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TEMPERATURE OF GEOTHERMAL RESERVOIR "KU" FIELD ANALYSIS BASED ON SECONDARY MINERALS AND GEOCHEMISTRY WELL "X" PANGOLOMBIAN DISTRICT, MINAHASA, NORTH SULAWESI

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Abstract

Geothermal is one of alternative energy which is very potential to produced in Indonesia because Indonesia have 40% world geothermal reserve . Nowadays, geothermal potential in Indonesia up to 28,5 Giga Watt (GW). Whereas Installed Geothermal Power Generator only about 1948,5 MW. North Sulawesi is one of geothermal generating area in Indonesia, spesifically in Minahasa Compartment. Research area geomorphologically consist of Volcanic Hill Unit, Volcanic crater lake Unit, Tampusu Volcanic slope Unit, Kasuan Volcanic slope unit, and Tondano Caldera slope Unit. Research area composed of Volcanic products with volcanostratigraphy from the youngest is Pangolombian Volcanic Breccia Unit, Tampusu Basaltic Andesite lava unit, Linau basaltic andesite lava unit, and kasuan basaltic andesite lava unit. Geothermal manifestation in research area consist of Linau Fumarol, Leilem Hotspring, Lahendong I and II Hot spring, Leilem Mudpool. Fluid geochemistry analysis shows all manifestation samples are steam heated water and immature water. While well "X" fluid sample shows Sulphate-Chloride water in partial equilibrium to immature condition. Hydthermal alteration in well "X" consist of Kaoline±Smectite±Chlorite zone, Kaoline±Illite±Sericite zone, and Epidote±Hematite±Chlorite±Illite zone. Geothermal reservoir temperatur based on Linau Fumarole Geothermomether about 292°C – 304°C, fluid well "x" geothermomether about 276°C – 294°C, ancient temperature based on secondary minerals about 230°C – 290°C, and measured temperature from temperature graph on well "X" about 276°C - 294°C. Depends on reservoir temperature, "KU" Geothermal Field is High Temperature Geothermal System.

Keyword : *Geothermal, Temperature, Alteration, Geochemistry, North Sulawesi*

INTRODUCTION

Indonesia is an archipelago, geologically Indonesia is an area where there are three tectonic plates (Indo-Australia, Eurasia, and Pasific). Interaction of those plates has important role in the formation of volcanoes in Indonesia and the complexity of geological structure. These conditions make Indonesia has a lot of energy resources and one of them is geothermal energy. Geothermal energy is one of alternative resources and very potential to developed in Indonesia because Indonesia has 40% of world geothermal reserves. This circumtance caused by Indonesia has 129 active volcanoes. Nowadays, geothermal potential in Indonesia up to

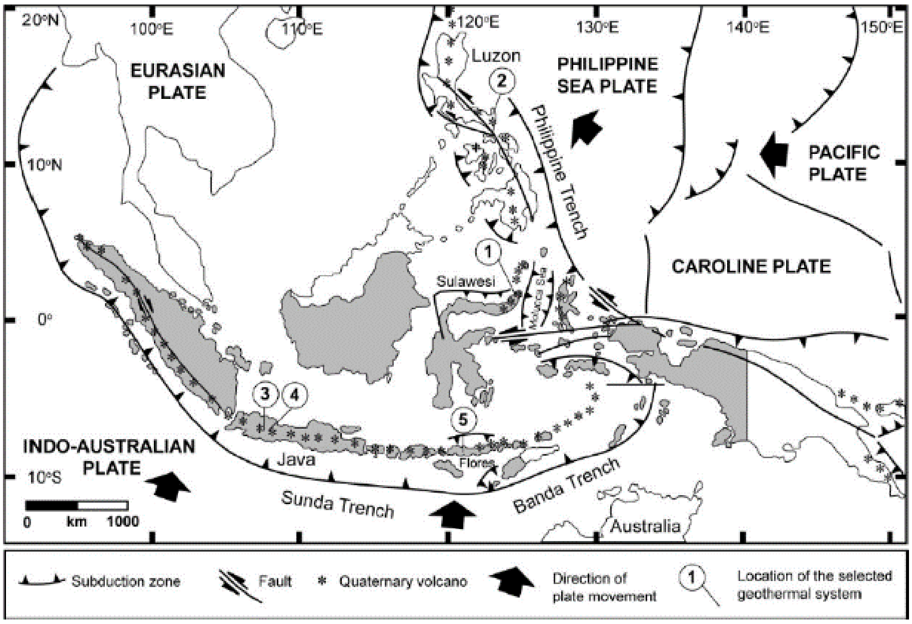

Figure 1. Plate movement in Indonesia (Kavalieris, 1992)

28,5 Giga Watt (GW) consists of geothermal reserve about 17,5 GW and geothermal resources about 11 GW. Whereas Installed Geothermal Power Generator only about 1948,5 MW (Kementrian ESDM, 2018). Thus, we know that Indonesia has great potential to develop geothermal electricial generator. Beside, geothermal energy is renewable and clean energy

REGIONAL GEOLOGY

Geology of North Sulawesi

The formation of Sulawesi is caused by the movement northward of Australia plate and anti clockwise rotation of New Guniea which formed about 5 million years ago (Katili 1990, in Siahaan, 2005). Interaction of three giant plate (Southeast Asia, Pasific, Indo-Australia) has a major role in East Indonesia tectonic framework from mesozoikum to kenozoikum (Hammilton, 1979). During this period, the east margin of southeast asian plate in Sulawesi involved at least the subduction event from the west. Sulawesi is an island that has an area of about 172.000 km^2, being the third in area of the larger Sundaland. Sulawesi in entirely occupied by mountainland being one of the most mountanious of the larger islands of the archipelago (Bemmelen, 1949).

North arm Sulawesi has three compartments:

1. Minahasa compartment (NE-SW)
2. Gotontalo compartment (E-W)
3. Neck Compartment (N-S)

Minahasa compartment is a part of Sangihe ridge which is formed in the volcanic arc. The Northesast edge of North arm Sulawesi, Minahasa compartment, develop Sangihe volcanic arc extend from Sulawesi to Mindanao. at both side, the active ridge bordered by subduction zone: North Sulawesi trench to Sangihe trench. At the middle part of plate interaction, a compression existed and formed a huge dome (Van Bemmelen, 1949). The ridge's basement formed during Miocene which consisted of pyroclastic sequences and alternation of lava flow and sedimentary formation. In the late period, Minahasa compartment begin appeared and formed a volcanic island.

Quaternary volcano is not found in Gorontalo and Neck compartment. These compartments dominated by the older rocks like granite, schist, nad the end of volcanic activity. Thus, geologically Gorontalo and Neck compartment is more stable than Minahasa compartment (Siahaan, 2005).

Minahasa compartment is characterised by the formation of volcanic belt, consists of Mt. Soputan, Mt. Lokon-Empung, Mt. Mahawu, Mt. Klabat, and Mt. Dua saudara wich trending SW – NE.

Northarm Sulawesi fault pattern is formed by the movement of Sulawesi oceanic plate from the north and small plate called Tomini plate from the south. This plate interaction makes north arm Sulawesi moves eastward and collided with Maluku oceanic plate that move westward. .

Volcanostratigraphy of Minahasa can be divided into three units, they are Pre tondano, syn Tondano, and post Tondano unit.

The basement of Pre Tondano unit composed by thick hyaloclastic rocks, basaltic andesite, andesite, alternation of pyroclastic and sedimentary rocks that found in Lahendong field well.

Tondano unit consist of ryodacitic pumice and ignimbrite on the upper part. Whereas the effect of microdiorite intrusion at the lower part is difficult to determine (Koestono, 2010).

Depend on the presence, post Tondano unit has relation with Pangolombian depression and can be divided to two sub units, they are:

1. Pre Pangolombian sub unit
2. Post Pangolombian sub unit

Pre Pangolombian sub unit consist of baslatic andesite lava which deposited om the north part and south part from Pangolombian depressio. Post Pangolombian sub unit consists of some of eruption product which located at the middle part of the depression.

Tectonically, there are five main structures that controlled north Sulawesi, they are Pangolombian rim, and faults trending NE-SW, E-W, NW-SE, N-S (Koestono, 2010).

Geology of Pangolombian

Drainage pattern of Pangolombian

Drainage pattern of Pangolombian is made by tracing the stream on the valley. The stream will have some patterns that reflect the geological condition of that area. (Figure 2)

1. Subdendritic drainage pattern

This drainage pattern found on northwest to south part. This drainage pattern has branch-like form, tight space between stream, found in moderate slope to steep topography. Reflects moderate to high resistance area. This drainage pattern indicates that stream flows on the basement and controlled by lithology, slope, rock resistance, and landform.

2. Parallel drainage pattern

This drainage pattern found on the middle part. This drainage pattern has streams that flow to one direction, found in steep topography. Reflects uniform resistance area. This drainage pattern indicates that stream flows on the basement and controlled by lithology, slope, and rock resistance.

3. Centripetal drainage pattern

This drainage pattern found on the south part. This drainage pattern at a glance has similar form to radial pattern that characterised by stream flow to every direction. The differences located on the direction of flow, streams on radial pattern flow from top of cone to the lower side, on the other hand streams on centripetal pattern flow from upper side to one central depression.

Geomorphology of Pangolombian

Geomorphology of Pagolombian can be divided into five units, Pangolombian volcanic hill unit, Linau crater lake unit, Tampusu volcanic slope unit, Kasuan volcanic slope unit, and Tondano caldera slope unit (figure 3).

1. Pangolombian volcanic hill unit (V1)

This unit occupy about 65% of map and located at the middle, northwest, and southwest of map. This unit has moderate slope, altitude 700-900 masl. Pangolombian volcaninc hill unit consists of Volcanic breccia, basaltic andesite lava, pyroclastic breccia, and tuff (Utami, 2011). This unit is uplifted, wheatered, and eroded.

2. Linau crater lake (V2)

This unit occupy about 9% of map and located at the middle of map. This unit is a volcanic depression and forms a crater filled by water. Linau crater lake consists of high-moderate resistant rocks that is lava and pyroclastic breccia from Tondano volcano. This unit is wheatered and eroded.

3. Tampusu volcanic slope unit (V3)

This unit occupy about 8% of map and located south part of map. This unit is a volcanic cone shape with steep slope. This unit has altitude 700-1150 masl. Tampusu volcanic slope unit consists of moderate to high rock resistance such Volcanic breccia and basaltic andesite lava (Utami, 2011). This unit is uplifted, wheatered, and eroded.

4. Kasuan volcanic slope unit (V4)

This unit occupy about 11% of map and located northeast part of map. This unit is a volcanic cone shape with moderate steep slope. This unit has altitude 700-962,5 masl. Kasuan volcanic slope unit consists of moderate to high rock resistance such Obsidian, basaltic andesite lava, and tuff (Utami, 2011). This unit is uplifted, wheatered, and eroded.

5. Tondano caldera slope unit (V5)

This unit occupy about 7% of map and located on the middle to east part of map. This unit has altitude 850-950 masl. Tondano caldera slope unit consists of moderate to high rock resistance such volcanic breccia, basaltic andesite lava, and tuff (Utami, 2011). This unit is uplifted, wheatered, and eroded.

Volcanostratigraphy of Pangolombian (Figure 7)

1. Pangolombian volcanic breccia unit

Pangolombian volcanic breccia unit is the widest unit in research area. This unit occupy 67% of map and marked by orange colour. Pangolombian volcanic breccia unit consists of volcanic breccia, andsite lava, and pyroclastic breccia (Utami, 2011).

2. Tampusu basaltic andesite lava unit

Tampusu basaltic andesite lava unit occupy 10% of map and marked by red colour. Tampusu basaltic andesite lava unit consists of volcanic breccia and andsite lava (Utami, 2011).

3. Linau basaltic andesite lava unit

Linau basaltic andesite lava unit occupy 9% of map and marked by red colour. Linau basaltic andesite lava unit consists of basaltic andesite lava with sheeting joint structure and pyroclastic breccia (Utami, 2011).

4. Kasuan basaltic andesite lava unit

Kasuan basaltic andesite lava unit occupy 14% of map and marked by red colour. Kasuan basaltic andesite lava unit consists of basaltic andesite lava, obsidian, and tuff (Utami, 2011).

Structural geology of Pangolombian

Research area controlled by tectonic and volcanic structure. The results from tracing the lineament shows that research area dominated by structure trending NW-SE and few structures trending NE-SW. These strucutres to cause the formation of volcanoes along the Minahasa trend. These structures formed by the between moluuca oceanic plate move westward and collided with minahasa compartment.

DISCUSSION

Subsurface geology well "X"

Lithology

Well "X" penetrates three units, they are Post Tondano unit which consist of Basaltic andesite, altered andesite, and altered volcanic breccia. The second is Tondano unit which consists of altered ryolit and altered volcanic breccia. The last one is pre Tondano unit which consists of altered andesite and altered volcanic breccia. These units can be determined by cutting description from Utami (2011) and Pertamina (2013), and then author classified lithologies in certain depth to make a unit of rock.

1. **Post Tondano basaltic andesite and volcanic breccia unit**

45 – 155 meter depth

Consists of basaltic andesite at the upper part which composed of plagioclase and pyroxene, while at the lower part consists of altered andesite, composed of pyroxene, pyrite, and clay mineral.

155 – 335 meter depth

Consists of volcanic breccia at the upper part and andesite at the lower part. Volcanic breccia is altered indicated by the presence of pyrite and clay minerals. Andesite is also altered indicated by the presence of clay minerals, calcite, pyrite,and quartz fragment 1 – 3 mm. Petrographic analysis is done to sample at 175 – 190 meter and shows the presence of calcite (rare), chlorite (rare), zeolite (rare), and quartz (common)

335 – 860 meter depth

Consists of altered volcanic breccia. Volcanic breccia composed altered tuff fragment, indicated by the presence of oxide minerals and clay minerals (kaoline/illite), and also altered andesite indicated by the presence of clay minerals. At the lower part is altered andesite indicated by clay minerals (kaoline, smectite), pyrite, and anhydrite. Petrograhic analysis is done to sample at 536 – 539 m that shows altered andesite with epidote (rare) and secondary quartz (common).

2. **Tondano ryolite and volcanic breccia unit**

860 – 1190 meter depth

Consists of ryolite at the upper part in 860 – 890 deoth and volcanic breccia at the lower part. Ryolite is altered indicated by the presence of 1 – 2 mm chalcopyrite, <1 mm secondary quartz, and 1 – 3 mm sericite. Volcanic breccia is composed by altered tuff and andesite fragment. Indicated by the presence of calcite, chlorite, chalcopyrite, and clay mienrals. Petrographic analysis is done to sample in 884 – 887 m that shows the presence of secondary quartz (common) and epidote (rare).

3. **Pre Tondano andesite unit**

1190 – 1337 meter depth

consist of altered basaltic andesite. Basaltic andesite composed by plagioclase and pyroxene. Secondary minerals present as secondary quartz, fine grained pyrite, and clay minerals. Petrographic anlysis is done to sampe in 1223 – 1226 m that shows altered andesite with calcite, chlorite, secondary quartz, and epidote.

1337 – 1616 meter depth

Composed of altered andesite. Shown by the presence of secondary minerals such as sericite, secondary quartz, epidote, opaque minerals, sulfur mineral fragments 1-3 mm. The petrographic analysis was conducted on samples at a depth of 1466-1469 meters which showed altered andesite which was attended by secondary minerals in the form of quartz and epidote that were common. XRD analysis is also carried out and the results are ilite minerals, chlorite-smectite and calcite. Wairakit minerals are also present in small amounts.

1337 – 1703 meter depth

The upper part is composed of altered andesite which is attended by secondary minerals such as pyrite, clay minerals, sulfur fragments, opaque minerals, and secondary quartz. At the bottom is composed of volcanic breccias which are composed of Tuffs and Andesites which are transformed to be attended by clay minerals, secondary quartz, pyrite, chalcopyrite, and chlorite. Petrographic analysis was performed on samples at a depth of 1667 - 1670 meters which showed a altered andesitic that was attended by abundant quartz and epidote minerals. XRD analysis was also carried out which showed the results contained ilite minerals and smectite-chlorite.

Hydrothermal Alteration

1. Kaolin Zone ± Smectite ± Chlorite

The Kaolin Zone ± Smectite ± Chlorite in the well "X" at depth of 115 - 536 meters. In that zone is found very small amounts of anhydrite, zeolite and hematite minerals and also found a large amount of pyrite and quartz. Epidotes also appear at this depth but it is thought that the epidote appears as a fossil mineral that often appears in geothermal systems which indicates that the initial formation of the epidote occurred at that depth. The lower part of this zone is characterized by the appearance of sericite minerals. This zone is located in the upper Tondano and Tondano post units. The Kaolin Zone ± Smectite ± Chlorite in the geothermal system of the study area is included in the clay cap zone because it has poor permeability which blocks the fluid to surface.

2. Kaolin Zone ± Ilit ± Sericit

The Kaolin Zone ± Ilit ± Sericite in the well "X" at depth of 536 - 860 meters. In this zone there are also small amounts of chlorite, calcite, and chalcopyrite minerals, and large quantities of quartz and pyrite minerals. Epidote minerals are also found at this depth but are also thought to be fossil minerals . Kaolin Zone ± Ilit ± Sericite in the geothermal system of the research area is a clay cap and shallow reservoir zone characterized by a well temperature graph that shows an isothermal state where the condition is controlled by convection heat transfer.

3. Epidote Zone ± Hematite ± Chlorite ± Ilit

Epidote Zone ± Hematite ± Chlorite ± Ilit in the well "X" at depth 1223 - 1703 m. This zone is characterized by an abundance of epidote minerals. In this zone there are also small amounts of Kaolin, Smectite, Sericite, Wairakit and Chalcopyrite minerals, and large quantities of Calcite, Quartz, Pyrite and Sulfur minerals. Epidote Zone ± Hematite ± Chlorite ± Ilite in the geothermal system the research area is a deep reservoir zone characterized by an abundance of epidote minerals.

Geochemistry of Geothermal Fluid

Geothermal Manifestations of Research Areas

Based on the research results of Pertamina Geothermal Energy (2011), in the research area five geothermal manifestations were obtained, Linau fumarol, Lahendong I&II hot springs, Leilem hot springs, and Leilem mudpool. The chemical parameters of linau fumaroles can be seen in Table 1, and other manifestation chemical parameters can be seen in table 2.

From the results of plotting the diagram Cl – SO_4 – HCO_3 (Figure 4) shows that the manifestation fluid in the study area is dominated by sulfur element (SO_4) which indicates that the geothermal manifestation fluid in the study area is steam heated water type . This type of water is formed when the H_2S gas originating from magmatic is separated from the chloride water in the reservoir due to boiling. This H_2S gas moves upward then near the oxidation surface producing Sulfate (SO_4^{2-}) and two Hydrogen atoms ($2H^+$).

The results of plotting manifestation samples on the Na-K-Mg diagram (Figure 4) show that all manifestation samples are in the immature waters zone which indicates that the manifestation fluid does not reflect the reservoir condition. Sodium and Potassium elements controlled by temperature are common elements in high temperature geothermal systems. The ratio of these two elements (Na / K) in the study area shows a very small value indicating upflow . Then the high value of Magnesium (Mg) indicates the washing of rocks near the surface which is rich in Mg by acidic water.

The composition of geothermal gas in the manifestation of Fumarol Linau shows the dominance of CO_2compounds with a concentration of 97.93, and several other gas compounds such as H_2 and N_2 which indicate the presence of high-temperature fluids below the surface (Prasetio, 2017). The low concentration of NH_3 and CH_3 indicates that the geothermal system is not affected by sedimentary rocks which are rich in organic content, low

Geochemistry of Well "X" Fluid

There are three Geothermal Fluid Samples in the well "X" that were analyzed, namely the sample April 7, 2011 (X1), the sample July 12, 2010 (X2) and the sample November 19, 2009 (X3). From the results of the plotting in the Cl - SO_4 - HCO_3 diagram (Figure 5) it can be seen that all samples have a relatively balanced composition of Cl and SO_4 . Samples X1 and X2 are close to the volcanic water zone with samples dominated by SO_4 compounds then Cl elements with very little HCO_3 content . This marks the fluid coming from the gas H_2S which comes from volcanic activity which then experiences condensation near the surface. Although it is located near the surface, this sulphate water can also penetrate into the geothermal system through fractures (Nicholson, 1993). This causes the fluid in the well "X" to have a high sulfate concentration.

From the results of the plotting on the Na-K-Mg diagram (Figure) , the samples X1 and X2 are in the immature water zone and the X3 sample is in the partial equilibrium zone . The thing that distinguishes between the results in samples X1 and X2 with X3 is the element Mg. Where in samples X1 and X2 have a greater content of Mg (sample X1 3.88; sample X2 1.419) compared to sample X3 (0.94). This is related to the more acidic types of X1 and X2 fluids.

Because only X3 samples are not located in the immature water zone , the geothermometer analysis only uses X3 samples.

Geochemical analysis using the Cl - Li - B diagram (Figure 5) is carried out to determine the geothermal formation environment or type of reservoir rock in the geothermal system. Placing fluid samples indicates that the fluid comes from the environment with andesitic rocks. Boron content in geothermal systems usually ranges from 10 - 50 mg /

L which indicates that the geothermal system is associated with andesitic rocks. But if the boron content is very high (800-1000 mg / L) it indicates that the geothermal system is associated with sedimentary rocks. In the well "X" the Boron content ranged from 21 - 24 mg / L which indicates that the "KU" geothermal system is associated with andesitic rocks.

Geothermal Reservoir Temperature

Mineral Geothermometer Analysis

Kaolin ± Smectite ± Chlorite (Depth 0 - 554 m) zone

From the temperature distribution of each mineral at a depth of 0 - 554 m, the authors make a temperature withdrawal based on the temperature range of all minerals that appear. The results obtained are at a depth of 0 - 554 m (zone Kaolin ± Smectite ± Chlorite) temperature based on mineral geothermometers ranging from 180°C - 200°C.

Kaolin ± Ilit ± Sericit (Depth 554 - 1190 m) zone

Based on the withdrawal of the temperature range of all minerals that appear, the temperature at a depth of 554 - 1190 m (zone Kaolin ± Ilit ± Sericte) ranges from 180 o C - 255 o C.

Epidote Zone ± Hematite ± Chlorite ± Ilit (Depth 1190 - 1703 m)

Based on the withdrawal of the temperature range of all minerals that appear, the temperature at a depth of 1190 - 1703 m (Epidote ± Hematite ± Chlorite ± Ilit zone) ranges from 230 - 290°C.

Geothermal Fluid Geothermometer Analysis

Linau Fumarol Geothermometer

Geothermometer analysis for Linau Fumarol samples using CO_2/Ar - H_2/Ar Geothermometer and CO_2 - H_2 Geothermometer .The results of the CO_2/Ar - H_2/Ar geothermometer show that Reservoir Temperature is 292°C. Whereas the results of geothermometer CO_2 - H_2 show a value of 304°C. Therefore, it can be concluded that the temperature reservoir of the research area based on Linau Fumarol geothermometer analysis ranges between 292°C - 304°C.

Geothermal Fluid Well “X” Geothermometer Analysis

The type of geothermometer analysis suitable for geothermometer well “X” samples is Na – K geothermometer. Geothermometer Na-K looks at the equilibrium of Na elements in Albit minerals with K elements in the K-Feldspar mineral at high temperatures. The Na / K ratio will decrease with increasing temperature. Fluids from high temperature resrvoir (> 180 o C) are suitable for geothermometer analysis using this method. The Ca content of the well sample "X" also shows a small value (0.57 - 1.63) so that geothermometer analysis can be used with this method, considering that the high Ca value causes invalid geothermometer calculation results with this method (Karingithi, 2009).

From the results obtained, the geothermal reservoir temperature of the study area based on Na-K geothermometer ranged from 276°C - 294°C.

Tabel 3 Geothermometer Results

Sampel	Na/K Fournier 1979	Na/K Truesdell 1976	Na/K Giggenbach 1988	Na/K Arnorsson 1983
X3	284	276	294	278

Classification of the Geothermal System Research Area Based on Temperature

From the results obtained from the temperature analysis it was found that the reservoir temperature of the study area ranged from 250°C - 294°C according to Muffer & Cataldi (1978), Benderiter & Cormy (1990), Haenal, Rybach & Stegna (1988), and Hochsteni (1990) Research areas include high temperature geothermal systems.

Tabel 4 Geothermal "KU" Field Classification Based on Temperature

	Muffer & Cataldi (!978)	Benderiter & Cormy (1990)	Haenel, Rybach & Stegna (1988)	Hochestein (1990)
Sistem Panasbumi Temperatur Rendah	<90°C	<100°C	<150°C	<125°C
Sistem Panasbumi Temperatur Sedang	90-150°C	100-200°C	-	125-225°C
Sistem Panasbumi Temperatur Tinggi	>150°C	>200°C	>150°C	>225°C

CONCLUSION

1. The Geomorphology Unit of the study area consisted of the Pangolombian Volcanic Unit, Linau Crater Lake Unit, Tampusu Volcanic Slope Unit, Kasuan Volcanic Slope Unit, and Tondano Caldera Slope Unit. The rock units of the study area consisted of the Pangolombian Volcanic Breccia Unit, Mount Tampusu Andesite Lava Unit, Linau Andesite Basaltic Lava Unit, Kasuan Mountain Andesite Lava Unit. The research area was controlled by the geological structure of the NE-SW and NW-SE direction and the structure of the volcanic activity in the form of a caldera.
2. The Manifestation of the Research Area consisted of Lahendong I Hot Springs, Lahendong II Hot Springs, Linau Fumarol, Leilem Hot Springs, and Leilem Mud Pool. All manifestations have acidic fluids and are steam heated water with immature water conditions
3. Fluid Geothermal well "X" has an acidic pH to nearly neutral. From the analysis of fluid types obtained well water "X" type sulphate - Chloride Water with equilibrium conditions of partial equilibrium to immature water
4. The geothermal reservoir temperature of the study area based on gas fumarole geothermometer ranged from 292°C – 304°C,Well "X" water geothermometer valued at 276 o C - 294 o C, geothermal reservoir temperature past the study area based on mineral geothermometers ranging from 230 °C - 289 °C, and the measured temperature is based on the temperature chart and the pressure of the well "X" is 276 °C - 294 °C

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Appendix

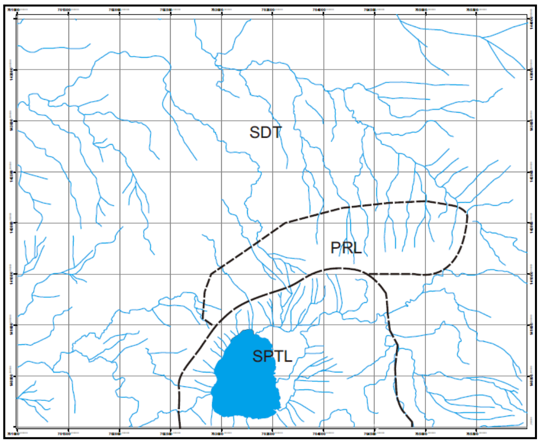

Figure 2 Drainage Pattern of Pangolombian

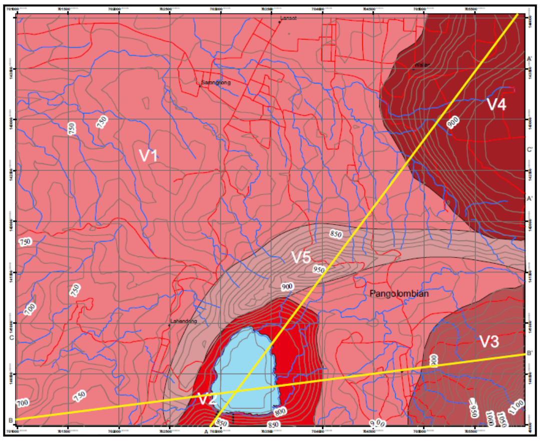

Figure 3 Geomorphology of Pangolombian

Table 1 Chemical Parameter of Linau Fumarole

Sampel	CO2	H2S	NH3	Ar	N2	CH4	H2	CO
Fumarol Linau	97,9285	0,8371	0,0056	0,0018	0,7021	0,0019	0,4442	0,0001

Table 2 Chemical Parameter of geothermal Manifestation

Parameter Kimia	SATUAN	MAP LAHENDONG I	MAP LEILEM	KOLAM LUMPUR LEILEM	MAP LAHENDONG II
pH		1,98	5,86	2,00	2,40
Li	mg/L	0,010	0,001	0,001	0,020
Na		5,800	22,000	11,000	28,000
K		21,000	13,000	7,400	6,900
Ca		7,700	63,000	24,000	38,000
Mg		8,400	7,700	8,600	21,000
SiO2		264,000	202,000	329,000	272,000
B		0	0,090	0,130	0,250
Cl		7,000	7,000	3,000	5,000
F		0,100	0,001	0,001	0,010
SO4		1681,000	138,000	501,000	1111,000
HCO3		0,900	98,000	0,100	0,100
NH4		0,290	0,980	0,010	0,010
As		0,001	0,001	0,001	0,13
Fe		3,5	0,08	6,5	70
Ion Balance		-48	5	9	-34

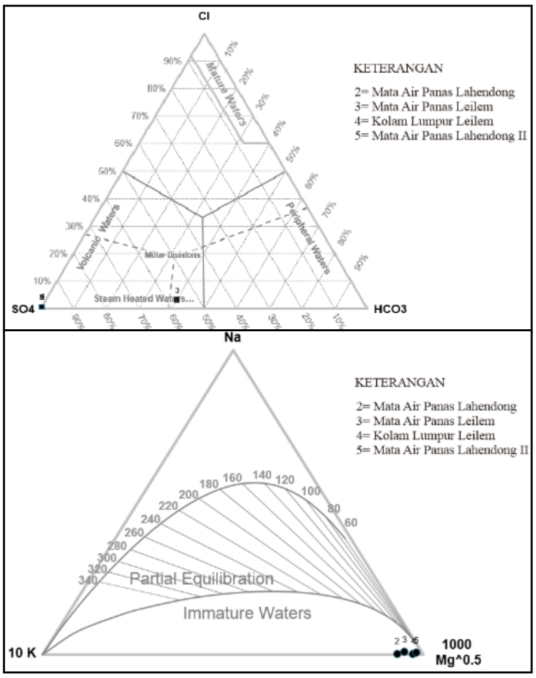

Figure 4 Geochemical Analysis of Geothermal Manifestation

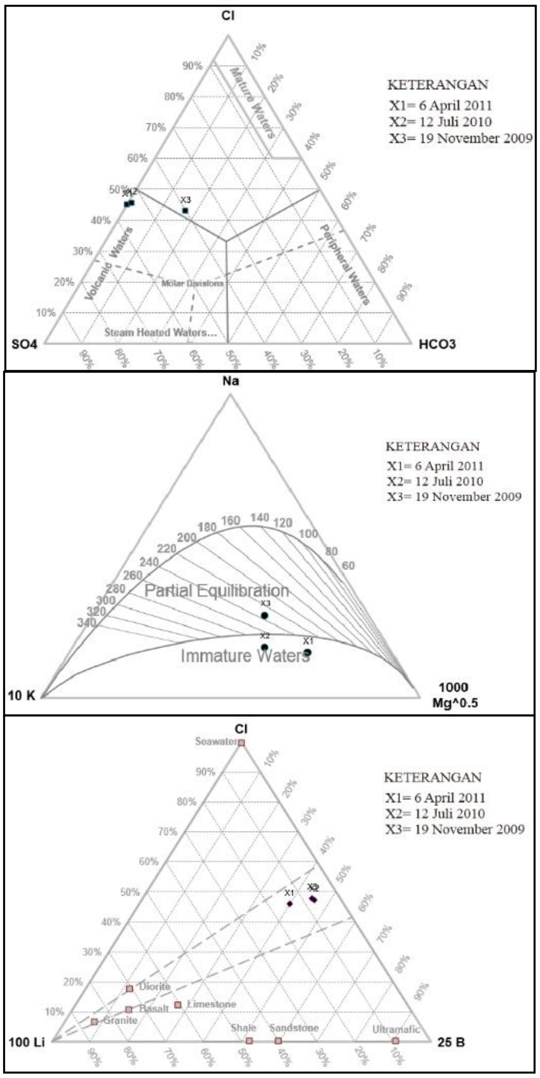

Figure 1 Chemical Parameter of Well "X"

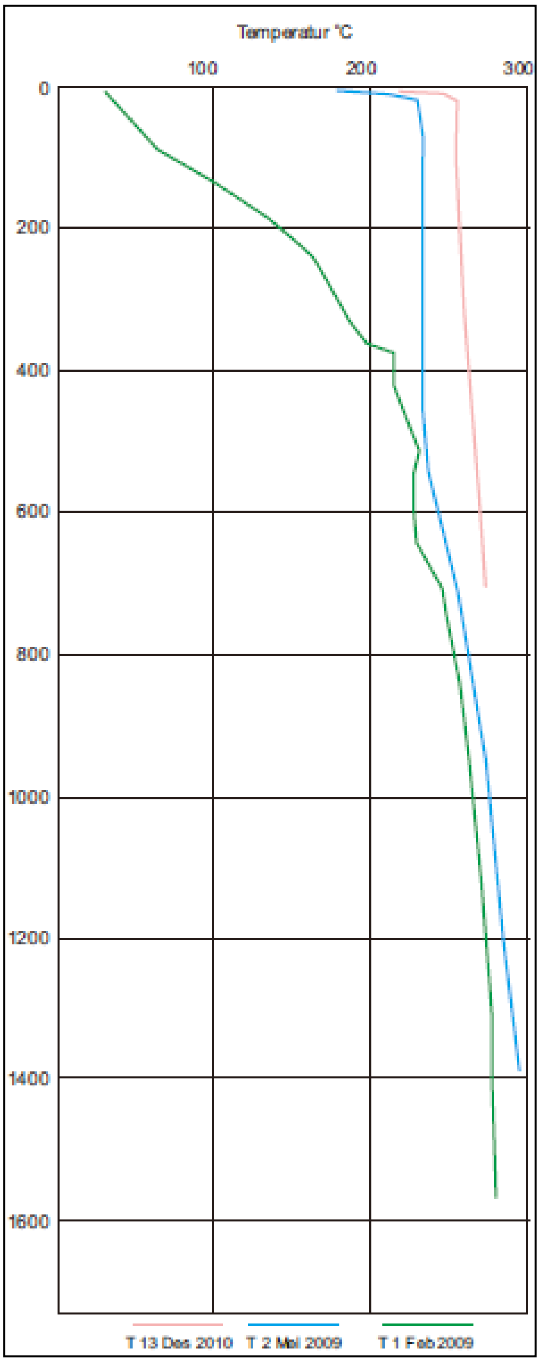

Figure 6 Temperature Chart of Well "X"

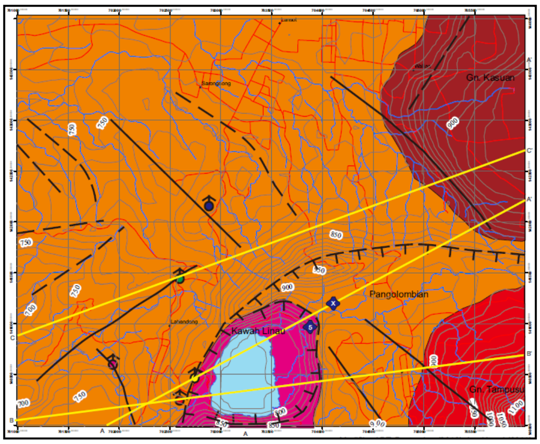

Figure 7 Geologic map of Pangolombian