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Submission date: 24-Sep-2020 09:33AM (UTC+0300)
Submission ID: 1395598508
File name: 41._ReTII_2011.pdf (308.61K)
Word count: 2413
Character count: 14364

GENERAL GEOLOGICAL CHARACTERISTICS OF GEOTHERMAL FIELDS IN VOLCANIC AREAS OF JAVA ISLAND
Case Study : Guci, Tangkuban Parahu and Gedongsongo

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Abstract

Java Island has many geothermal fields which spread in volcanic areas. This paper is the result of a comparative study of various geological data of the three geothermal areas in Java, which is intended to infer general geological characteristics of those area. Geological observation of some geothermal fields showed that there are many similar geological characteristics. Geomorphologically, the prospective areas are usually located in active volcanoes but post volcanism stages, indicated by gently slope topography in their summit or slopes. Geologically, geothermal fields consist of cap rock, reservoir rock and heat source which is originated from middle age magma residue (mainly not older than Late Quaternary). Cap rocks have low permeability, usually consist of Quaternary volcanic rocks. Whereas, reservoirs are formed by Late Quaternary volcanic and Tertiary volcanic/sedimentary rocks. The geothermal fields are usually controlled by geological structures such as normal faults or ring of normal faults (rim structure) formed *graben* (collapse structure) which is used as the boundaries of geothermal prospective area.

Abstrak

Pulau Jawa memiliki banyak lapangan panas bumi yang umumnya terdapat di wilayah gunung api. Tulisan ini merupakan hasil studi komparatif dari berbagai data geologi terhadap tiga daerah lapangan panas bumi di Jawa, yang ditujukan untuk menarik kesimpulan umum dari karakteristik geologi panas bumi di daerah tersebut. Hasil pengamatan lapangan di berbagai lapangan panas bumi menunjukkan bahwa suatu lapangan panas bumi memiliki beberapa kesamaan dalam hal karakteristik geologinya. Dalam hal geomorfologi, daerah yang memiliki prospek panas bumi umumnya terdapat pada gunung api aktif namun berada pada stadia post *volkanisme, ditunjukkan oleh morfologi gunungapi yang sudah tererosi, relatif landai di bagian tubuh atau puncaknya. Secara geologi, daerah panas bumi tersusun oleh batuan tudung, reservoir dan sumber panas yang umumnya berasal dari sisa magma yang belum terlalu tua (biasanya berumur Kuarter Tua). Batuan tudung memiliki permeabilitas rendah, umumnya tersusun oleh batuan gunungapi Kuarter. Batuan reservoir berupa batuan gunungapi berumur Kuarter Tua serta batuan gunungapi/sedimen berumur Tersier. Dari aspek struktur geologi, umumnya daerah panas bumi didukung oleh adanya sesar turun atau sesar normal setengah melingkar (struktur rim) yang membentuk graben (*collapse structure*) yang berfungsi sebagai pembatas daerah prospek panas bumi.*

INTRODUCTION

This paper wrote as the result of comparative study of several geothermal prospect areas in Java. Three geothermal fields have been chosen to represent the geothermal condition in Java, there are Guci, Tangkuban Parahu and Gedongsongo fields. The analysis of general characteristics of geothermal has been carried out based on secondary data, supported by author's experiences in some geothermal projects.

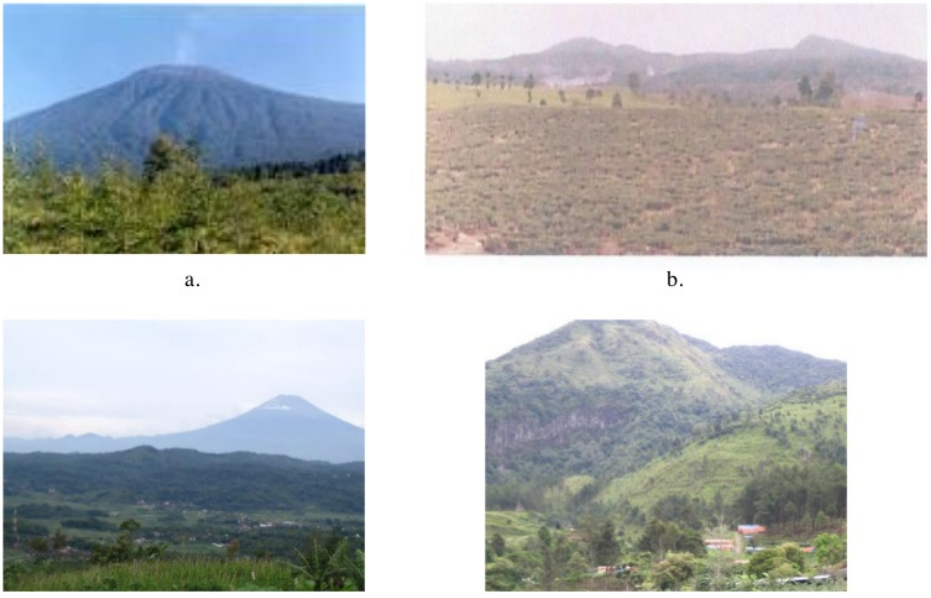
The geothermal is well known as alternative energy resource in Indonesia right now. This resource may be main resource in the future, as the most increasing of demand of energy supply. Geothermal itself, affords to alternate others non renewable energy sources because of its characteristics such as renewable, sustainable and friendly to our environment.

One of the most popular region of geothermal in Indonesia is Java Island. This island has many geothermal spots, all of them are in volcanic areas. There are active volcanoes in Java which have potential of geothermal resources, for examples Slamet, Tangkuban Parahu and Ungaran volcanoes. These volcanoes yield Guci and Baturraden, Ciater and Kancah, and Gedongsongo prospect areas successively. This article tells about these geothermal areas for being comparative study. The comparison has been made to summarize about general geological characteristics of geothermal fields representing at Guci, Tangkuban Parahu and Gedongsongo. This article has been written based on the experiences in geothermal fields from the author and by studying of secondary data.

GEOMORPHOLOGY

Both of Guci, Tangkuban Parahu and Gedongsongo geothermal fields are located in Quaternary active volcanoes. These geothermal fields are formed by Slamet, Tangkuban Parahu and Ungaran volcanoes. Slamet and Ungaran volcanoes still show good shape of cone, but does not Tangkuban Parahu . The Tangkuban Parahu itself shows more eroded morphology compare with the others, but this volcano seems more prospective in geothermal potential. This eroded morphology of Tangkuban Parahu indicated by gently slope at its summit, even sometimes there are valleys topography on the top of its. Presumably, eroded morphology show its older age or long time of geomorphological processes during its geological history.

The morphology of three mountains studied here can be compared to their sizes, shapes and slopes. Slamet and Ungaran body seem smaller relatively than Tangkuban Parahu. The two mountains called previously have better cone shape than the last, with relative sharper peaks. Tangkuban Parahu peak show the larger, longer and more gently peak. The morphology of the three mountains can be compared in Figure 1 below.



a. b. c. d.

Figure 1. Morphology of Slamet, Ungaran, and Tangkuban Parahu mountains.
a. Mt. Slamet (kheybhot.blogspot.com).
b. Mt. Tangkuban Parahu (PT. Istech Resources Asia, 2008).
c. Mt. Ungaran (Dinas Pertambangan dan Energi Jawa Tengah – Geomap, 2005).
d. The southern slope of Mt. Ungaran appearance from Gedongsongo tourism area (Dinas Pertambangan dan Energi Jawa Tengah – Geomap, 2005).

Guci geothermal field is actually formed by Old Slamet activity. This old mountain morphology looks as gentle, hilly morphology and usually forms low topography called Guci Graben. This graben has been eroded even the erosion process still develop continuously. Young Slamet looks blunter and wider than Mt. Ungaran. This phenomena should show longer time of Slamet evolution. Long duration of Slamet's development probably give higher potential than Ungaran ones.

Furthermore, the bluntest, most eroded morphology of Tangkuban Parahu prove its highest geothermal potential than the others. The morphology of Tangkuban Parahu has developed to be low, almost flat to rolling, gentle topography, even forms concave shape peak. Tangkuban Parahu and surrounding areas include in Sunda Volcanoes Complex. This Sunda Volcanoes Complex have been developed to form large caldera. This big size of Sunda Caldera shows its advance development of morphology with some exogenous processes have been lasting significantly, such as weathering, erosion, transportation and sedimentation. This caldera prove Tangkuban Parahu's evolution have run so far and fortunately, its geothermal potential looks quite promising.

STRATIGRAPHY

The geothermal system consists of three components, that are heat source, reservoir rock and cap rock. In Java, there are geothermal energy producted by volcanic activity. Then, under the deep of Guci, Tangkuban Parahu and Gedongsongo geothermal areas, there are magma chamber of old volcanoes as heat sources. The heat source mainly from magma activity whose age is not older than Pleistocene, usually in post volcanism stage. Heat source of Guci prospect area might be under Guci – Mingkrik Hill – Penjara Hill Depression and Batursari – Sigedong Depression (part of Sawangan Depression). On the other hand, heat source of Gedongsongo prospect is under active Ungaran Mountain. Heat source of Tangkuban Parahu prospect area might be significantly support by old Sunda Mountain.

The reservoir rock should be porous, permeable rock, meanwhile, cap rock must be impermeable one. Types of geothermal reservoir in Java usually are volcano types. According to Sudradjat (2009), volcanic facies as the reservoir in Java Island combined with the ancient diatrema and local faultings. The volcano type of geothermal potential refer that the steam related to the old volcanoes at the fumarolic or solfataric stage in the Quaternary volcanic belts. This type mainly distributed in the Quaternary volcanic belt in Java, in addition to Nusa Tenggara and North Sulawesi. Reservoir rock of Guci geothermal area are basement volcanic and Tertiary sedimentary rocks (shale and marl with calcareous sandstone intercalation of Rambatan Formation). Tangkuban Parahu's reservoir rocks consist of Quaternary basaltic-andesitic pyroclastic rocks and Tertiary sedimentary rocks of Subang, Kaliwungu and Citalang Formations. While, Gedongsongo area supported by old pre caldera volcanic an sedimentary rocks of Kerek and Kalibeng Formation.

Young Quaternary volcanic rocks, especially lava, usually act as cap rocks. Young Slamet volcanic rocks act as Guci's cap rocks. Young volcanic rocks of post caldera activity of Mt. Ungaran well functioned as cap rock of Gedongsongo geothermal system. Geologically, Tangkuban Parahu Mountain consists of andesitic to basaltic lava which take role as cap rocks.

GEOLOGICAL STRUCTURE

Many geological structure support the geothermal system in Java. These structure usually develop form rim structure or depression / collapse structure called graben. The graben usually formed by several normal faults or rift faults. Several major structural phenomena often increase vertical permeability of reservoir rocks.

a. Guci

Geological structure pattern here are Cowet Escarpment – Kaliguwa, Sawangan, and Guci Depressions. The density of structural geology zones range in high to very high intensity, predicted as high porosity and permeability zones. These zones allow the presence of geothermal reservoir both of sedimentary and volcanic rocks.

b. Tangkuban Parahu

Geological structure pattern in Tangkuban Parahu trending east – west follow direction of Java major faults. The graben structure (Figure 2) act as major geological structure in this area. Supported by field study and satelite image, the east – west structures known as product of beginning volcanism of Sunda Complex, such as Lembang, Tambakan and Gurudug Faults. Lembang and Tambakan Faults are caused by Java regional tectonic system. Mt. Sunda within Lembang – Tarakan Graben began its activities after the formation of those two faults. Mt. Sunda activities lasted in three phases, there were A and B eruption phases (effusive) and C strong explosion phase.

c. Gedongsongo

Gedongsongo geothermal system formed by Mt. Ungaran activities. Eruption center of its mountain is lied in collapse structure (Figure 3). This structure looks like cross faults made round shape, formed rift fault system which opened northeastward (to Mt. Ungaran peak direction). The activities of Mt. Ungaran were controlled by this collapse structure. The other structures appearance are northwest – southeast and southwest – northeast faults. The north – south direction fault passed Gedongsongo area is predicted to control geothermal manifestation in this region.

HYDROGEOLOGY

The hydrogeology greatly influence the renewable energy of geothermal. The sustainability of geothermal resource is depends on hydrogeology system of geothermal area. In Guci, the hydrogeology system is supported by Guci Catchment which consists of five sub-catchments. Catchment which act as well to very well recharge zones (PT. Spring Energy Sentosa, 2008).

There is high recharge of hydrology flow as well as significant regional hydrology gradient in Tangkuban Parahu area. This radial flow comes from higher and develops to the south and north lower elevation. While, there is no data about hydrology system of Gedongsongo until right now.

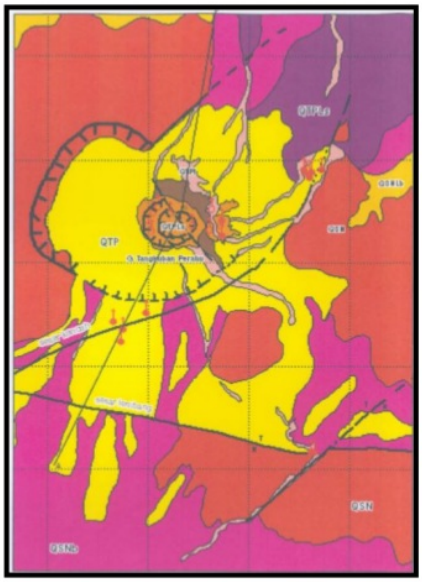


Figure 2. Caldera type of graben structure of Mt. Tangkuban Parahu (PT. Istech Resources Asia, 2008).
Explanation : Caldera type

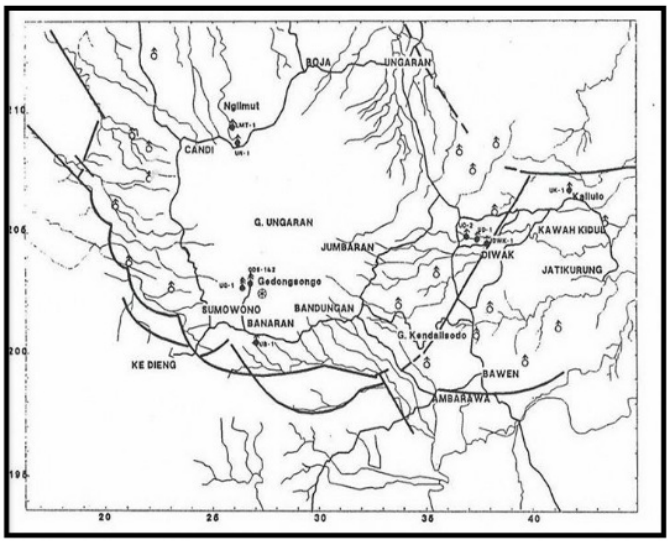


Figure 3. Manifestation map of Ungaran geothermal area (Pertamina, 1994). The collapse structure indicated by cross curves around the peak.

As the general characteristics of geothermal prospect area explained above, Table 1 is shown to summarize them.

Table 1. Geological elements of geothermal characteristics.

Element	Guci	Tangkuban Parahu	Gedongsongo
Geomorphology	Quaternary volcano of Slamet, still active, form good shape of cone, slight eroded.	Quaternary volcano form strong eroded morphology, large caldera, almost flat even form basin slightly on the peak.	Quaternary, active volcano of Mt. Ungaran
Stratigraphy and heat source	Cap rock : Young Quaternary volcanic rocks, especially lava Reservoir rock : Quaternary volcanic rocks and Tertiary sedimentary rocks of Rambatan Formation (shale, marl intercalated with calcareous sandstone) Heat source : magma chamber of Old Slamet	Cap rock : lava, young volcanic rocks. Reservoir rock : basaltic to andesitic pyroclastic rock, volcanic rocks, sedimentary rocks of Subang, Kaliwungu and Citalang Formations. Heat source : volcanic activity of large Tangkuban Parahu Volcanic Complex.	Cap rock : post caldera young volcanic rocks. Reservoir rock : pre caldera volcanic rocks; sedimentary rocks of Kalibeng & Kerek Formation. Heat source : Magma chamber of Ungaran active volcano
Geological structure	Controlled by Igir Cowet - Kaliguwa, Sawangan and Guci Depressions. High to very high density of geological structures	Lembang – Tambakan faults graben controlled Sunda Mountain.	a. Collapse structure, circular, intersect of faults formation b. North-south fault support manifestation appearance
Hydrogeology	Supported by Guci catchment (devided to five sub-catchments).	High capacity of water flow, supported by significant regional hydrogeology gradient.	No available data

CONCLUSION

There are some general characteristics of geothermal system in Java can be concluded from geomorphology, stratigraphy, geological structure as well as hydrogeology, as explained below.

1. Geomorphology of geothermal area shows that the old Quaternary volcanoes are considered more potent than young ones. The volcano which in the post volcanism have more potential than active volcano, indicated by eroded morphology on the top part of volcano.
2. Geothermal system is supported by heat source, reservoir and cap rocks. In Java, the heat sources are originated from magma chamber of old Quaternary volcanic activities. The reservoir rocks mainly composed by old Quaternary volcanic rocks and Tertiary volcanic/sedimentary rocks. On the other hand, the cap rocks usually formed by young volcanic rocks.
3. The general appearance of geological structure that controlled geothermal system are faults, rim structure / depression or collapse structure called graben.
4. The geothermal system strong influenced by the hydrogeology of certain area, supported by significant catchment zones.

ACKNOWLEDGMENT

This paper was written based on many experiences that have got mainly from projects. Therefore, the author would like to appreciate to all persons who have given the opportunity for participating in geothermal projects, which can not be enumerated.

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