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Geothermal Development Potential of Papandayan Volcano, Garut City, West Java Province Through Geochemical Analysis Study & Field Activity

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ABSTRACT

The utilization of geothermal resources in order to fulfill national electrical energy and geothermal resources inventory require some supporting instruments, either from a practitioner, academic and also government officials. Beside that, increasing of personnel competency primarily associated with geothermal potential inventory is a very important needs. Center of Geological Education and Training (Pusdiklat) as one unit executing training of the Ministry of Energy and Mineral Resources served to identify techniques of geological data in geothermal exploration, analyzing geological data of geothermal, identify techniques of geochemical data retrieval and also knowing techniques of geophysical data retrieval.

Research area is located surrounding Papandayan Volcano, Garut City, West Java Province. Papandayan Volcano which has a summit elevation about 2.665 meters above sea level is believed to have potential geothermal resource. The Methods used in the implementation of this activity through three methods include: method studios, by reviewing literature data based on regional circumstances and previous researchers. The second one is field methods which is reviewing the morphology of the area and measuring pH of geothermal potential surrounding Papandayan Volcano, and the last one is laboratory methods, including reviewing and assessing the pH content of mineral element content in the region.

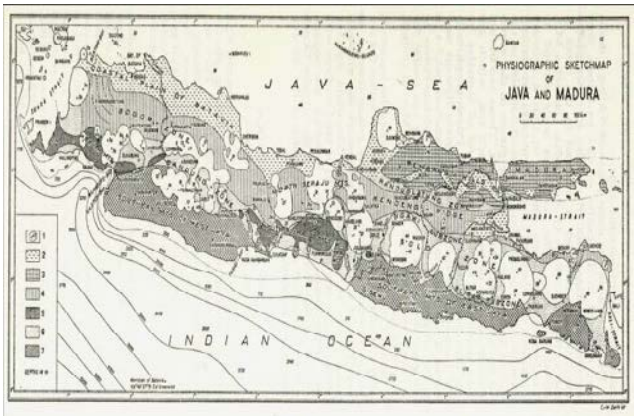
Geological area of the Papandayan Volcano can be divided into three aspects such as : the morphology of this region is dominated by a very steep to steep slope with high mountains landform. The geological structure of the Papandayan Volcano is controlled by normal fault structures that are found in the vicinity of Mount of Nangklak, Crater of Tegal Alun-Alun, Crater of Mas, Mount of Walirang, as well as in the northwestern and southeastern slopes of the Papandayan Volcano with direction of Northeast-Southwest and Northwest and Southeast. The lithology of the area is dominated by the volcano breccia and tuff.

The field work was conducted through the interpretation of geochemical data as well as making a direct measurement on one of the manifestations of geothermal springs in the area around Papandayan Volcano which has temperature of 48.3^0C and the air temperature is about 20.5^0C. While the pH of hot water is about 2.2. Based on laboratory analysis of the element chemical content known to be dominated by very high chlorite levels, resulting in very acidic pH springs. Based on the research potential of the geothermal area of the Papandayan Volcano, it can be concluded that the area of the Papandayan Volcano has a high geothermal potential and can be developed for further research.

I. INTRODUCTION

In physiographic, West Java included in the northern plain area in Jakarta, Bogor Zone, Bandung zone in the central part and the South Mountains in the south part. Lithology of is influenced by the results of the Late Cretaceous - Miocene-Pliocene subduction and magmatism activities until the age of Recent.

In general, the northern part of West Java dominated by Miocene-Pliocene sediments. In the central part of West Java is dominated by Miocene-Pliocene volcanic rocks. Meanwhile, in the southern part of West Java is dominated by products of volcanic rocks associated with sedimentary rock series Eocene-Oligocene. Lithological variations and complex geological processes that occur provide potential geological resources, one of the potential one is geothermal energy.



Picture 1. Regional Phisiography of Java and Madura (Van Bemmelen, 1949)

Geothermal Energy & Geothermal System

Geothermal resources consist of thermal energy from the Earth's interior stored in both rock and trapped steam or liquid water. Geothermal has its own systems which are the temperatures and depths of the reservoirs vary accordingly. Hydrothermal system (many high temperature >180°C) are associated with recent volcanic activity and found near plate tectonic boundaries (subduction, rifting, spreading or transform faulting) or at crustal and mantle hot spot anomalies. Intermediate system (the temperature between 100°C to 180°C) and low temperature system (the temperature is <100°C) are also found in continental settings, where the aquifers are charged by water heated through circulation along deeply penetrating fault zones.

Geothermal resources can be classified as convective (hydrothermal) systems, conductive systems and deep aquifers. Hydrothermal systems include liquid and vapor

dominated types. Conductive systems include hot rock and magma over a wide range of temperatures (Mock et al., 1997). While deep aquifers contain circulating fluids in porous media or fracture zones at depths typically greater than 3 km, but lack a localized magmatic heat source.

Geothermal of Mt. Papandayan Volcanic Complex & Surrounded Area

Geographically, Mt. Papandayan volcanic complex has a high of 1.100 – 2.665 m above sea level. It is located at 107°44'00" E and 7°19'00" S between Bandung and Garut Districts, West Java Province. Volcanologically, Mt. Papandayan is an active volcano, having its last eruption in 2002. It produced phreatic products and volcanic debris.

Mt. Papandayan Volcanic Complex is classified into the Quarter volcanism systems, which are associated with history of Quarternary volcanic deposits around eruption center. Mount Papandayan is a stratovolcano located in Garut and Bandung Regency, West Java Province. This mountain is situated about 30 km to the south of Bandung City.

Picture 2. Topographic Map of Research Area

An explosive eruption has occurred in November 2002. This caused the formation of Kawah Baru. The characterization of eruption until 2002 tend to be more explosive. The displacement center of eruption from South to the North is controlled by structure. In Mt. Papandayan there are five large craters which comprise active thermal manifestation of fumaroles and springs. The active manifestation of fumaroles and hot springs are distributed around craters within Mt.Papandayan. The temperature of fumarole discharges ranging from 90°C to 260°C with the gas content of H_2O, CO_2, and H_2S are dominant.

II. RESEARCH METHOD

This research activities can be grouped in several stages, among others:

Studio Method: done by literature study of Papandayan geothermal volcano and the surrounding area through geothermal previous inventory reports, geothermal regulation, articles, and Landsat imagery.

Field Method: done through investigations and measurements directly into the field purposed to take the primary data by using the field tools include: inventory of altered rock types, manifestations of geothermal energy, the data collection temperature, pH, and water samples in several research areas.

Laboratory Methods: is a primary data processing activities further conducted through chemical analysis of water and gas sample analysis.

III. RESULT & DISCUSSION

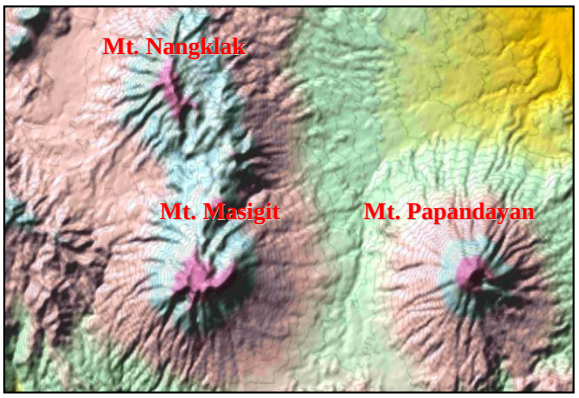
3.1 Geology Mt. Papandayan Volcano Complex

Morphology

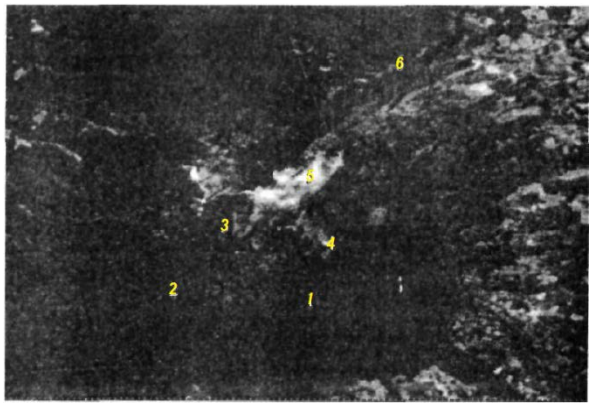
- Morfologi Tapalkuda : merupakan depresi berarah timurlaut mulai dari Kawah Mas hingga Kampung Cibalong dan Cibodas sebagai hasil dari peristiwa pembentukkan endapan guguran puing (debris avalanche deposit).

The morphology division of the complex Papandayan volcano (Picture. 3) is based on differences in the shape, slope, shape and structure of the basin, divided into :

- Peak Morphology : characterized by sharp walls, narrow valleys, strong erosion, and dense vegetation. This section includes the volcano (altitude of ± 2640 m), Mt. Masigit (altitude of ± 2671 m), Malang Sand (height of ± 2679 m), and Mt. Nangklak (altitude of ± 2474 m).
- Body Morphology : characterized by a radial flow pattern of the river formed by lava flows and pyroclastic deposits. This section includes the Brungbrung Crater, Manuk Crater, Nangklak Crater, Baru Crater and Ruslan Valley.
- Foot Morphology : characterized by a dendritic pattern of stream flow and smooth morphology relief in northeastern and southern sectors, and medium morphology relief in the southern sector . This section is formed by lava flows and pyroclastic flow deposition.
- Horseshoe Morphology : is a northeast trending depression ranging from the Mas Crater to the Cibalong Village and Cibodas as a result of debris avalanche deposit.



Picture 3. Complex Morphology in Mt. Papandayan and Surrounding Area



Picture 4. Landsat Imagery RGB 542 of Mt. Papandayan, September 13rd 2002 (Wikanti, 2002).

Picture 4 shows a visual image of the volcano that consists of several parts, among others:

1. Mt. Papandayan
2. Alun-Alun Crater
3. Nangklak Crater
4. Baru Crater
5. Mas Crater
6. Cibeureum Gede Crater

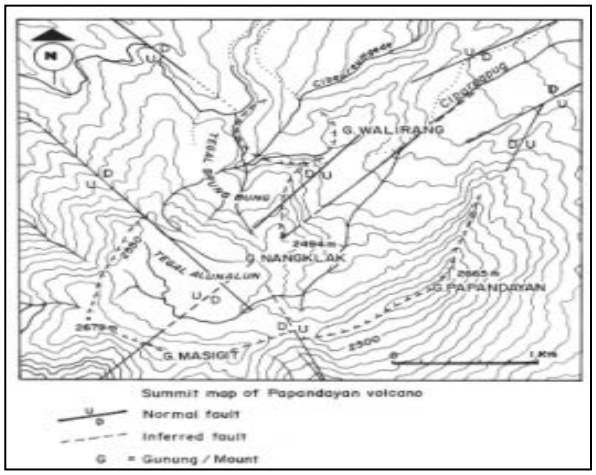
Stratigraphy

Stratigraphy of the Mt. Papandayan can be divided into several lithological complex resulted from volcanism products include:

- Primary Products: consist of Tertiary andesite, found in the south area of the Mt. Papandayan.
- Volcano Products Around Mt. Papandayan: consist of pyroclastic fall deposition from Mt. Geulis, Mt. Kembar intrusion, pyroclastic fall deposition and lava flows Mt.Cikuray, pyroclastic fall deposition Mt. Jaya, and pyroclastic flows Mt. Puntang.
- Products of Mt. Papandayan : consist of lava flow sediment fall out and pyroclastic flows.
- Products of Tegal Alun-Alun Crater: consist of lava flows and pyroclastic flow deposition.
- Products of Mt. Nangklak : consist of pyroclastic falldeposition.
- Products of Manuk Crater Manuk: consist of pyroclastic fall deposition.
- Products of Mas crater Mas: consist of pyroclastic fall deposition, and
- Secondary Products: consist of debris avalanches from Manuk Crater & Mas Crater, and lava.

Geological Structure

Geological structure of the Mt. Papandayan and area surrounding can be separated into the fault structure and the structure of the crater. Fault structures are generally the type of major normal faults were found in the vicinity of Mt. Nangklak, Tegal Alun-Alun Crater, Mas Crater, Mt. Walirang, as well as in the northwest and southeast slopes of the volcano. Two normal faults have fault direction SE-NW and NE-SW. Indications of normal faults are characterized by the presence of brecciation, topographic lineaments, and crushed zones. The structure of crater found in the Mas Crater, Manuk Crater, Brungbrung Crater, Tegal Alun-Alun Crater, Nangklak Crater, and Baru Crater (**Picture 5**).



Picture 5. Geological Structure in Mt Papandayan and Surrounding Area

3.2 Geochemistry Analysis of Mt. Papandayan Volcano Complex

Based on geochemical analysis, the lava in the Mt. Papandayan area and around the cone have a silica content of 54.57%. This makes the value of SiO_2 variation of volcano classified as medium-K andesite (Le Maitre, 1989). Variations in the value of silica and potassium content of the volcano lava known to slightly higher than the lava of the calc-alkaline series.

The results of geochemical investigations carried out by taking as well as direct measurement on one of the manifestations of geothermal springs to perform gas analysis, water analysis, water and air temperature, and pH value.

Picture 6. One of the hotspring water in research area

Gas Analysis

Type of gas contained in the Mt. Papandayan and the surrounding area consists of CO_2, SO_2 and H_2S. Solfatares temperature ranged of Mas Crater is about 180° C to 375° C. Temperature often rise up to 43 ° C and decreased at 80° C-115°C). The results of the gas analysis of gas taken from the volcanic craters : Mas I Crater, Mas II Crater, Nangklak Crater and Manuk Crater generally exceed the limit value/ NAB (permissions gas concentration). The content of CO_2, SO_2 and H_2S are shown in Table 1.

TABLE 1. The Gas Content of CO_2, SO_2 and H_2S in Mas I Crater, Mas II Crater, Nangklak Crater, and Manuk Crater.

Name of Crater	CO_2 (ppm)	SO_2 (ppm)	H_2S (ppm)
Mas I Crater	27.100	7.500	400
Mas II Crater	25.100	7.600	400
Nangklak Crater	905.900	79.350	5.000
Manuk Crater	66.500	10.900	900
Maximum permissible concentration	5.000	5	10

Geochemical analysis shows that volcanic gas levels detected by Kitagawa gas detector (CO_2, SO_2 and H_2S) is quite high. High content of volcanic gases that reflect a fairly intensive volcanic activity below the surface could produce a heat source potential in the area of the volcano Mt. Papandayan its surroundings. But from a social aspect, semi-quantitative analysis of volcanic gas show the gas content above has been in level of harm to human health. It is therefore very important to be disseminated to the public as well as warning signs around the area of high gas contamination.

Water Analysis

The results of chemical analysis of the water showed that the levels of CO_2, SO_2 and pH have a high price. Water acidity (pH) in 3 different places showed a low price (2.95; 4.60; 3.23). The low pH value is most likely caused by sulfate solution coming from the crater mixed with some springs in the vicinity. Sulfate levels at 11.50 can still be found in some springs around the area of the volcano. This indicates that the system is in the waters around the crater of the Mt. Papandayan relative has been affected by solfatara activity. The content of CO_2 and SO_2 from water samples obtained in spring in Cisurupan Village.

Temperature Value Nilai & pH

The results of the investigation survey conducted by the temperature and pH as well as making direct measurements on one of the manifestations of geothermal springs. These measurements resulted in water temperature of 48.3^0C and 20.5^0C of air temperature. The content of the pH on one of the manifestations of the volcano showed the value of 2.2.

Picture 7. Temperature Measurements and pH Measurements of the Fumarole

IV. CONCLUSION

- Geology of the volcano and the surrounding area has 4 different morphology among others : peak morphology, body morphology, foot morphology and horseshoe morphology.
- Stratigraphy of the volcano and the surrounding area can be divided into several lithological results of product volcanism include: Primary Products, Products of Around Mt. Papandayan, Products of Mt. Papandayan, Products of Tegal Alun-Alun Crater, Products of Nangklak Crater, Products of Manuk Crater, Products of Mas Crater Mas, and Secondary Products.
- The geological structure of the volcano and its surroundings can be separated into normal fault structures that have a SE - NW and NE – SW direction of the fault and the craters structure contained Mas Crater, Manuk Crater, Brungbrung Crater, Tegal Alun-Alun Crater, Nangklak Crater, and Baru Crater.
- Geochemical analysis of the Mt. Papandayan and the surrounding area carried out by gas analysis, water analysis , temperature and air hot springs, as well as pH. Gas analysis showed that volcanic gas levels detected by Kitagawa gas detector (CO_2, SO_2 and H_2S) is quite high. Analysis of the water showed levels of sulfate of 11.50. While the measurement of thermal springs indicate the value of the water temperature was 48.3^0C, the air temperature is 20.5^0C, and pH value is 2.2. These results indicate that the activity of volcanism of Mt. Papandayan and surrounding areas potentially generate geothermal.

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REFERENCES

- Asriningrum, W. 2002. *Identifikasi Morfologi Gunung Api Sebagai Antisipasi Bahaya Letusan*. Dipublikasikan pada Jurnal LAPAN.
- Delmelle, P., et al. 2000. *Geochemistry of the magmatic-hydrothermal system of Kawah Ijen volcano, East Java, Indonesia.* Journal of volcanology and Geothernal Research edition 97, 31-53 pp.
- Dickson, M.H., and M. Fanelli. 2003. *Geothermal energy: Utilization and technology*. Renewable Energy Series, United Nations Educational, Scientific and Cultural Organization, Paris, France, 205 pp. (ISBN: 92-3-103915-6).
- Goff, F., and Janik, C. J. 2010. Geothermal *Systems Encyclopedia of Volcanoes.* Academic Press: San Diego. 817-834 pp.
- Herdianita, N.R., Julinawati, T., and Amorita, I.E. 2010. *Hydrogeochemistry of Thermal Water from Surface Manifestation at Gunung Ciremai and it Surounding, Cirebon, West Java – Indonesia*. Proceedings World Geothermal Congress 2010, Bali, Indonesia.
- Hochstein, M. P., and Browne, P. R. L. 2010. *Surface Manifestations of Geothermal Systems With Volcanic Heat Sources*. Encyclopedia of Volcanoes, Academic Press, San Diego, 834-856 pp.
- Le Maitre. R.W., Bateman, P., Dudek, A., Keller, J., Lameyre, J.. Le Bas, M.J., Sabine, P.A., Schmid, R., Sorensen, H., Streckeisen, A., Woolley, A.R. &

Zanettin, B., 1989. *A Classification of Igneous Rocks and Glossary of terms: Recommendations of the International Union of Geological Sciences Subcommission on the Systematics of Igneous Rocks.* Blackwell Scientific Publications, Oxford, U.K.

- Mock, J.E., J.W. Tester, and P.M. Wright. 1997. *Geothermal energy from the Earth: Its potential impact as an environmentally sustainable resource.* Annual Review of Energy and the Environment, 22, pp. 305-356 (ISBN: 978-0-8243-2322-6).
- Sukhyar, R., et al. 2010. *Potensi dan Pengembangan Sumber Daya Panas Bumi Indonesia*. Badan Geologi, Kementerian Energi dan Sumber Daya Mineral, Bandung.
- Van Bemmelen, R.W. 1949. *The Geology Of Indonesia, Volume 1 A*. The Hague Martinus Nijhoff, Netherlands, 732 pp.