GREEN FIELD GEOTHERMAL SYSTEMS IN JAVA, INDONESIA

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ABSTRACT

Most of geothermal production fields in Indonesia are situated in Java Island, besides geothermal prospect with less data or green field areas distributed from West Java to the East Java. Some of geothermal prospects are associated with a specific geological setting on Java. Those geological setting are on a subduction zone which is located on the South of Java Island. The subduction of oceanic crust (Indo-Australia) beneath continent crust (Eurasia) produces magma that ascends to the surface and forms a volcanic arc along Java Island. Volcanoes in Java are dominantly composed by andesitic rock that is related with a stratovolcano - high terrain geothermal system.

All of these geothermal systems might be associated with volcanic or non-volcanic. Volcanic geothermal system tends to show fumarole discharges on the surface which indicates high temperature fluid within reservoir. On the contrary, non-volcanic geothermal system indicates low to moderate temperature reservoir.

The propose of this paper is to describe each geothermal green field area based upon geological and geochemical data and to separate the prospect into some groups. Geological data includes surface lithology and structures, whereas geochemical data includes springs and fumaroles of active thermal surface manifestation (water and gas geochemistry). From surface lithology and structure data, a prospect can be interpreted as volcanic or non-volcanic association. On the other side, geochemical data can estimates reservoir temperature and can decide if the system is related to volcanic or non volcanic association.

High temperature systems (>225°C), detected on Java Green field geothermal system, is definitely related with volcanic geothermal system and be sides other geothermal systems is related with low to medium temperature systems (<225°C)

Those fields which are related with non-volcanic geothermal systems, probably are related with geopressure and fracture zone system.

INTRODUCTION

Tectonic setting of Java, that obviously produces volcanic arc parallel to Java Island, is controlled by subduction between oceanic crust (Indo-Australia) beneath continent crust (Eurasia). Volcanoes in Java are dominantly characterized by andesitic type that is related with a stratovolcano-high terrain geothermal system.

Most of geothermal production fields in Indonesia are dominantly situated in Java Island. Besides that there are green fields areas from West Java to East Java. Green field geothermal prospect is non-geothermal production fields which have a few data sets from: geochemistry, geophysics, shallow wells or thermal gradient wells and exploration wells.

The occurrences of geothermal system might be associated with volcanic: Quaternary volcanism, Tertiary volcanism and outflowstructure, and non-volcanic system such as: geopressure and fracture zone system or active fault.

Hydrothermal system is a type of geothermal system where heat transfers from a heat source (often a cooling pluton) to the surface by free convection involving meteoric waters with or without traces of magmatic fluids (Hochstein and Browne, 2000). It can be associated with Quaternary or Tertiary volcanism or as an outflow from adjacent volcanic system or volcanic hydrothermal system. Quaternary volcanism is associated with young igneous-magmatic intrusion, and it is certainly coincided with the presence of high temperature fluids in reservoir, and is indicated by the presence of thermal features like fumarols and hot springs. Tertiary or outflow systems are low-temperature reservoirs with an appearance of bicarbonate or chloride warm springs.
on the surface. Heat sources of this system are controlled by cooled intrusion magmatic. Quaternary volcanism is much hotter than Tertiary volcanism system.

Non-volcanic systems are associated with geopressure or fracture zone/active fault. There is no involvement of volcanic in these geothermal systems, so the temperature of fluid has to be lower than volcanic systems. The heat can be provided from active fault or overpressured in sedimentary basins (Goff and Janik, 2000). Not like geopressure systems, on the active fault systems the active thermal feature can emerge on the surface along the fault.

The distribution of geothermal production fields and geothermal prospects that is associated with volcanic or non-volcanic systems are showed in Figure 1.

VOLCANIC SYSTEM

Quater Volcanism System

The Quarter volcanism systems are associated with history of Quaternary volcanic deposits around eruption center. The prospects are as follow:

Banten Caldera (Mt. Pulosari, Rawa Danau and Mt. Karang)

Kaldera Danau Banten geothermal area is located at Serang and Pandeglang Regency, Banten. This area consist of 3 prospect which is Rawa Danau, Mt.Karang and Mt.Pulosari. Geothermal systems in this area is indicated by the presence of surface thermal manifestation, especially in RawaDanau. Manifestation that are shown in RawaDanau consist of warm and hot springs that lies almost in all over the area with the temperature range from 39-69°C (Herdianita, 2007). Most of the water type in RawaDanau are bicarbonate, while in Mt.Karang and Mt.Pulosari are Sulfate water. Upflow zone is located at Mt.Karang and Mt.Pulosari which can be seen by the presence of fumarol. Moreover the outflow zone lies in RawaDanau. Water geothermometer calculation indicated reservoir temperature range from 73-235°C in RawaDanau, while in Mt.Karang and Mt.Pulosari 110-237°C. Gas geothermometer calculation indicate reservoir temperature can be around 284°C.

Mt. Endut

Gunung Endut geothermal area is located at Lebak Regency, Banten. Geology of the area is dominated by Quaternary volcanics of Endut volcano, Tertiary sediments of Badui and Bojongmanik Formation, and tertiary intrusion rocks. NWW-SEE normal fault structures are found around tertiary intrusions and quaternary Endut volcano activities. Geothermal system in this area is indicated by hot springs with temperature 57-88°C and Chloride – Bicarbonate type with neutral pH. Those water lies in the partial equilibrium zone, moreover from the isotop analysis lies in the right of meteoric water line indicates richness of 18O. Bouguer Gravity anomaly indicated there is intrusion in this area that is potential to be a heatsource beneath Cikawah and beneath Handeuleum (PSDG, 2006).

Tangkuban Parahu, Maribaya, and Sagalagerang

Tangkuban Parahu geothermal area is located at Bandung and Subang Regency, West Java. This area consists of two prospects which are Kancah and Ciater. Geothermal system in this area is indicated by a lot of surface thermal manifestation like: fumaroles, hot and warm spring, and steaming grounds. Surface manifestation found in Kancah and Ciater consists of warm springs with the temperature approximately 34°C in Kancah and 44°C in Ciater. Water type in Kancah and Ciater is dominated by chloride sulfate waters. The geothermal system in this area is possibly associated with Mt. Tangkuban Parahu stratovolcano as a potential heat source. Upflow zone is located at the summit of mount Tangkuban Parahu indicated by fumaroles, while the outflow zone lies in Maribaya and Sagalagerang. Gas geothermometer from fumaroles give an reservoir temperature estimation above 250°C.

Mt. Papandayan, Cilayu and Ciarinem

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. The location lies in high terrain, 2665 m above sea level, with volcanic rocks. An explosive eruption occurred in November 2002, that emmited from KawahBaru. 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. At the summit, 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 H2O, CO2, and H2S dominant. Thermal springs, which is in Cilayu about 25 km to the southwest from Mt.Papandayan, from each craters consist of acidic SO4-Cl waters and neutral pH CI-HCO3 waters. A Low pH (1.5-3.0) manifestation contains SO4-Cl waters might originated from the absorption of magmatic volatiles or H2S condensation into shallow ground water.
Figure 1: Geothermal potential map in Java. Color symbols show a prospect and system (modified from Sukhyar dkk., 2010).
About 8 km on the North flank of Mt. Papandayan, there is Cibeureum Leutik warm spring (T ± 35 °C) with low pH (2.5 – 2.8) (Primulyana, 2010). It had just found after the last eruption of 2002. The fumarole discharges of five craters within mount Papandayan indicate upflow zone, whereas the Ciarinem and Cilauy neutral springs on the South and West flank indicate outflow zone. The CO₂ geothermometer of fumaroles suggest that reservoir temperature equals about 310 °C.

**Tampomas**

Tampomas geothermal area is located at Sumedang Regency, West Java. Geothermal system in this area is indicated by hot springs. Surface temperature of hot springs in North East flank of mount Tampomas reach about 51 °C which water type is chloride bicarbonate with neutral pH. Calculation of water geothermometer base on hot springs in North East flank of Mt. Tampomas is 180°C until 240°C. The geothermal system in this area is possibly associated with Mt. Tampomas potential heat source.

**Mt. Ciremai, Mt. Kromong, Sangkanhurip, Subang, and Cibingbin**

Gunung Ciremai geothermal area is located at Cirebon regency (Mt. Kromong) and Kuningan regency (Ciremai, Sangkanhurip and Cibingbin). Geothermal system in Ciremai is indicated by warm springs and Fumaroles at Mt.Ciremai (Mt.Kromong, Sangkanhurip and Cibingbin) with temperature range 42–55°C and pH 6-7. Those manifestation lies NW-SE following the same direction as the fault in this area. Water type in Sangkanhurip, Ciniru and Subang are Chloride, while in the Pejambon are Sulfate-Chloride with a lot of Bicarbonate water. From the water geothermometer we found that the range of reservoir temperature are 115–180°C. The gradient well at Sangkanhurip is 8°C/100 m and in the Kaliaren is 3°C/100 m. The upflow zone is indicated by the presence of fumarole at Mt.Ciremai and outflow zone is in Ciniru and Sangkanhurip.

**Gede-Pangrango**

Gede – Pangrango geothermal area is located at West Java and encompasses three regency which are Bogor, Cianjur, and Sukabumi. Geothermal system in this area is indicated by surface thermal manifestation: fumaroles, sulfatara, and warm springs. Temperature of sulfatara in Wadon Crater is approximately 167 °C. The geothermal system in this area is possibly associated with Mt. Gede stratovolcano potential heat source. Gas geothermometer from fumaroles indicate reservoir temperature above 220 °C.

**Ungaran**

Ungaran geothermal area is located at Semarang and Kendal Regency, Central Java. Geothermal system in this area is indicated by the presence of surface thermal manifestation like fumaroles, steaming grounds, hot springs, and alteration rocks. Ungaran lithology is dominated by igneous rock from Ungaran volcano activity. In general lithology in Ungaran prospect can be divided into two, basaltic igneous rock from old Ungaran volcano activity (pleistocene) and andesitic igneous rock from young Ungaran volcano activity (holocene).

Fumaroles field and sulfate hot spring found in Gedongsongo area, at the southern flank of the dormant Ungaran volcano, have a temperature up to 90°C. Chloride-bicarbonate water found at Diwak, Klepu. This type is found at Kaliulo 10–15 km East side of Ungaran Vulcano and 6-8 km South side of Banaran and Kendalisodo. The geothermal system in this area is possibly associated with Ungaran stratovolcanoes potential heat source. The upflow zone is located around Gedongsongo area as supported by the presence of fumaroles in that area and while hot springs in Diwak, Klepu, and Kendalisodo possibly associated with an outflow zone. Gas geothermometer calculation indicates a temperatur reservoar for about 230°C.

**Mt. Lawu**

Mount Lawu geothermal prospect is predominantly located at Karang Anyer Regency, Central Java and Magetan Regency, East Java. Geothermal system in this area is indicated by the presence of active thermal manifestations like: fumarole, hot springs, and warm springs. Thermal features in Mount Lawu prospect appear to be mainly structurally controlled and reflect to be a high temperature geothermal system. From the highest elevation to the lowest consist of fumarol and Candradimuka acid sulphat hot spring (2540 masl), and neutral chloride warm spring on the Northern-Western-Sothern flank of Mount Lawu at 300 to 1050 masl. The potential heat source is possibly associated with Mount Lawu and Mount Jabolarangan based on eruptive product in surrounding area. The reservoir is inferred to be high temperature (~280 °C) based on gas geochemistry which may indicate conditions in the deeper reservoir (Permana, 2011). The fumarol of Candradimuka at the top of Mount Lawu provide confidence of upflow and high permeable zone. It is controlled by NS fault trending along Mount Lawu to Mount Jabolarangan that is related to the displacement of eruption center. Out flow zone is characterized by chloride-bicarbonate water that distributed at the Western to Northern flank of Mount Lawu.
Ngebel-Wilis

Ngebel-Wilis geothermal prospect located at Ponorogo and Madison District, East Java. Geothermal manifestation in this area mostly located close to Lake Ngebel, consist of hot springs, mud pools and rock alteration. Ngebel-Wilis geological setting is dominated by volcanic rocks from volcanic activity of Ngebel and Wilis mountains, composed of volcanic breccia, tuff, and andesite lava.

There are two group of hot springs in the Ngebel-Wilis area, namely Padusan group and Talun Group. Padusan hot spring has a 55-90°C temperatur, neutral pH, with travertin deposit in the surface. Geochemical analysis results show Padusan hot springs are Dilute Chloride-Bicarbonate type (CI-HCO₃) which shows there has been a dilution of chloride water by meteoric water. Talun hot spring has a temperature range 45–80°C, acidic pH, and there is a pool of mud in the surface. The results of geochemical analyze indicate Talun hot spring group are acid sulfate type. Water geotemometer calculation indicates reservoir temperature range 200 – 260°C.

Arjuno-Welirang and Cangar

The geothermal prospect of Arjuno Welirang is located in Mojokerto Regency, East Java about 100 km southwest of Surabaya, the capital of East Java. The high temperature geothermal system is characterized by the presence of thermal features that emitted solfatar and fumarol with high content of sulfur deposit. Heat souce and upflow zone are under Mount Welirang’s summit that associated with andesitic. On the northern and northeastern flank, appears to be bicarbonate warm spring known as Cangar and Padusan (Kasbanai, 2008). Reservoir temperature has range 190 to 230 °C, and it is derived from Na-K-Ca water geothermometer. This temperature estimations will be higher if gases data are available. Reservoir is possibly composed by Quartenary volcanic rock as a result of stratigraphic correlation based on surface lithology. High content of sulfur deposit indicate reservoir fluid is acid that obviously is influenced by active magmatic.

Guci

On the South-East of Slamet Mountain slope (Central Java), there is a 14.360 ha geothermal system known as Guci. The Guci Contract of Work (COW), 25 km on the South of Tegal city and 20 km on the north of Purwokerto city, is on 3 regency which are Brebes, Pemalong and Tegal.

Indication of the geothermal system is obvious by the hot water manifestations such as pancuran 13, Cahaya, Saketi and Sigedong. These manifestation is being controled by a graben structure which is located at the North of Slamet Mountain Summit, otherwise there are being controled by structures related with that graben. From the geochemistry, these manifestations are bicarbonate type which indicate that the hot waters are from condesate water. Moreover from the isotop analysis has shown that these hot waters come from meteoric water.

According to the mountain systems, The Guci geothermal system is predicted to be associated with Slamet Mountain. Reservoird is predicted to be on the Guci graben area directing to Igir Cowet Mountain. The reservoir has a volcanic rock type with 1-1.3 km thickness measured from the surface. From the low magnetic anomaly, there is a hydrothermal system indication associated with the graben directing to Igir Cowet.

On the Na-K-Ca and Mg correction geothermometer, reservoir temperature is being suspected to be about 200°C - 230°C.

Baturaden

On the South of Slamet Mountain (Central Java), near by the Guci geothermal system there is an other system known as Baturaden which is on 4 different regencies named Tegal regency, Banyumas regency, Brebes regency and Purbalingga regency. Baturaden is a 24.660 ha area located 25 km on the South of Tegal city and 20 km on the North of Purwokerto city.

The geothermal system is indicated by many hot water manifestation such as pancuran 7 and pancuran 3. As the geochemistry analysis has been done, these hot water is a mixing type consisting of chloride mixed with Sulfate-bicarbonate condensate water. As the result of this mixing type water, silica sinter is found on Pancuran 3. Furthermore from the isotop analysis has shown that these hot waters is being diluted by meteoric water.

There is an evidence of a suspected outflow from a travertine deposit found on pancuran 7 and pancuran 3. As a recap that a rich Ca²⁺ kation water will produce a travertine deposit and travertine deposit generally found on the outflow side of a geothermal system.

Along with Guci geothermal system, this close gap differences with Baturaden makes a same prediction which these system are related with Slamet Mountain. But with a contradiction there are 2 system beneath Slamet mountain which is Guci geothermal system and Batu Raden geothermal system. Batu Raden geothermal reservoir has a 1-1.25 km
thickness with an elevation about 1-0.5 km from the surface with piroclastic and andesite rock domination. The Na-K-Ca and Mg correction geothermometer delivers a 200°C - 210°C reservoir temperature.

**Blawan - Ijen**

When we look at Blawan – Ijen area, there will be 3 regencies related such as Bondowoso regency, Banyuwangi regency and Situbondo regency. The Contract of Work (COW) has an authority of a 62.620 ha area. Blawan-Ijen has a caldera related system which is produced by the explosion of Old Ijen Mountain. This morphology can be seen by Kendeng mountain rim caldera on the North and on the South side with a series of a volcanic mountain activities such as Merapi mountain, Ranteh mountain and Jampit mountain.

Blawan-Ijen is dominated by Quarternary volcanic activities. On the North side rocks are dominated by Old Ijen mountain such as breccia, lava and basaltic – tuf. On the internal of the caldera which is dominated by Young Ijen mountain activity rocks which are tuf, breccia and lava. And on the other side, other volcanic activities such as Mount Merapi, Mount Ranteh and Mount Jampit are dominated by breccia, lava and tuf.

The geothermal system has a famous manifestation named as Kawah Ijen, which is on the North-West flank of Merapi Mountain. This kawah Ijen has many solfatar with its temperature reaching 200 °C, on the other side there are a few hot water manifestation North side of the Kawah Ijen which are located on Blawan village and other hot water manifestation located nearby Ijen Mountain. Based on trilinear He-N2-Ar diagram, it is confirmed that those gas produced is a vulcanic arc type gas. Surface temperature of those hot water located on Blawan village are 35-50°C, moreover from geochemistry analysis it is confirmed to be a bicarbonate condensate water. At the other hand the hot water from near Kawah Ijen has a 61°C surface temperature.

Geophysics survei indicated several anomaly which are Kawah Ijen aiming to the North, around Ranteh Mountain, and around Jampit Mountain. The Jampit Mountain anomaly is confirmed by a ISH-1 slimhole bore, located on the North side of Jampit Mountain, which has a 30°C/100 m geothermal temperature gradient starting at the depth of 300m.

Based on the analysis, Blawan-Ijen prospect is divided into 2 systems which are Ijen Mountain aiming North-Blawan and on Jampit Mountain. The first system has an upflow zone which is Kawah Ijen and the outflow zone located at Blawan. Suppose to be Jampit system has a boundary which is S.Banyupahit fault moreover there is still an uncertainty about wether the heatsource is the same with Kawah Ijen system or not. Reservoir rock is dominated with the old Ijen mountain and with the eruption from volcanics from Blawan-Ijen area. To be acknowledge that Kawah Ijen has a very acidic fluid with a 800-1000 m reservoir thickness with an elevation 750-1000m from the surface. From the CO₂ gas geothermometer it is conducted that the reservoir temperatur has reached 310 °C, on the other side water geothermometer reservoir supposed to be 270°C.

**Argopuro**

Iyang-Argopuro geothermal system is at East Java province with specifically related to 5 different regencies, which are Probolinggo, Situbondo, Bondowoso, Lumajang and Jember. It has a vast +102.400 ha area.

This geothermal system is indicated with fumarol that exist at the summit of Argopuro mountain. Posibly this fumarol is a strong sign of an upflow zone and posibly there is an outflow zone which condesate water following the same direction as faults at North-South and North West – South East direction. With an area of 50 km² low conductivity zone, possibly the reservoir has andesit, basalt and tuff reservoir rock. The heat source is located under the upflow zone of the Argopuro summit. This reservoir has a approximation range until 310°C.

**G. Pandan**

This geothermal system is located on East Java Bojonegoro regency near the border of Bojonegoro and Madiun regency. Untill present there have not been any survey related with geology, geochemistry and geophysic about this area. But this system is indentified by a hot water with a surface temperature around 35 °C near Pandan mountain which is a pleistocene volcanic type of mountain.

**Tertier Volcanic System**

**Candi Umbul-Telomoyo**

Umbul Telomoyo geothermal prospect area is predominately situated at Semarang - Magelang Regency with a small area situated at Temanggung-Boyolali regency, Central Java. It is located about 34 km south of Semarang, the capital of Central Java. Geothermal system in this area is indicated by three warm springs around Mount Telomoyo (Tim
Rejosari-Melati
Rejosari-Melati geothermal prospects located at Pacitan, East Java. Geothermal activity in this location is marked by the appearance of warm springs in the Karangrejo and Tinatar Village, Arjosari district. Lithology of this region is dominated by tertiier volcanic and sedimentary rocks (miocene), such as conglomerate, sandstone, siltstone, limestone, and mudstone from Arjosari and Jaten Formations. The other one is volcanic breccia, lava, and tuff from Mandalika Formation. There also dasitic, diorite, and basaltic some intrusive rock.

Karangrejo and Tinatar warm springs has temperature about 40°C and neutral pH, geochemical analysis showed that both warm spring are sulfate (SO₄) water type. Water geothermometer calculation indicated reservoir temperature range between 100 to 130°C. The high sulfate concentrations indicate that this prospect is associated with volcanic activity. The heat source is thought to be associated with the end of the southern mountains volcanic activity (Middle Miocene).

Outflow System

Cisolok – Cisukarame
Cisolok – Cisukarame geothermal area is located at Sukabumi Regency, West Java. Geothermal system in this area is indicated by hot springs and hydrothermal alteration. Temperatures of hot springs in Cisolok vary from 71°C until 100°C and hot spring in Cisukarame nearly boiling condition. Water type in Cisolok – Cisukarame is dominated by chloride and immature waters. Calculation of Na-K-Ca geothermometer indicates reservoir temperature 160°C until 200°C. Cisolok – Cisukarame geothermal system is predicted as deep outflow from Mount Halimun. Heat source possibly is provided by from Mount Halimun.

Jampang
This geothermal prospect is located about 35 km to the south of Awibengkok geothermal production field. Geothermal prospect is indicated by the presence of warm springs along Cimandiri River. Temperature of bicarbonate warm springs are up to 42°C and based on it, the reservoir temperature is ranging from 100-120°C. ¹⁸O and ²⁰D isotope from Awibengkok is similar to this prospect, so it is possibly associated as outflow system from Awibengkok geothermal system. The presence of active thermal manifestations are controlled by fault Cimandiri with azimuth of East-West direction.

Tanggeung-Ciburung
Tanggeung-Ciburung geothermal prospect is located about 30-50 km to the southwest of Patuha-Kawah Cibuni geothermal field. The prospect is indicated by the presence of Tanggeung hot spring (70°C) which is controlled by NW-SE fault and Cibuni warm spring (53°C) controlled by the contact of lithology. Both are chloride-sulphate water with neutral pH that indicate outflow zone from Patuha-Cibuni geothermal system, with reservoir temperature <125°C.

Parangtritis
Parangtritis geothermal prospect is located at Bantul and Gunungkidul Regency, Yogyakarta. Geothermal system in this area is indicated by the presence of two warm springs within adjacent area (Tim Pemutakhiran Database PanasBumi, 2004). Na-K water geothermometer indicates reservoir temperature ranging from 90 to 100°C. Geothermal system of Parangtritis is possibly associated with active volcano (Mount Merapi) that lies on 60 km to the North. Then we interpret that Parangtritis geothermal prospect is an outflow zone from Merapi.

Songgoriti
Songgoriti geothermal prospect is situated about 18 km South of Mount Welirang, Malang Regency, East Java. Geothermal potencies is indicated by the presence of warm springs with temperature about 47°C. Songgoriti geothermal system is a different system with ArjunoWelirang at the north because of different fluid characteristics. Heat source is possibly related to Mount Panderoman or Mount Kawi, both are a latter eruption rather than ArjunoWelirang. Mount Kawi lies on the southwest Mount Panderoman about 5.5 km. Water geothermometer calculation indicated temperature reservoir ranging from 170 - 210°C with lithology of Quartenary volcanic rock. Active surface manifestation in Songgoriti geothermal prospect only indicates the geothermal system is in the outflow.
Tiris
This prospect lies on the eastern of Gunung Lamongan, Probolinggo Regency, East Java. The geothermal system is indicated by the distribution of four warm springs along Tancak River as northwest-southwest fault trending. The type of warm springs is bicarbonate-chloride with temperature up to 43°C and neutral pH. The reservoir temperature is 180-220°C based on Na-K-Ca water geothermometer. The origin of fluids came from meteoric waters thataccomodated in reservoir rocks, possibly composed by volcanic breccia and andesite lava. Based on water type and temperature of manifestations, Tiris geothermal system is an outflow zone of the Mount Lamongan upflow zone.

NON VOLCANIC SYSTEM

Fracture zone system

Krakal
Krakal geothermal prospect is located at Kebumen Regency, Central Java. Geothermal phenomenon in this area is indicated by the presence of warm springs located in Arian district, southeast corner of Karangsambung National Geology Park. Geological setting of this region is dominated by tertiary sedimentary rocks, such as the Penosogan Formation, Halang Formation, and Waturandaf Formation, which composed of sandstone, limestone, mudstone, and tuff. The dominant geological structure is the presence of Kedungkramat (Kedungbener) faults, trending north-south along 12 miles from south coast to Karang Sambung mountains in the north. Krakal warm spring temperature around 40°C, pH 8, the results of cation analysis from Na-K-Mg triangular diagram shows that this water is an immature water.

Krakal geothermal prospects expected to be a fracture zone system (heat sweep system) and are not associated with volcanic activity. The system seems to be controlled by the presence of Kedungkramat fault, with the heat source is likely originate from residual heat (Granite radiation) and / or a very intense tectonic activity in Karangsambung area.

Geopressured System

Kuwuk
Kuwuk geothermal prospect administratively located in Grobogan District, Central Java. Kuwuk prospect is related to the existence of mud vulcano complex around Grobogan District, namely Bleduk Kesongo, and Bleduk Koprak, and Bledug Kuwu. As the largest in the area. The presence of mud diapirs and mud volcanoes actually quite common found in Java, especially along the depression zone (from West to East) Bogor - North Serayu – Kendeng - Madura Strait.

A mud diapir / mud vulcano is an intrusion of relatively mobile mass that intrudes into preexisting strata which is caused by buoyancy and differential pressure. The mobile mass is either mud/shale or salt. Diapir relates to the creation of overpressure in deep strata. Non-equilibrium compaction is believed to be the dominant mechanism in formation of overpressured sediments. During burial and compaction, water is physically expelled from sediments. In thick, rapidly deposited fine- grained sections reductions in porosity and permeability related to compaction inhibit the flow of water out of the shale. As burial continues, fluid pressure increases in response to bearing the increasing weight of the overburden (Satyana, 2008).

Tirtosari
Tirtosari geothermal prospect is located at Pragaan District, Sumenep, East Java (Madura). The existence of a geothermal prospect in this area is indicated by the appearance of hot springs in the village of Aengpanas. Geological setting of this area is dominated by sedimentary rock from Madura Formations and Ngayong Formation, which consist of limestone reefs, dolomite limestone, and sandstone.

Tirtosari geothermal prospect expected to be a geopressured system associated with depression zone / sedimentary basin that extends from west java to east java, namely: Bogor - North Serayu - Kendeng - Madura Strait depression zone.

CONCLUSION

From the previous explanation of each prospect, we have made the conclusion that in Java we found there were 2 big type of geothermal system in Java. Its the volcanic system and non volcanic system. The volcanic system consist of three type, the first one is the young volcanic system (Quarternary volcanism), old volcanic system (Tertiary volcanism) and outflow structure system.

The young volcanic system were represented by Mt. Lawu, Ungaran as we talk above which have the quartenary heatsource, mostly high temperature and
the manifestations that presence were almost complete like: fumarola, steaming ground, hot springs, silica sinter and travertin, mud pools and acid crater lake.

Old volcanic system were represented by Umbul telomoyo and Rejosari Melati which have the tertiary heat source and mostly medium temperature and the manifestation that presence were warm springs. Outflow structure were represented by Cisolok-Cisukarame and Bumiayu which have the medium temperature and the manifestation that presence were hot springs, warm springs and travertin (Bumiayu). Conceptual model for volcanic systems is similar among three types, the differences are the presence of active thermal manifestations on the surface. Figure 2 show the conceptual model of Mt. Arjuno-Welirang and Cangar geothermal prospect.

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Table 1. Characteristics of active surface features and depositions of each system.

<table>
<thead>
<tr>
<th>Surface Manifestation</th>
<th>Non volcanic</th>
<th>Old volcanic</th>
<th>Outflow structure</th>
<th>Young volcanic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Warm Spring</td>
<td>x</td>
<td>x</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Neutral hot spring</td>
<td></td>
<td></td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Add hot spring</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Travertine</td>
<td></td>
<td></td>
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<tr>
<td>Silica Sinter</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Mudpool</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Add crater lake</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fumarola</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Estimated reservoir temperatures are based on water and gas geothermometer. The reservoir temperature of each system is showed in Figure 3. The Young volcanic is the highest reservoir temperature > 200°C, and Old volcanic, Outflow structure and non volcanic is < 200°C.

Figure 3: Estimated reservoir temperature of each system.

Future studies were necessary to improve this paper furthermore, and to make some recomendation which area were prospect to develop more over.

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REFERENCES


Sumber Daya Mineral, Pemerintah Daerah Jawa Barat.


