An Overview of Hydrothermal Alteration & Subsurface Geology in Dieng Geothermal Field, Central Java, Indonesia as Potential Area of Energy Efficiency 2020

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ABSTRACT

The Dieng geothermal field is located in central Java Island approximately about 80 kilometers northwest of the city of Yogyakarta surrounded by mountainous terrain. Dieng geothermal is a two-phase system which occurs in a caldera on the eastern margin of the Dieng volcanic complex. The Dieng field is the only geothermal area in Central Java that has been exploited and it is currently producing 60MW of electrical power. Manifestations of thermal activities are extensive in this field and consist of solfatara, fumaroles, hot springs, mud pools, phreatic explosion craters and altered grounds.

This paper tries to describe the subsurface geology and hydrothermal alteration of the Dieng geothermal field. Geothermal field in Dieng comprised of three prospect areas namely, Sileri, Sikidang and Pakuwaja blocks. In this study, the results of hydrothermal alteration in Sikidang block can be grouped into four zones which include, from shallow to greater depths, smectite + cristobalite + kaolin zone, smectite + quartz + kaolin zone, interlayered illite/smectite + corrensite + epidote-clinozoisite zone and illite + chlorite + epidote-clinozoisite zone.

I. INTRODUCTION

Regional Geology of Dieng Area

Dieng Plateau is a volcanic complex, forming vast plains with a length of approximately 9 miles (14 km) and 4 miles wide (6 km). It extends from the southwest - southeast area. Dieng derived from old volcanic decreased dramatically (dislocation) by fracturing trending of northwest and southeast. The old volcano is Mount Prau. In the section collapsed appeared small mountains namely : Mt. Alang, Mt. Nagasari, Mt. Panglimunan, Mt. Pangonan, Mt. Gajahmungkur and Mt. Pakuwaja.

In the regional geology, Dieng Volcanic Complex area is covered by Quaternary age sediments, such as lava flows, pyroclastics, phreatic sediment, sludge lava, sediment surface, and the result eruption of Mt. Sundoro. These deposits can be divided into 5 precipitated based on the eruption source (R. Sukhyar, et al, 1986), with the young to the old sequence consists of :

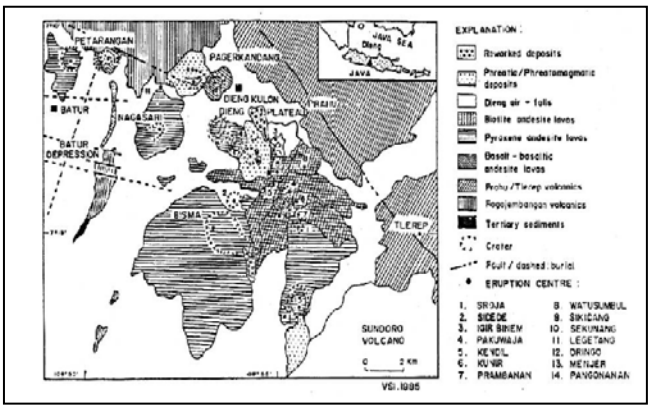
• Surface Deposition ;

• Young Deposition of Dieng ;

• Mature Deposition of Dieng ;

• Old Deposition of Dieng ; and

• Volcanic Eruption Results of Sundoro.



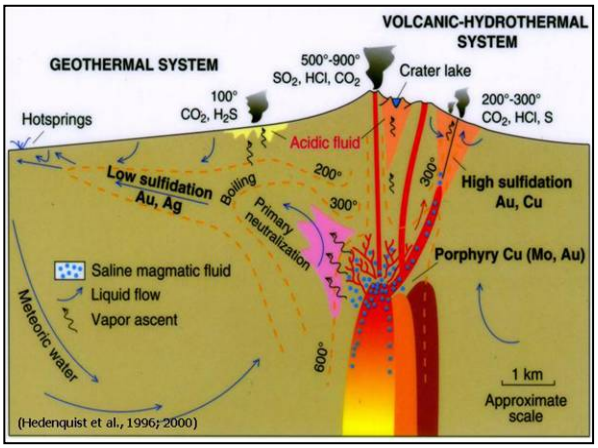
Picture 1. Regional Geology Map of Dieng (Sukhyar, 1994)

Geothermal System of Dieng Area

Dieng Geothermal included in hydrothermal systems. During the movement toward the surface, the magma is likely to interact with groundwater, connate water, sea water, river or lake water, ice or rain water. Environmental of water under the surface includes all the activities and the results of the water activities.Volcanism that heats groundwater resulted the vapors eruption without throwing the fragments of juvenile magma called phreatic or hydrothermal (Muffler drr., 1971; Nairn and Solia, 1980).

Hydrothermal geothermal systems is influenced by geological conditions, where certain geological conditions at depths below the surface of the hydrothermal fluid pressure exceeded litostatik pressure will cause widening of rock cracks. The geological conditions can occur around the breakthrough or extrusion of magma. When the volcanic cracks have sufficient increase in the permeability of the host rock surrounding the heat source, it will create a significant hydrothermal circulation (Knapp and Knight, 1977; Norton, 1984) and an increase in convective vapor transport.

As per the passage of time a geothermal system can be formed. In this case the process of its formation is determined by geological control factors, such as age and size of early breakthrough in igneous rocks beneath the surface, the presence of aquifers, porosity-permeability host rock as a reservoir, and the impermeable covering rock.



Picture 2. Hydrothermal Type of Geothermal System (source: http://www.google.com)

Geothermal Potential of Dieng Area

Dieng geothermal potential of the area is quite high. Geothermal which has been undertaken by PT Geo Dipa Energy for power generation has potential capacity of 60 MW. This huge potential remains largely untapped.

II. RESEARCH METHOD

The research methods used in the manufacture of this study refers to the methods of quantitative non-experimental study (McMillan & Schumacher, 2001), among others :

Observation Method
A variety of information and data collected by the authors obtained through observation method derived from direct observation and systematic recording of the object under study on the actual circumstances.

Descriptive Method
After recording the current research observations, the researchers focused on the issues that became the main focus in the study. Through descriptive methods, researchers attempted to describe deeply the research object without giving special treatment to the object.

The data sources used in the writing of a scientific paper are obtained through secondary data from journals and scientific publications, text books, articles, and materials related to the discussion of research on the Dieng geothermal area.

III. RESULT & DISCUSSION

Hidrothermal Alteration in Dieng Geothermal Field

The system is defined as the circulation of hydrothermal fluid heat (50 ° C - > 500 ° C), laterally and vertically at varying temperatures and pressures below the earth's surface. This system contains two main components, namely the heat source and the fluid phase. Hydrothermal fluid circulation caused mineral assemblage in the rock wall to become unstable and tend to adjust to the new equilibrium mineral assemblage formed in accordance with the new conditions, which is known as an alteration (change) hydrothermal. Hydrothermal mineral deposits can be formed due to hydrothermal fluid circulation leached, transported, and precipitated new minerals in response to physical and chemical changes (Pirajno, 1992, in Sutarto, 2004).

Hydrothermal alteration is a very complex process that involves changes in mineralogy, chemistry, and texture caused by hot fluid interaction with rocks in its path, under the conditions of the physico-chemical evolution. The process is a form metasomatism alteration, namely the exchange of chemical components between fluids with wall rocks (Pirajno, 1992). Several factors influence the process of hydrothermal alteration are the temperature, chemical, fluid, concentration and composition of the rock side, the duration of hydrothermal activity and permeability. However, chemical and fluid temperature factor is the most influential factor (Browne, 1994 in Corbett and Leach, 1995).

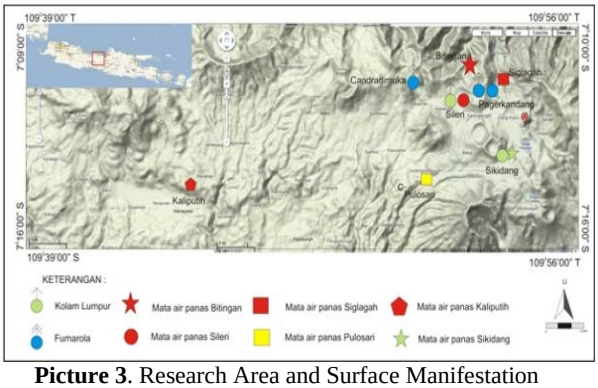
As a hydrothermal system, geothermal contains various minerals in varying levels. Minerals who contained in geothermal such as: silica, zinc, strotium, rubidium, lithium, potassium, magnesium, lead, manganese, copper, boron, silver, tungsten, gold, secium, and barium (Pohan and Hutamadi, 2010). However, there are certain minerals that can represent the state of the subsurface temperature.

During this time, there are generally two groups of minerals that can represent geothermal potential, they are calc-silicate minerals and clay minerals group. Calc-silicate minerals groups such as epidote, prehnit, wairakit, wollastonit and biotite are commonly used as an indicator of high-temperature minerals. The presence of these minerals indicates temperatures >220° C (Silaban, 2001).

For clay minerals themselves have a structure that is sensitive to changes in temperature and chemical conditions. So, in the study of hydrothermal alteration, this minerals used as Geothermometer minerals, ranging from a low temperature (~ 50° C) to high (> 220° C); and also to evaluate the condition of the fluid chemistry when interacting with rocks. Hydrothermal clay minerals is a silicate-hydrate alumina minerals (hydrated alumino-silicate) which formed through the alteration of the primary minerals, such as feldspar, mica, and ferromagnesium minerals. In general, these minerals can be grouped into 6 types: kaolin, pyrophyllite, mica, illite, smectite, and chlorite (Silaban, 2001). Smectite, has a temperature below 140^o - 150^oC. Meanwhile, chlorite formed between temperatures of 100^o - 140^oC (Cahtelineau in Silaban, 2001). However, in Iceland, Kristmannsdottir and Tomasson (1975) noted the formation of chlorite is present in association with epidote at 230^oC in basalt rocks.

Dieng is located 26 km north of Wonosobo which geographically located between 7 ° 11' 00" S - 7 ° 14' 00" S and 109° 51' 00" E - 109° 54' 30" E. The area is largely fit into Banjarnegara district, and some into the district of Wonosobo, Central Java (Pohan and Hutamadi, 2010).

Dieng Plateau area is a volcanic complex, forming vast plains with a length of approximately 14 km, wide of approximately 6 km and extends from the southwest to southeast. Dieng Plateau Area is derived from an old volcano (Mount Prau) which decreased drastically (dislocation) by faulting in northwest and southeast direction. In the section that collapsed appeared small mountains, they are: Mount Alang, Mount Nagasari, Mount Panglimunan, Mount Pangonan, Gajahmungkur Mountain and Mount Pakuwaja (Pohan and Hutamadi, 2010).



Picture 3. Research Area and Surface Manifestation (source: http://www.maps.google.com)

The Dieng geothermal field is the only developed geothermal area in Central Java. It is comprised of three prospect areas namely, Sileri, Sikidang and Pakuwaja blocks (Calibugan, et al., 2010). Hydrothermal alteration in Sikidang is characterized by occurrence of smectite, interlayered illite-smectite, illite, corrensite, interlayered chlorite/smectite, chlorite, kaolin (halloysite, kaolinite, etc.), sulfates (jarosite, alunite, gypsum, anhydrite, natroalunite, alunogen), zeolites (analcite, clinoptilolite, mordenite, natrolite, phillipsite, chabazite), silica (quartz, tridymite, cristobalite), silicates (epidote, secondary tremolite-actinolite, pyrophyllite, zunyite, secondary albite, adularia), calcite, diaspore, pyrite, sulfur and hematite.

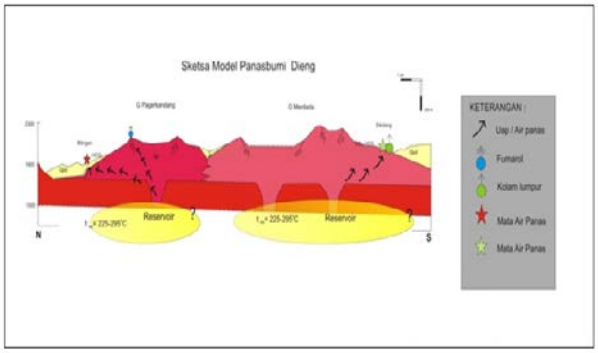
Zonation with increasing depth is observed for clay minerals: smectite (+kaolin) occurs at the shallowest level (from surface up to ~800m), interlayered illite/smectite (+corrensite) at depths of ~800m to ~2100m, and illite (+ chlorite) at the deepest level (~>2100m depths) (Calibungan, 2010). Results of Calibungans et al (2010) study show that hydrothermal alteration in Sikidang block can be grouped into four zones which include, from shallow to greater depths, smectite + cristobalite + kaolin zone, smectite + quartz + kaolin zone, interlayered illite/smectite + corrensite + epidote-clinozoisite zone and illite + chlorite + epidote-clinozoisite zone.

These data show us that hydrothermal alteration in Dieng Geothermal Field contains clay mineral, such as: illite, smectite, chlorite, etc which indicate the area is a potential geothermal field.

Subsurface Geology in Dieng Geothermal Field

The estimated subsurface temperatures were calculated using geothermometer method of Na-K-Ca compared with fumarol manifestations available in the studied area (Ramadhan et al, 2013). Geothermometer of Na-K-Ca was used to calculate the reservoir temperatures at the studied area because hotwater in this area has interacted with surrounding rocks and has high Ca content. The hotwater used for geothermometer calculation is from Pulosari that has a mix type of sulfate chloride with pH value. Based on the geothermometer calculation of Na-K-Ca, hotwater reservoirs in the studied area have a temperature of 295^0 C.

As a comparison, manifestation as dry fumarol with dry characteristics and thundering sound is available in Pagerkandang and Sipandu fumaroles. According to Hochstein and Browne (2000) dry fumarol show the geothermal reservoir of $\geq 225^0$ C. Therefore, it can be interpreted that Pagerkandang and Sipandu geothermals have reservoir temperatures of $\geq 225^0$ C. Thus, it can be said that the geothermal temperature of the studied area is above 225^0 C, and may be it reaches 300^0 C.



Picture 4. Tentative model of Dieng geothermal field based on Condon et al. (1996).

The Constraints of Dieng Geothermal Utilization

Currently, Dieng geothermal energy utilization is only able to supply 20 MW of about 60 MW of potential exploitation each year. This is because some of the obstacles faced by entrepreneurs of Dieng geothermal energy developers include:

- The high cost of tools maintenance of exploration and exploitation because the pH of the water in drilling wells is highly acidic and corrosive.
- Conflicts on the issue of environmental damage caused by Dieng geothermal project.
- Extensive areas of forest that replaces the potato field in the area of Dieng geothermal exploitation. This leads to reduced water catchment areas which is an important factor in exploitation.
- Law geothermal exploitation that is not in harmony with environmental regulations and forestry.

Dieng Geothermal Development Strategy Towards Energy Security in 2020

Dieng is a geothermal field that could become a hope to meet the 2020 Energy Security. Therefore to achieve this required, the formulation of synergy development strategies is very needed. Some ways we could do, among others :

- Local governments should provide convenience and simplification of regulations and licensing that can help improve the economics and security of geothermal projects.
- Development of data systems, information, technology and human resources should be implemented immediately.
- The use of drilling techniques "Cluster System" as an attempt to decrease land use exploitation.
- Adaptation and modification of technology creation to reduce the impact of high acid so that the corrosion in pipes of Dieng geothermal can be reduced. This certainly must involve chemists, geologists, and environmental engineers.

IV. CONCLUSION

- Dieng Geothermal Field is classified into Hydrothermal Geothermal System which can be grouped into four zones : smectite + cristobalite + kaolin zone, smectite + quartz + kaolin zone, interlayered illite/smectite + corrensite + epidote-clinozoisite zone and illite + chlorite + epidote-clinozoisite zone.

- Based on the geothermometer calculation of Na-K-Ca, hot water reservoirs in the studied area have a temperature of 295^0 C which may be reaches 300^0 C.
- To prepare Dieng geothermal field to be one of the potential field in order to achieve energy security in 2020, required the synergy of local government, central government, employers, and communities to design a regulatory strategy, technology, and human resources.

REFERENCES

- Browne, P.R.L. and Ellis, AJ.1970, *The Ohaki Broadlands Hydrothermal Area, New Zealand,* Mineralogy and Associated Geochemistry American Journal of Science 269: 97 – 131.
- Browne, 1970, *Hydrothermal alteration as an aid in investigating Geothermal fields.* Geoth. Special issue.
- Condon W.H., Pardiyanto L., Ketner K.R., Amin T.C., Gafoer S., dan Samodra H. 1996, *Geological Map of Banjarnegara dan Pekalongan Quadrangle, Central Java*. Geological Research and Development Centre (GRDC), Bandung.
- Hochstein, M.P. dan Browne, P.R.L., 2000. *Surface Manifestation of Geothermal Systems with Volcanic Heat Sources.* In Encyclopedia of Volcanoes, H. Sigurdsson, B.F.Houghton, S.R. McNutt, H. Rymer dan J. Stix (eds.), Academic Press.
- Knapp, R.B. dan Knight, J.E., 1977. *Differential thermal expansion of pore fluids: fracture propagation and microearthquake production in hot pluton environments*, Journal of Geological Research, 82, h.2515-2522.
- McMillan & Schumacher, 2001, *Research Method*, Published by : Arizona University.
- Muffler, L.J.P., White, D.E., dan Truesdell, A.H., 1971. *Hydrothermal explosion craters in Yellowstone National Park*. Geological Society of American Bulletin, 82, h. 723-740.
- Nairn, I.A. dan Solia, W., 1980. *Late Quaternary hydrothermal explosion breccias at Kawerau geothermal field, New Zealand*. Bulletin of Volcanology, 43, h.1-13.
- Silaban, MSP, 1998, *Hydrothermal alteration and fluid inclusion study of samples from well UBL-03, Ulubelu Geothermal Field, Sumatra, Indonesia*, Geothermal Institute, the University of Auckland, Report no. 98.21.
- http://maps.google.com.html, accesed in 23rd May 2014.