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Geoscientific Studies of Geothermal Resources of Gunung Endut Area, Banten Province, West Jawa-Indonesia

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ABSTRACT

The Gunung Endut geothermal area is located in Lebak Regency, Banten Province-West Jawa,Indonesia Its located about 40 km south of Rangkasbitung.the town city of Lebak Regency. The purpose of the studies are to develop the prospect area in order to support the Indonesian Government Policy to utilize the clean, environmentally and sustainable energy along with to reduce the use of fossil energy as an electrical power plant in the future. Geoscientific studies (geologi-geochemistry and geophysics) in the Gunung Endut geothermal field is to delineate the geothermal potency of the area. The results of the study indicates that the hot water surface temperatures vary from 53ºC to 88ºC, with neutral pH. Based on the surface temperatutre data and referring to SiO^2 and NaK geothermometry equation, therefore, the calculate of sub surface temperature is 162ºC dan 180ºC and can be classified as an intermediate enthalpy. The prospect area is about 4.5 km^2, with the possible resources are 60 Mwe.. The heat source of the geothermal system in the area is considered to be associated to volcano-tectonic activities.

1. INTRODUCTION

The Gunung Endut geothermal field lies along the volcanic belt of Indonesia that is stretching along 7000 km from North Sumatra-Jawa-Bali-Nusatenggara-Banda –Halmaher-North Sulawesi (figure-1. Administratively, the Gunung Endut geothermal field lies aproximately 40 km South of Rangkasbitung, the Capital City of Lebak Regency, Banten Province-West Jawa, Indonesia. The survey area can be reached from Jakarta using vehicle for 6-8 hours, and the UTM coordinates are 9261000–9274000 N and 639000–652000 E or 106º15'22" – 106º22'39" E dan 06º34'04" – 06º41'04" S). The area, since the Dutch era, has been surveyed by several geoscientist, some of them is Koolhoven (1939) Bemmelen, (1949), Prasetyo (1979), Saefudin (1987) and DIM (Directorate of Inventory Mineral), in 2006.

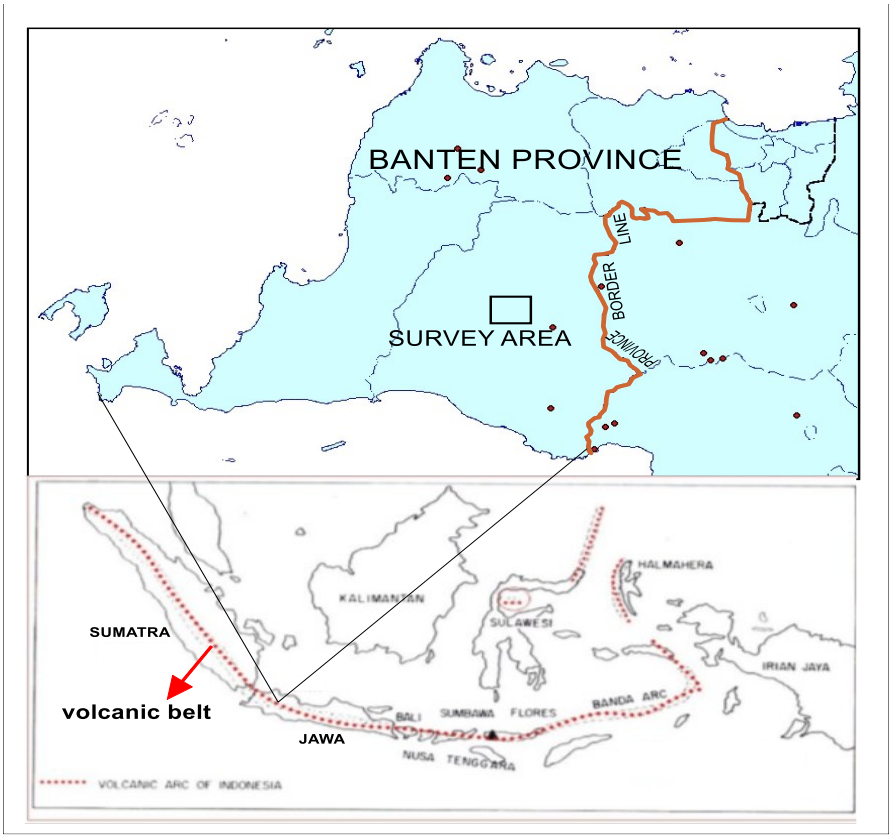

Figure 1: The location of Survey Area

The aims of the study is to investigate the potency of the geothermal resources in the area in order to support the Indonesian Government Policy to utilize the clean, environmentally and sustainable energy (geothermal) along with to reduce the use of fossil energy as electrical power plant in the future.

The geothermal prospect in the area is characterized by hot water, located 2 – 3 km of Bangkala village, in which the hot waters are found on the volcanic rock (breccia, lava and tuff) of the Gunung Endut. The manifestations is crop out in Cikawah and Handeuleum with the temperature range of 53 ° C to 88 ° C and normal pH. The manifestations are considered to be associated to volcano-tectonic activities, (Idral, 2010, 2015).

1.1 Methods

To gain of the aims, the integrated geoscientific methods such as, geology, geochemistry and geophysic have been carried out in the Gunung Endut geothermal field, Banten Province, covering an area of 169 km^2 (13 x 13 km^2). Geological method consists of detail geological mapping (rocks sampling, petrography and altered rock analysis, K/Ar dating); geochemical method is covering observation, collecting sample of hot water, gas and laboratorium analysis, whilst geophysical methods are covering collecting data and rocks sample, using gravity, geomagnetic and DC-resistivity meter equipments.

1.2 Regional Geology

Stratigraphically the regional geology of the Gunung Endut Geothermal area (figure 1-A) is composed of (young to old) (DIM 2006):

The Gunung Endut volcanic rokcs of Pleistocene age (Qpv), consist of volcanic breccia, lava, tuff and its deposited as land environment and it is considered to be the product of the Gunung Endut volcanic.

The Citorek Tuff of Pliocene age (Tpv), it is characterised by epiclastica tuff deposit with dacite and pumice in compoosition.

Andesite rocks of Tertiary age (Tma),

Calcite rocks of Tertiary age (Tmbl) ,member of Bojongmanik formation,

Badui Formatian of Tertiary age. (Tmd), is characterized by coarse clastic sediment and deposited as marine to land environment,

Calcite rocks of Midle Miocene age (Tmdl), the rocks is a member of Badui Formation, the rocks is deposited in shallow marine environment..

Clay stone of Midle Miocene age (Tms), it is member of Sareweh Formation.Its consists of clay stone, sand stone, marl stone and tuf The rock is characterised by find clastics rocks,

Cimapag formation of early Miocene age. (Tme). consist of breccia or conglomerate in which they component is composed by detrital of older rocks, lava and altered rocks.

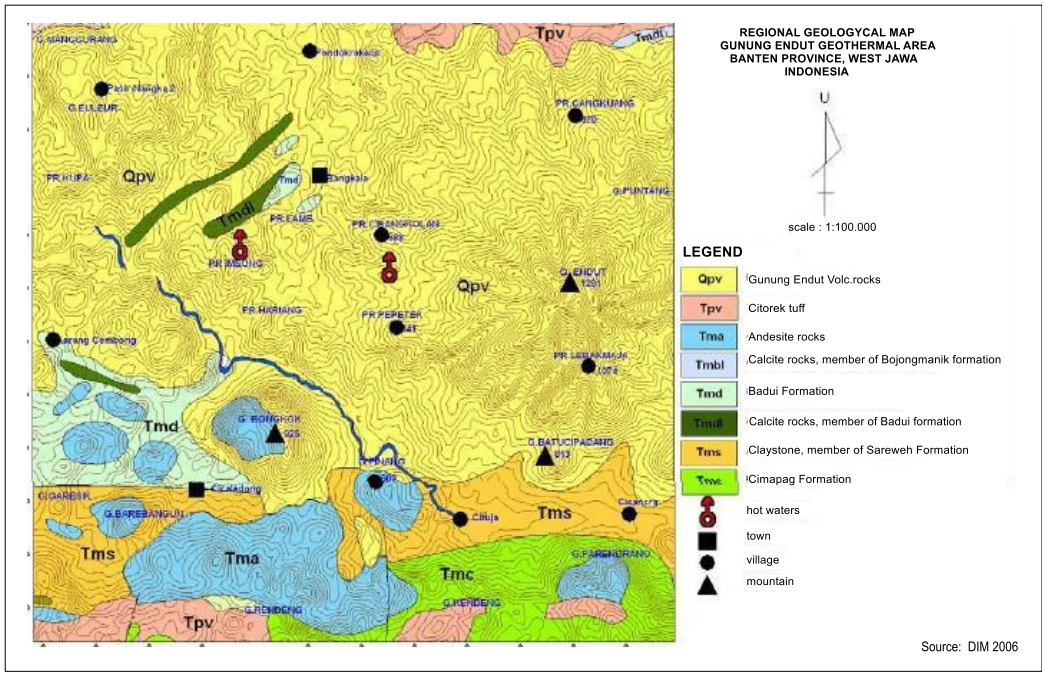

Figure 1-A: Regional geology of Gunung Endut Geothermal Area

2. SURVEY RESULTS

2.1 Geology

The total of 98 geological observation point have been carried out in the area and collecting 38 representative of rock samples, see figure 2, inwihich 10 of them is used to petrography analysis and 1 sample for fission track analysis/zircon mineral, (DIM 2006).

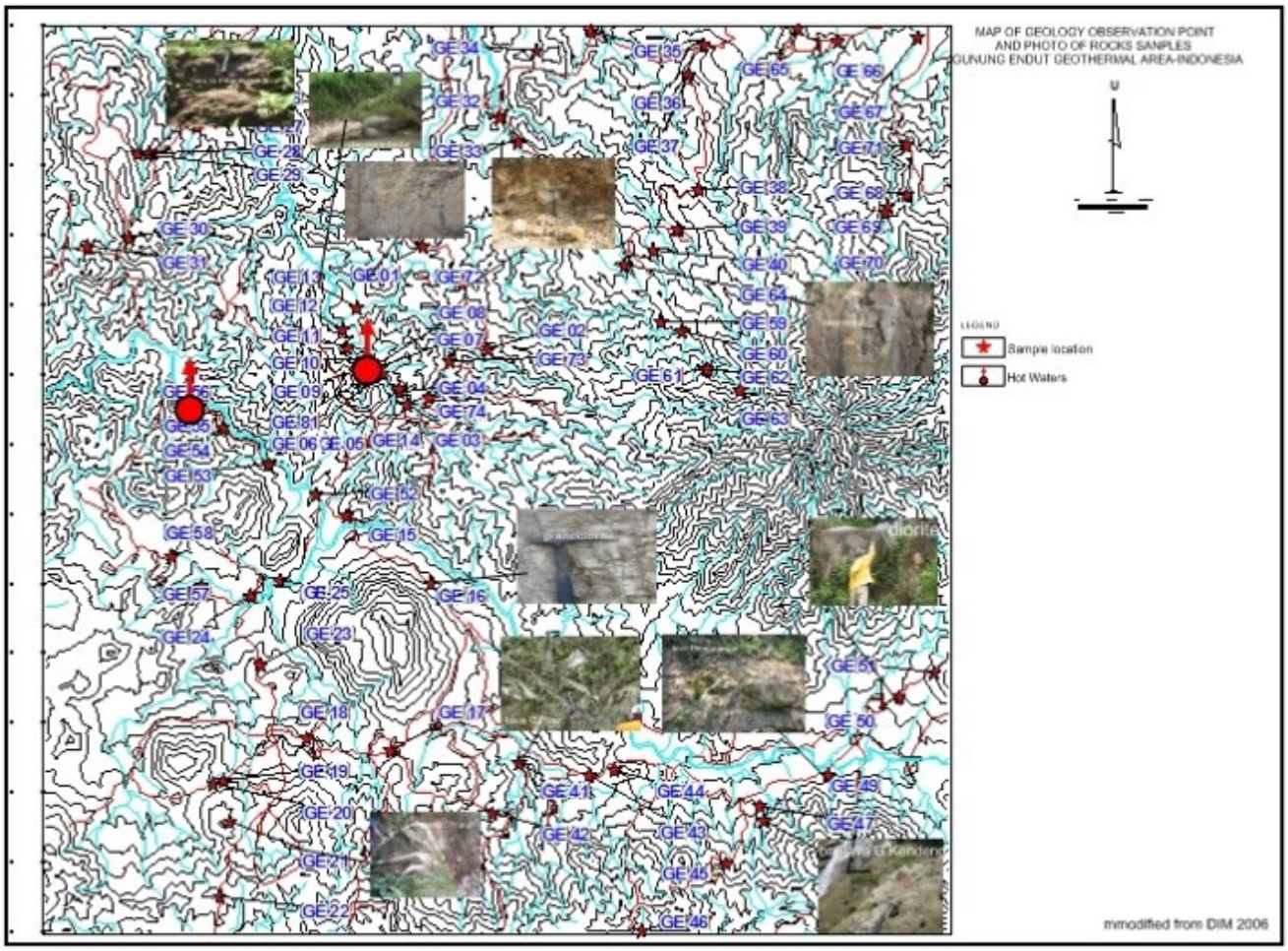

Figure 2: Geology Obsevation Point and some Photos of Rock Samples of Gunung Endut Geothermal Field

2.1.1 Stratigraphy

The stratigraphy of the Gunung Endut Area is composed base on they relation among an each of rocks unit. Based on the field survey result, the rock of the Gunung Endut geothermal field can be classified as follow, see fig 2-A, (young to old) :

-. Alluvium rocks of Quaternary age (Qal),
-. Quaternary volcanic product of Gunung Endut), according to Koolhoven (1933) and, Bemmelen, (1949) is Pleistocene age, its consist of Gunung Endut Lava-3 (Qle) ; Brecia-lava Gunung Endut (Qbe); Lava Gunung Endut-2 (Qle); Pyroclastic Flow of Gunung Endut (Qae); Lava Gunung Endut-1 (Qle).
-. Quaternary product of Gunung Pilar, is composed by Lava (Qlp) and Brx Lava Gunung Pilar (Qbp);
-. Intrusive rocks of Tertiary age, such as Granodiorite (Tgr) and Diorite (Td);
-. Tertiary age of Lava Gunung Pilangranal (Tlr);
-. Tertiary age of Brecia Lava Gunung Kendeng (Tbr)
-. Tertiary rocks of volcanic Pra Gunung Endut (Tlpe);
-. Tertiary Intrusive Andesite rocks (Ta),
-. Tertiary age of Bojong Manik Sediment Member (Tmb);
-. Unit Member of Badui Sediment of Tertiary age (Tmd)

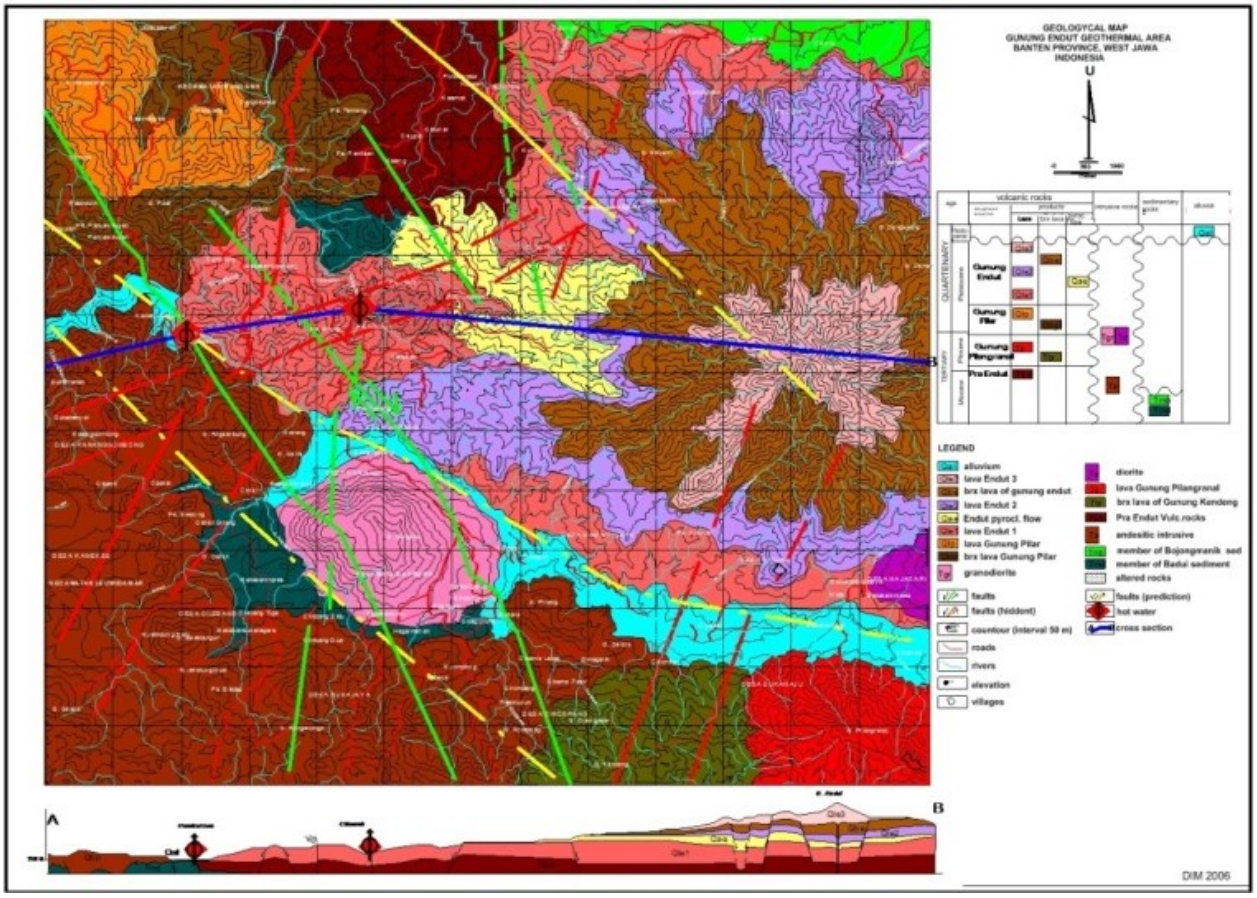

Figure 2-A: Geology and Structural Map of Gunung Endut Geothermal Field, Banten Province

2.1.2 Geological Structure

The geological structures of the area (see figure 2-A) is reflected by lineament, volcanic cone, geographic lineament, triangle facet, joints , rocks offset, slicken side, hot water manifestation and rock alteration, (DIM, 2006). Therefore based on those characteristic the structural geology of the Gunung Endut area consist of :

Normal fault of WNW – ESE, (280-300º E) direction that cause the intrusive and volcanic of Gunung Endut.
Strike- slip fault and normal rejuvenation with the direction of NE-SW (N-15-25 ºE) and then cut the exist rocks formation up to the basement of rocks and cause the Cikawah hot water crop out to the surface.
Strike slip-fault and normal rejuvenation with the direction of NE-SW (60-80 ºE) and then cut the rocks formation up to the basement rocks and cause sealing of the Cikawah.manifestaion,
The lineament of N-S (N 350-10º E) that cut the existingt structures.
Strike slip fault of NW-SE (320-340 ºE) direction, that is cut the existingt structures and rocks formation and cause Handeuleum hot water crop out to the surface.
Altered rocks (grey-white and red-yellow colour) is found around the Cikawah hot water and its consist of silicified breciated andesite, argilic clay contain opaline silica, and spot-spot of chlorite is alo oocured. In Handeuleum, is only argillic clay occured.

2.1.3 Geohydrology

The water re-charge area is covering +/- 45 % of the total survey area and it lies at an elevation of > 80 – 1250 above sea level. At this elevation the infiltration of meteoric water into the ground is passing through the fracture zones and rocks porosities and then accumulate as a ground water and as a catchment or reservoir area.. While the dis-charge area lies at an elevation of 0 – 80 m above sea level and covering +/- 38% of survey area, in this area (dis-charge) the ground water crop out as hot water or cold water. And-then, the run-off water area that is covering +/- 27% of the total area lies at an elevation 200 – 650 m above sea level. At this level the meteoric water can not penetrate to the ground but flowing as run-off water as/or to the rivers.

2.2 Geochemistry

The total of 118 samples have been collecting in the area, in which 114 samples are soil and CO_2 , the samples have been collecting from 7 gridding and random lines, whilst the rest is water sample that consist of 3 hot water and 1 cold water, (DIM 2006).

The geothermal manifestations (hot waters) in the area is found in Cikawah and Handeuleu. The Cikawah hot water is found in Sobang village in two locations. The first manifestation is called as APCK-1, the temperature is 80 ^{o}C with neutral pH (7.98), the second, located 50 m to the west of APCK-1, and is called as APCK-2 with the temperature of 53 ^{o}C and neutral pH (7.74), whilst the Handeuleum hot water (APHA) lies 2 km to the west of Cikawah hot water, and the temperature is 57^{o}C with neutral pH (7.70).

2.2.1 Fliud Characteristics

The result of the triangle diagram plottings (figure 3) using Giggenbach method (1988) are as follow :

Cl-SO4-HCCO3 plotting diagram indicates that the APCK-1 is chloride type, the type is also supported by silicified silica found in andesite rocks in the area, high chloride concentration in hot water is possibly also associated to deep water indication. While APCK-2 and APHA hot waters are associated to bicarbonate type.

Na-K-Mg plotting diagram shows all of hot waters lies in zone of partial equilibrium which is indicating the manifestation come out to the surface is influenced by interaction of fluid and hot rock before contaminated to meteoric waters. The interaction is also supported by isotope analysis result of all hot waters, in which all of it lies significantly in right hand side of meteoric water line

Cl-Li-B plotting diagram indicates all of hot waters are located in the middle of diagram, which indicates the balancing concentration of of Cl, Li and B occurred during the building process of neutral hot water in the area.

The result of isotope analysis of isotop ^{18}O dan ^{2}H (D) of hot water and cold water using sepectrometryc mass indicate that all hot water lie on the right hand side of the meteoric water line (^{18}O shift). It is an indication of the enrichment O18 of all hot water that is caused by the substitution reaction of O18 of rock with the O16 of hot fluid at the time of interaction of hot fluid and rocks before the hot rocks crop out to the surface. Meanwhlie, a cold water sample sample lies in line with meteoric-water line, see figure 3..

The sub surface temperature is estimated based on the surface geothermal manifestation data above and referring to SiO_2 geothermometry of Fournier (1981) equation, namely : T^{o}C = (1309)/(5.19 – log SiO_2) - 273.15, and NaK Geothermometry equation of Giggenbach,(1988), such as : T^{o}C = (1390)/(log Na/K + 1,75) - 273.15. Based on both equation, therefore the calculate of sub surface temperature is 162 ^{o}C dan 181 ^{o}C and can be classified as an intermediate enthalpy, (Badan Standarisasi Nasional,1998).

2.2.2 Soil and Gas (CO_2)

The soil temperatures vary from 24.3^{o}C to 36.6^{o}C (TAC), the variations give background value of 28.35 ^{o}C, threshold of 30.02 ^{o}C, and average value of 26.67 ^{o}C. Figure 3-A, shows the anomaly higher than 28.35 ^{o}C are found in Cikawah hot water and continue tu NE direction, while the temperature value that less than 26.^{o}C is distributed to the SSE,and NNE of the survey area.

The value of pH soils vary from 2.9 (point CD-2) to 6.92 (point E-5500), in which the background value is 6.07, threshold value is 6.60 and average value of distribution is 5.54. Figure 3-A, shows pH soils are dominated by the value of less than 6, while the value of > 6 and < 5 are spotted in certain area.

Th concentration values of Hg vary from 7 ppb (point E-1500) to 395 ppb (TAC), which is the background value is 149 ppb, and threshold value is 230 ppb, while average value is 69. Figure 3-A, shows that high Hg anomaly (> 150 ppb) lies around the Cikawah hot water, medium Hg anomaly (75-150mppb) is found to the center and continue to the NE of the area, and low Hg anomaly (less than 75 ppb) is distrubited almost all of the area.

The concentration of gas CO_2 vary from 0.13% (point E-0) to 1.73 % (point E-500). The background, threshold and average values of gas CO_2 are 1.26%, 1.63% and 0.88%, respectively. The high anomaly, > 1.5 % lies around Cikawah hot water and getting bigger to the NNE, medium anomaly, 1 – 1.15%, is distributed in the Noth and in the East of the area, whilst low anomaly, less than 1%, is found in the west of the area, see figure 3-A.

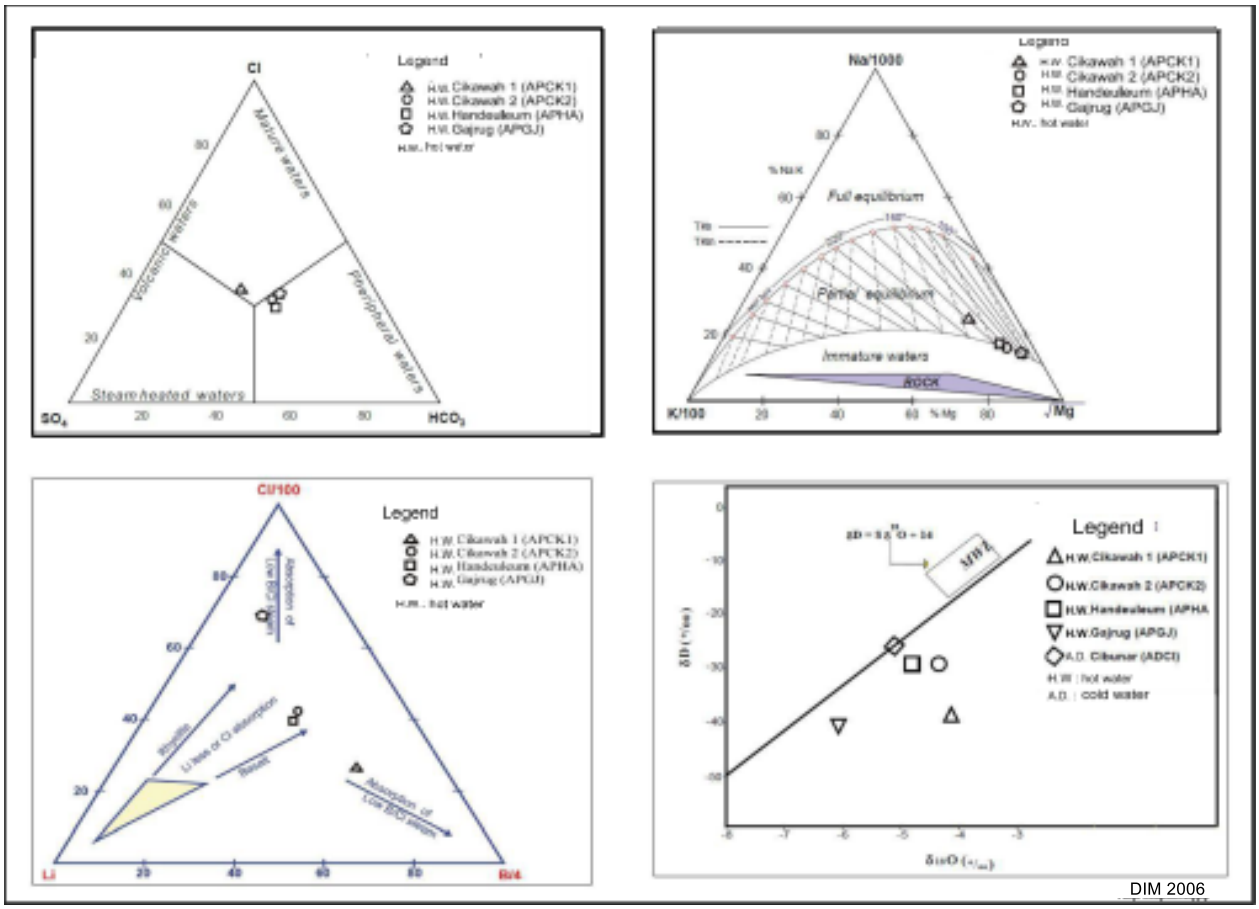

Figure 3: Triangle Plotting of Na, K, Mg; Cl- SO_4 -HCO_3; Cl-Li-B and Isotope Analysis Diagram of G. Endut Geothermal Area.

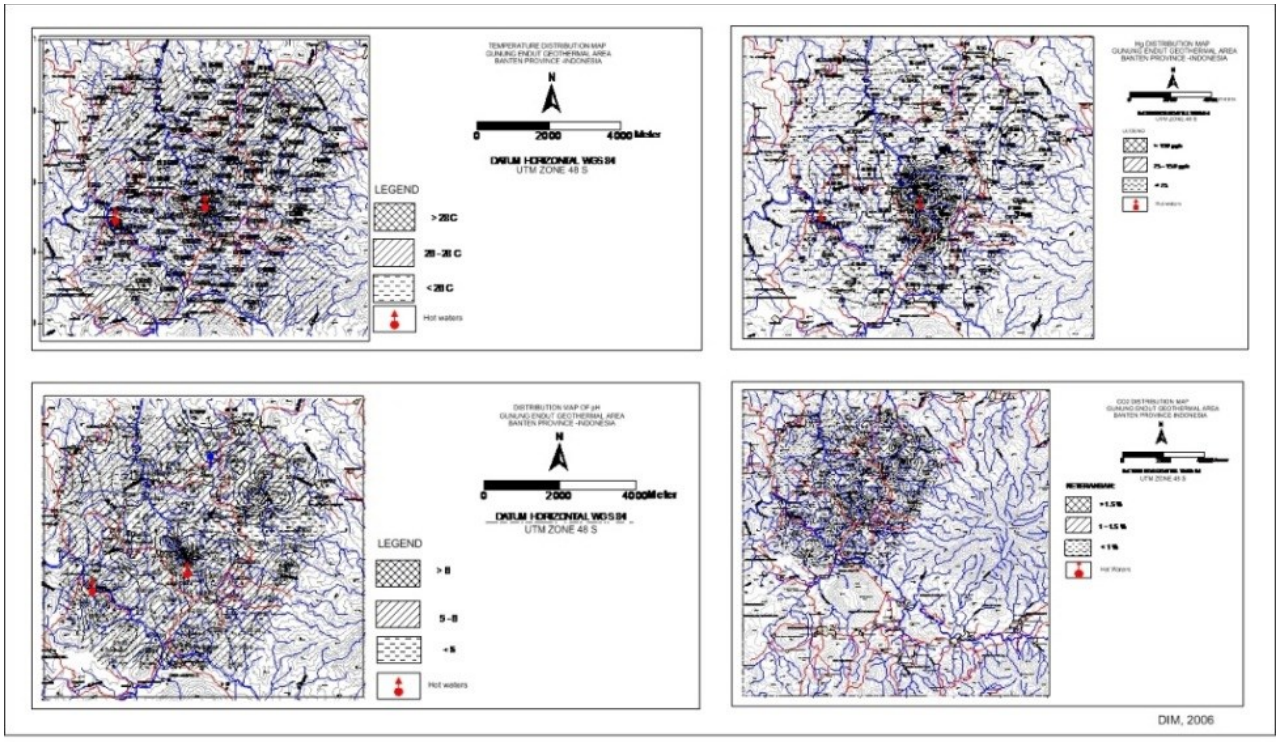

Figure 3-A: Map of pH, Temperature, Hg and CO_2 of Gunung Endut Geothermal Area, Banten Province

2.3 Geophysic

2.3.1 Gravity

The total of 247 data have been collecting from 247 observation points of random and 7 griding line, and collecting 8 representative rock sample for laboratory density measurement. The combine density of menasurenment and teoritical using Parasnis (1979) method are 2.65 gram/cm^3, and it is applied to analyze the data.

Generally speaking, the liniation of all anomalies (regional, bouguer and residual) are trending to NE – SW directions, in which to the NE the anomaly tend to decrease, whilst to the SW the anomaly is high especially around the manifestation. Relatively low Gravity anomaly to the NNE of the area is due to quarternary volcanik rock, such as: lava, brecci lava, pyroclastic flow, of G.Endut,. The relatively high gravity anomlay to the SSW direction is considered to be associtaed to intrusive rock underneath Gunung Bongkok and or G Angkaribung and imineralised lava volcanic rocks around Cikawah hot water (Lowless 1995), in which all of them have high density value. The Gravity liniation structures in the area is dominantly NNE-SW direction, whilst the NW-SE liniation structure lies in the southern part of the area, see figure 4.

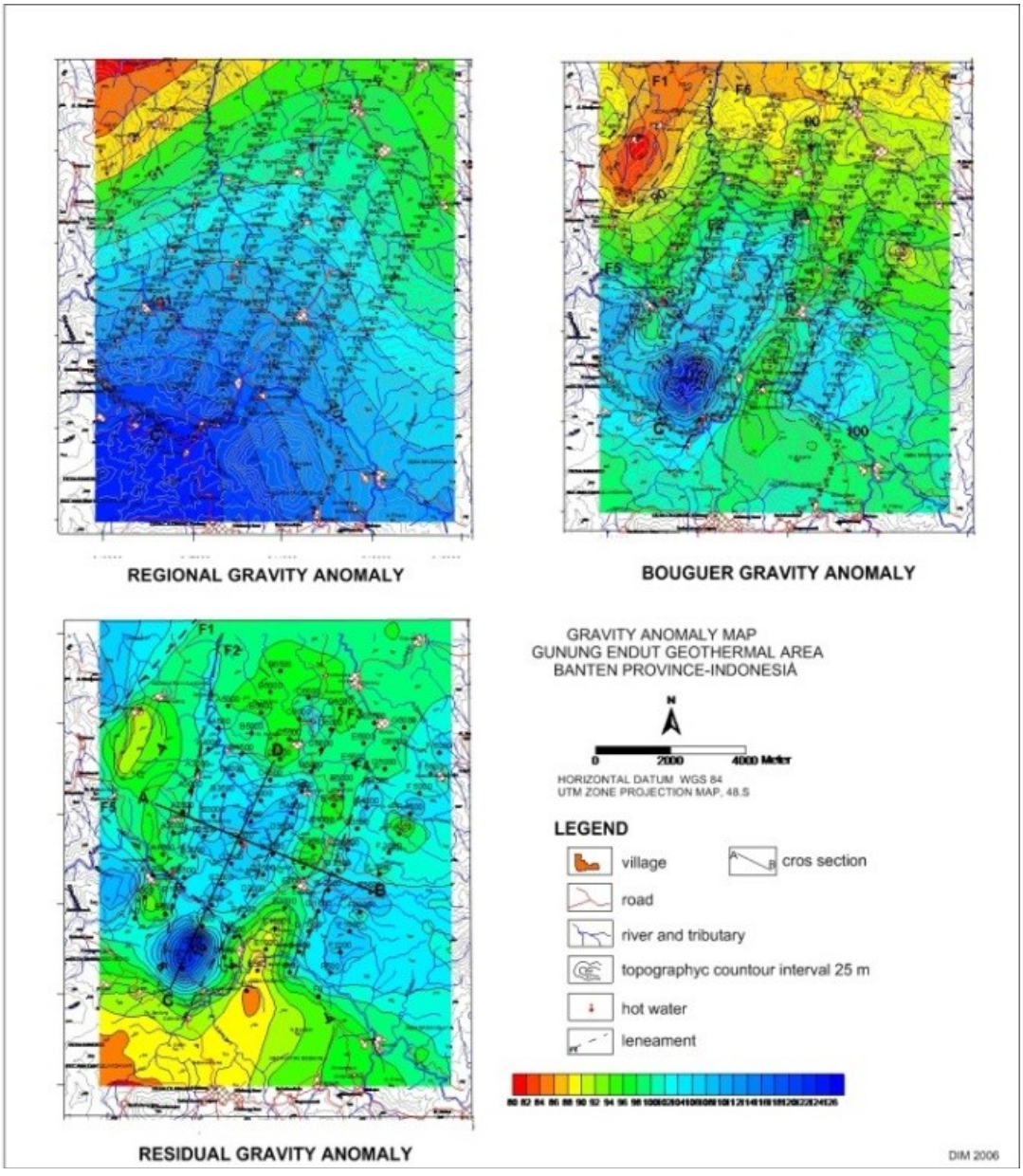

Figure 4 : Gravity Anomaly Map of Gunung Endut Geothermal Area, Banten Province-West Jawa, Indonesia

To identified the possible intrusive rocks occured in the area that is associated to the Cikawah and Handeuleum hot water, 2 x-section, line A-B and C-D, have been done, see figure 4-A.

The 2.5 D Gravity modelling of A-B line, show 2 relatively high (positive) density contras value, the first is found in the midle and the other lies in the eastern end of the cross section line. The high density contras value in the midle of x-section line is considered to be associated to silicified and mineralized (Lowless, 1995) of lava andesite that are related to the fault zone in the area, in which the fault is bielived to cause the Cikawah hot water come out to the surface as seen in the surface. Whilst the other high density contras value is assumed to be related to an intrusive rock underneath of the Gunung Endut. Mean while the relatively low density contras (negative) value in the cross section is believed to be refered to altered and and or weathered of volcanic product of Gunung Endut and Gunung Pilar. .

Th 2.5 D Gravity modelling of C-D line, is also shows 2 zones of relatively high density contras (positive) value, the first is found in the southern part and the second lies in the northern part of the cross section line. In the southern part, the high density contras value is enclosed by relatively low density contras (negative) value of weathered Quaternary product of Gunung Endut, whilst the high (positive) density contras value is assumed to be associated to intrusive rock of Gunung Angkaribung. . Whilst in the northern part, the relatively high positive density contras value is believed to be refered to unknown intrusive rock underneath, while medium positive density contras value that flank the high value of density contras is reckon as altered and mineralized (Lowless 1995) zone in the left side and an unaltered and un weathered rocks zone in the right side, both is a rock product of Gunung Endut as seen in the surface

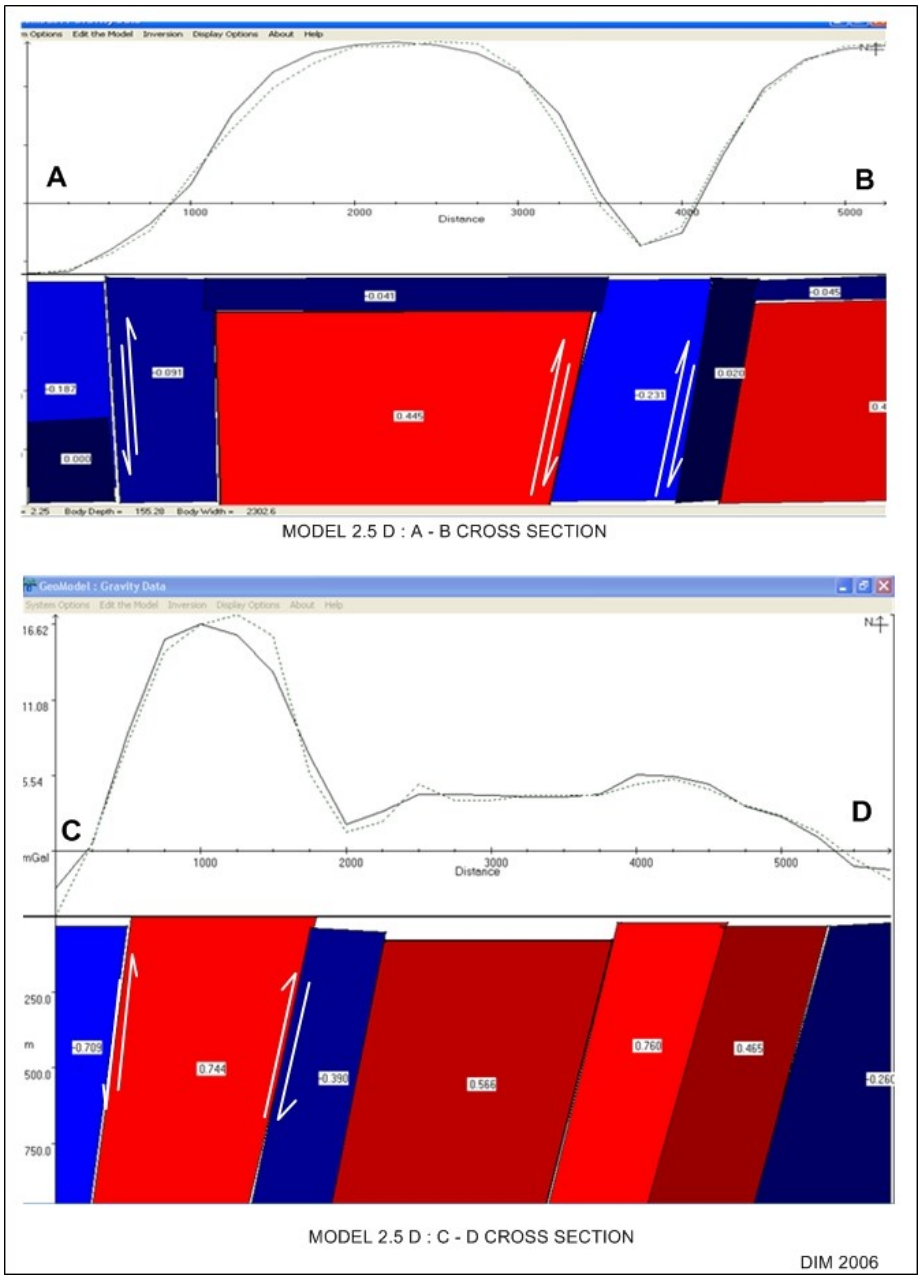

Figure 4-A : Gravity X-Section Map of Gunung Endut Geothermal Area, Banten Province-West Jawa, Indonesia

2.3.2 Geomagnetic

The total of 270 datas have been collecting from 270 observation points of random and 7 griding line and collecting 16 representative rock sample for magnetic succeptibility (K) measurement, in which the result indicates that its value range from 0.0 to 2,4 x 10^{-6} cgs. The low K value < 0.1 is non magnetic rock, such as limestone and altered rock, while the K value > 0.4 is fresh rock contain magnetic mineral such as andesite,
Residual magnetic anomaly map, see figure 5, is classified into relatively low, medium and high residual magnetic anomaly. In the area the relatively lens shape of high and low magnetic anomalies are distributed scatterly, whilst the medium magnetic anomaly is dominantly covered the entire area. High positive residual anomaly value around Cikawah hot water is bielive to be affected by intensive mineralization that occurred in the area. However, contrast to Cikawah, the Handeuleum hot water is located in low value of residual magnetic anomaly and it is considered to associated to altered non magnetic rock surrounding the manifestation.

The geomagnetic lineation structures are dominantly NW-SE direction, whilst the NNE direction is limited, as seen in figure 5.

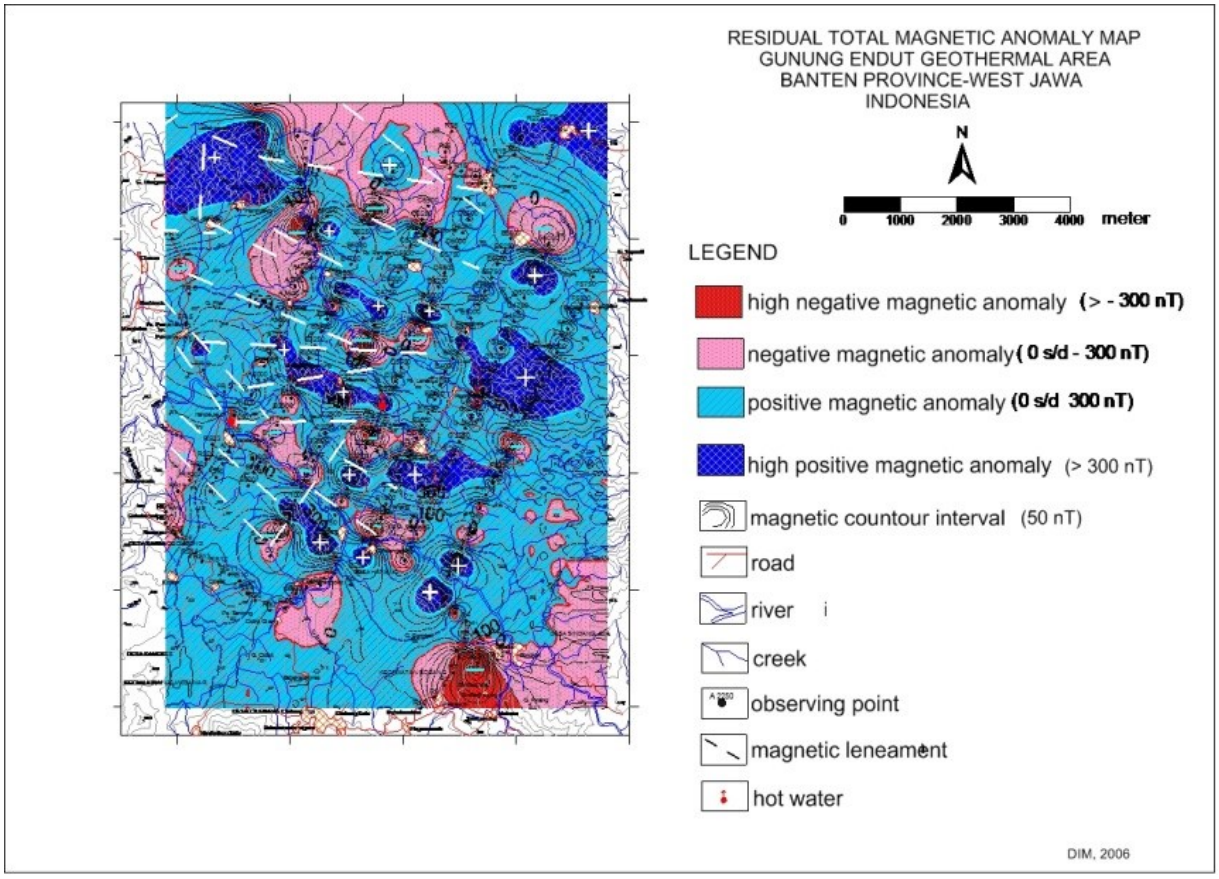

Figure 5 : Residual Magnetic Anomaly Map of Gunung Endut Geothermal Area-Banten Province

2.3.3 DC-Resistivity

Generally speaking, for all of AB/2 spread: 250 m, 500, 750 m and 1000m, see figure 6, show almost the same pattern in which relatively medium to high anomaly surrounding both of geothermal manifestations. Meanwhile the pattern of lineationis also relatively the same, namely west- east direction. However, the range of resistivity value up to AB/2=750 is relatively tend to decrease, and then the value range increase to depth (AB/2=1000m). The relatively low resistivity value (< 50 ohm-m) is possibly associated to sedimentary rocks underneath, whilst relatively medium to high resistivity value (> 50 – 240 ohm-m) is believed to be related to volcanic rocks (andesite) of Gunung Endut,

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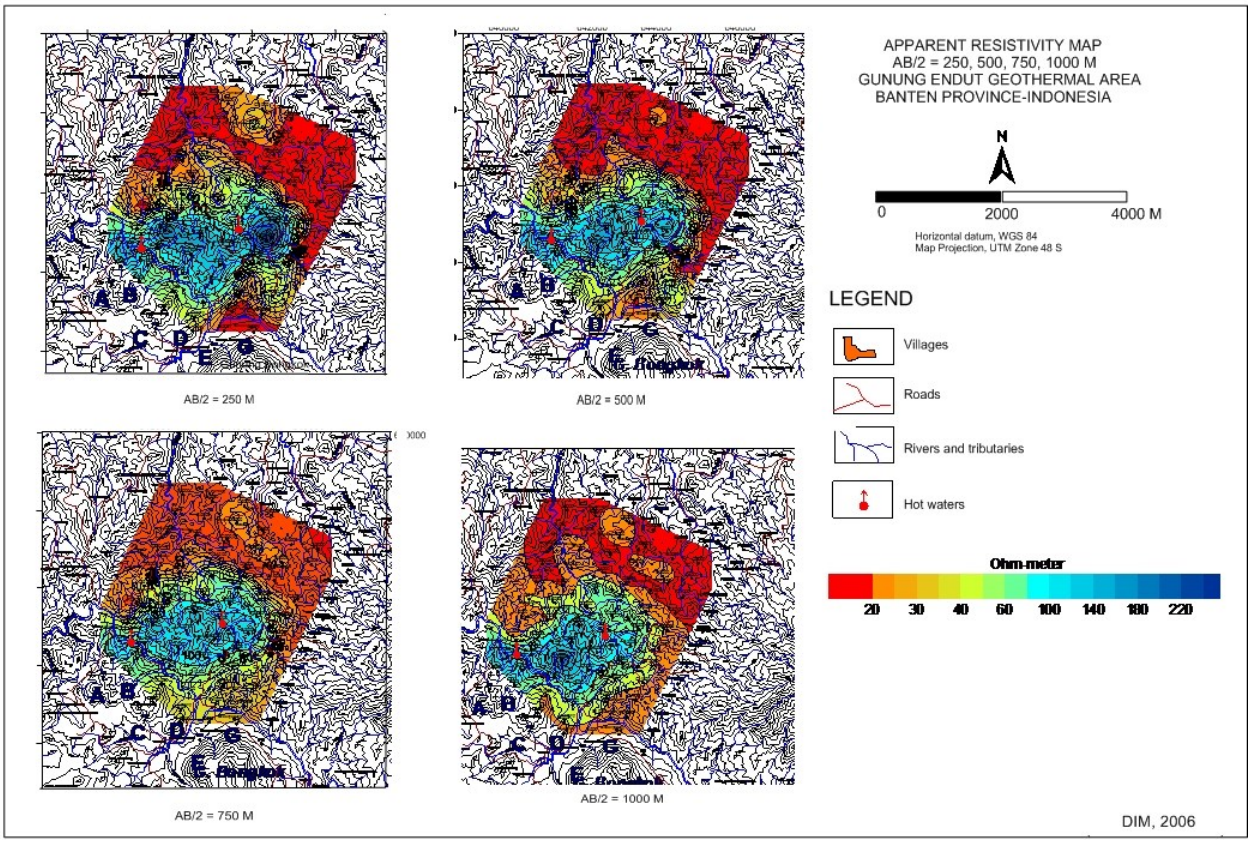

Figure 6 : Apparent Resistivity Map (250-5000-750-1000m) of Gunung Endut Geothrmal Area Banten Province

Figure 6-A shows that the true resistivity x-section of line D and E, are nearly the same condition, in which the altered rocks (clay cup) with low resistivity value (5 to 30 ohm) is found at the depth of 500 – >1000m) and the thickness is unknown, and then it is covered by rock layer of low to high resistivity value (6 – 2000 ohm-m). The low resistivity value is possibly related to altered and or wethered rocks of tertiary clay stone, whilst the high resistivity value is believe to be related to fresh volcanic product of Gunung Endut and or possibly intrusive rocks

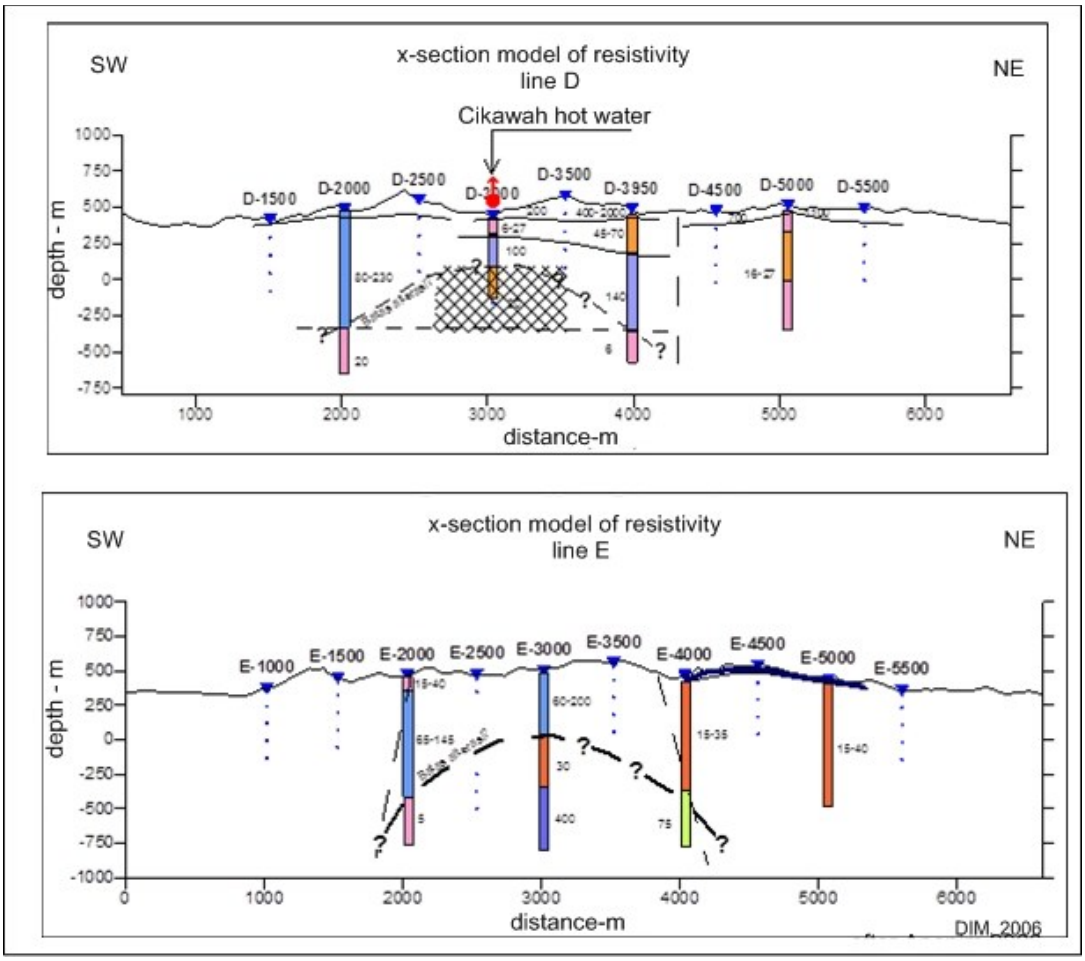

Figure 6-A: True Resistivity X-Section Model of Line D and E of Gunung Endut Geothermal Area

3. DISCUSSION

3.1 Tectonic Activities

The occurence of geothermal system in Indonesia is, generally, associated with quarternary or recent volcanism and non volcanism. The Gunung Endut geothrmal field lies in the volcanic belt of Jawa-Sumatra in the western side of Indonesia. As the field lies in a volcanic belt, therefore the Gunung Endutt geothermal prospect is considered to be associated with volcano-tectonic activties. The assumption is supported by geology, and geophysics data as mention in section 2.1 and 2.3.

The evolution of volcano-tectonic activities in the area occurred during the Oligocene up to the Middle Pleistocene time, that caused the occurence of folding, faults, joints, lifting, depression and deposition. The present of faults structures that is trending N20°E and N 330°E control the manifestations such Cikawah and Handeuleum to the surface respectively. The cross cut structures caused the hot fluids goes up to the surface and so altered rocks occurred, i.e. around Cikawah and Handeulemum areas. The present of altered zone around Cikawah hot water is not supported by low value of geophysics method as usual, or in other word the relatively medium value of geophysical anomaly around the manifestations is possibly due to the intensive mineralisation in Cikawah and altered rocks in Handeuleum, as mention in section 2.3. All those conditions are a good indicators for the development of geothermal system in Gunung Endut area. Therefore based on geoscientific data, the geothermal system of the Gunung Endut geothermal field consists of hydrogeology, fluid reservoir, clay cap, reservoir, and heat source, (see figure 7).

3.1.1 Hydrogeology

Hydrogeology of the area is classified into three category, such: recharge, discharge areas and run off waters. Meteoric water penetrate into the rocks after passing through the high permeability rocks such cracks and joints, and then keep the water in high porosity rocks as deep or short aquifers, called recharge area and its found at moderately deeping morphology around the manifestation. Discharge area occured around river flow zones or at relatively flate morpohology. Run off water occured when meteoric water relatively small or can not penetrate into the rocks and will flow as run off waters or into the river. Both hot water occured along the river or between a discharge area and run off water. The meteoric water, that penetrate into the rocks via primery and or secondary permeability of rocks,

and then the waters is heated up by heat source via conductor rocks by convection and or conduction, after that it goes up to the surface as hot waters

31.2 Fluid Reservoir

Hot fluid underneath goes up to the surface by convection via permeable rocks, fracture and fault zone then crop out as a hot water. As explain previously in section 2,2, the hot water crop out to the surface with vary temperature, and normal pH, such as Cikawah-1, T:80 ^{o}C, pH:7.98; Cikawah-2, T:53 ^{o}C, pH:7.78; and Handeuleum, T: 57 ^{o}C, pH 7.74.. The CIkawah 1-2 are chloride type, while Handeuleum is bicarbonate type. Based on all of the fluid characteristics, therefore the Cikawah hot waters is up flow and Handeuleum is out flow types, whilst the geothermal system of both manifestation is water heated domination reservoir system

3.1.3 Clay Cap

The clay cap is considered to be an altered volcanic rock and volcanic litho cap intrusive as a result of contact between hot fluids and those rocks, and is found at the depth of > 550 m below the Cikawah hot water or observed point of D-3000 and getting deeper to the left and right sides, (Figure 6-A). All geophysical (gravity, geomagnetic and resisitivity methods).data as mention in section 2.3. the anomaly values around both of manifestation is relatively medium anomaly value that is due to the intensively mineralization occurred around the Cikawah hot water, whilest in Handeuleum is considered to be related to the dominantly fresh un weathered rock of Gunung Endut volcanic product compared to altered zone of the same volcanic product around the manifestation, as expalained in section 2.1.

3.1.4 Reservoir

A reservoir is aplace where accumulate fluids are heated up by heat source. Resevoir occured as a result of tectonic processes, inwhich joints, cracks and faults that acts as secondary reservoir permeabilities, developed during the time. The zone of reservoir is considered to be permeable zone of Cimapag and Sareweh Formations. Based on resistivity data the top of reservoir layer with the resisitivity value of 400 ohm-m exist at the depth of > 1000 m below observation point of E-3000 (figure 6-A) and the thickness of reservoir is unknown as the resistivity data is only identified the top of reservoir.

3.1.5 Heat sources

Based on geophysical (gravity cross section) data there is an indication of stock-like intrusive body underneath the Cikawah and Handeuleum geothermal manifestations, (figure 4-A). The present of stock-like intrusive body is also supported by the present of altered and intensive mineralization around the Cikawah manifestation. All those data indicates that the heat source is considered to be a concealed stock-like intrusive body? that is caused by volcano-tectonic activities.

The Conductive rocks is considered to be basement rock of Cimapag Formation (Early-End Miocene age), in which the formation is might be recrystallize and silicified. Then the thermal conductivity goes up via the this formation and then the hot water occurs.

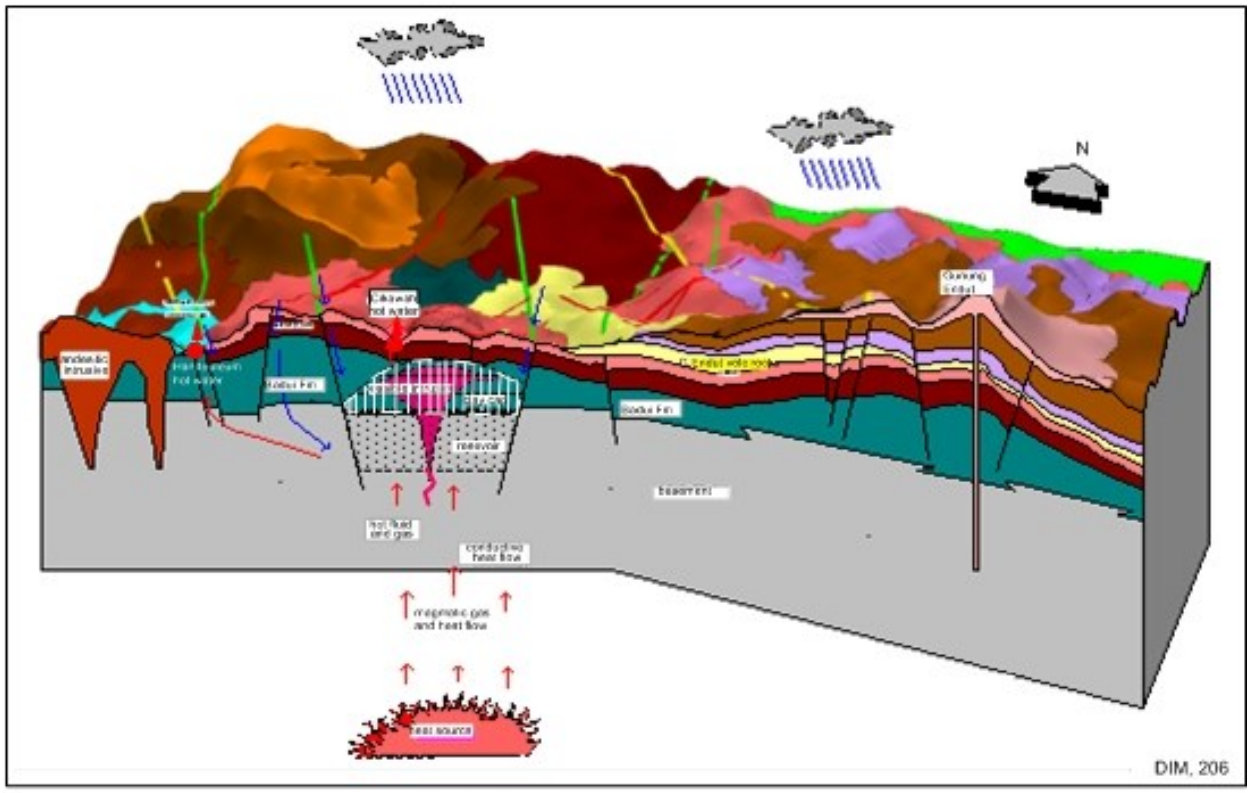

Figure 7 : Cartoon Model of Gunung Endut geothermal sytem

3.2. Prospect Area and Potency of Energy

Based on integrated geoscientiefic study of Gunung Endut geothermal field, the prospect area is 4.5 Km^2, see figure 8. As explained previously in section 2.1 and supported by section 2.3,. the Cikawah hot water is crop out to the surface is control by fault of N20°E direction , in which West bloc is relatively goes up compare to East block, mean while the Handeuleum hot water is control by fault direction of N330°E, in which SW block is relatively goes up compare to block NE

The potency of energy of both area, based on calculating reservoir temperature of 180°C, as explained earlier in section 2.2, therefore energy potency is 60 Mwe.

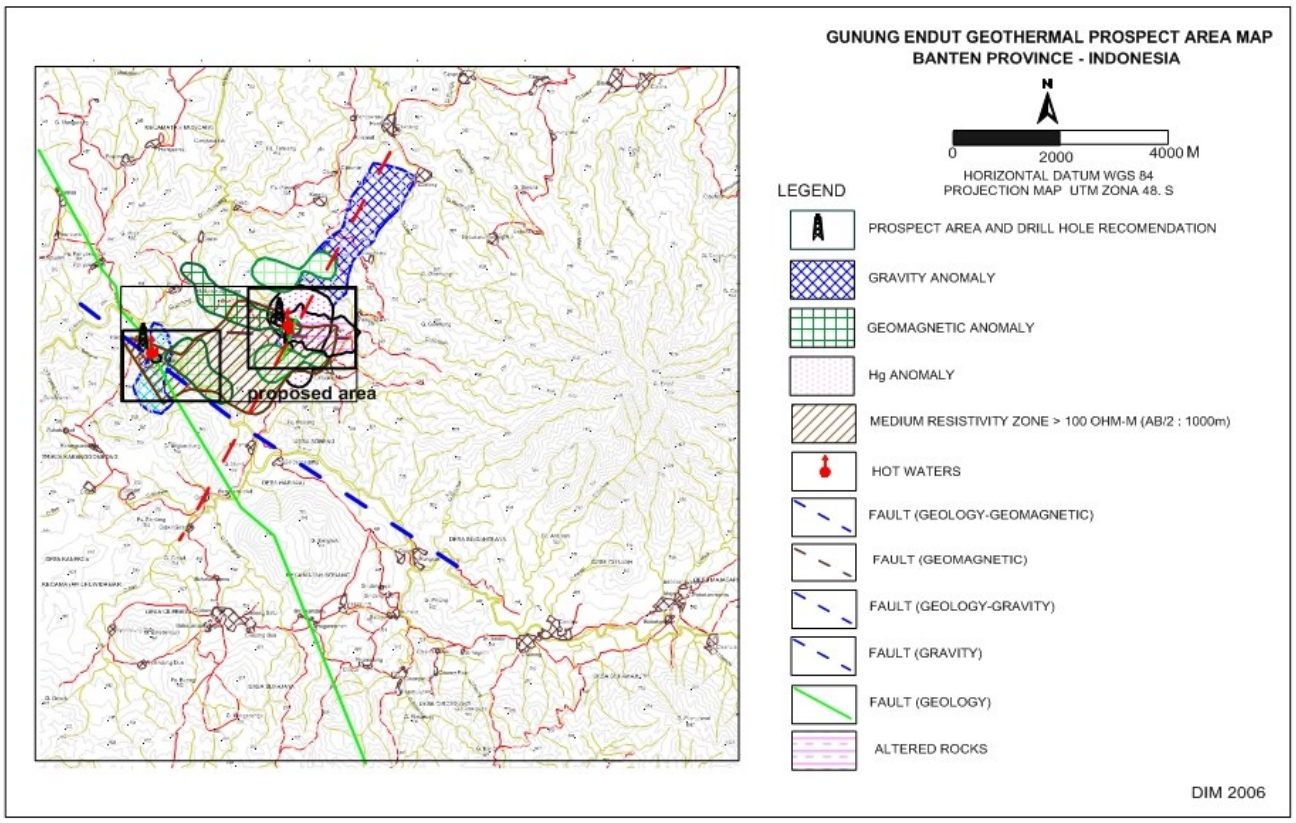

Figure 8 : Gunung Endut Geothermal Area Prospect

4. CONCLUSION AND RECOMENDATION

The geothermal system of the Gunung Endut area lies in Quartenery Volcanic environment with the estimated subsurface temperature of 180°C and belongs to intermediate enthalphy. The prospect area of The Gunung Endut geothermal field is characterize by relatively moderate value of geophysical anomaly (gravity, geomagnetic and resistivity) and is followed by high geochemical of Hg value around the manifestation, and covering wide area. The Cikawah hot water is considered as an up flow zone type, whilst Handeuleum hot waters is belong to an out flow zone type. The depth of reservoir zone is considered to be over then 1000 m depth. The wide of the prospect area is 4.5 km², with the potency of 60 Mwe.

To develop the area it is recomended that to do the MT method to get more accurate data and then is followed by drilling at observed point of D-3000 (Cikawah) and A-900 (Handeuleum), after combining the geology, geochemical, geophysic and MT methods.

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