mada.

Kastowo 1975. Peta Geologi, Lembar Majenang, Jawa, Skala 1:100.000, Direktorat Geologi, Departemen Pertambangan Republik Indonesia.

Lu, L., Pang, Z., Kong, Y., Guo, Q., Wang, Y. Xu, C., Gu, W., Zhou, L., Yu, D. (2018). Geochemical and Isotopic Evidence on The Recharge and Circulation of Geothermal Water in The Tangshan Geothermal System Near Nanjing, China: Implications for Sustainable Development. Hydrogeology Journal, 26(5), 1705–1719.

Nicholson, K. 1993. Geothermal Fluids, Chemistry and Exploration Techniques. Springer Verlag Inc.

Permana, L.A. and Mulyadi, E. 2018. Studi Geokimia Panas Bumi Jawa Tengah Bagian Selatan, ProvinsiJawa Tengah, Pusat Sumber Daya Mineral Batubara dan Panas Bumi. http://psdg.bgl.esdm.go.id/kolokium/2015/pabum/4.pdf.

Surmayadi M., 2014, Geokimia panas bumi gunung slamet jawa tengah, Proceeding Seminar Nasional, Bandung 24 Mei 2014,