Determination of Tanggamus Geothermal Prospect Area, Lampung Province, South Sumatra Based on Remote Sensing and 3D Micromine Software

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ABSTRACT

Geothermal has big potential in Indonesia because it is in the Ring of Fire. Indonesia has around 40% of global geothermal potential, however, only ±7% of identified potential being utilized. The research was conducted in one of the geothermal prospect areas in Indonesia which entered Tanggamus District of Lampung Province in South Sumatera. This research carried out using studio and field observation methods. In studio, remote sensing interpretation by using topography and landsat imaginary maps and application of 3D micromine software and also doing field observation to provide valid data information.

The purpose of this study is to evaluate the relation between structure geology and the distribution of geothermal surface manifestation based on landsat image and topographic maps with application of 3D micromine software. Interpretation of landsat and topography maps indicated that the Tanggamus geothermal prospect area controlled by a regional structure showing the trend direction of the surface temperature calculated from the landsat image 8 has range of > 50°C.

Based on landsat image analysis in the study area found a phenomenon that supports the remnants of volcanic eruption which shows that in this research area located in the depression area and shows the crater phenomenon with the appearance of circular structures.

The geothermal potential indication can be observed in field from geothermal manifestation on the surface, such as altered rock, hot spring, sulfates, and fumarole express the evidence of geothermal activity, indicating that the hydrothermal fluid originating from the reservoir has come out through the opening of structures or units of permeability rocks. In this geothermal prospect area the surficial thermal manifestations are indicated by the presence of fumaroles, mud pools and steam-heated water which are controlled by a NW-SE graben inside the semi-circular depression.

The Micromine software is used to process all data both of landsat and topographical map to delineate the geothermal prospective areas. The trend of of high temperature inline with the lineament trend whereas based on the surface temperature maps produced, the average temperature for both samples around 25^o-29^{o}C, with 99.86 % in some locations have temperatures reaching 74^{o}C.This can be assumed that the source of the heat related to the geological structure. From field

observations encounter hot springs have temperatures in ranges 40^o-97.2^{o}C and temperature of steaming ground in ranged between 74^o-91^{o}C which are encountered along the fault line

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1. BACKGROUND

Indonesia geologically positioned in convergent zone between Indian Oceanic Plate and Eurasian Continental Plate. This convergent zone is seismically active with many active volcanoes. Around 13% of global active volcanoes located in Indonesia, as part of “Ring of Fire” (Figure 1).

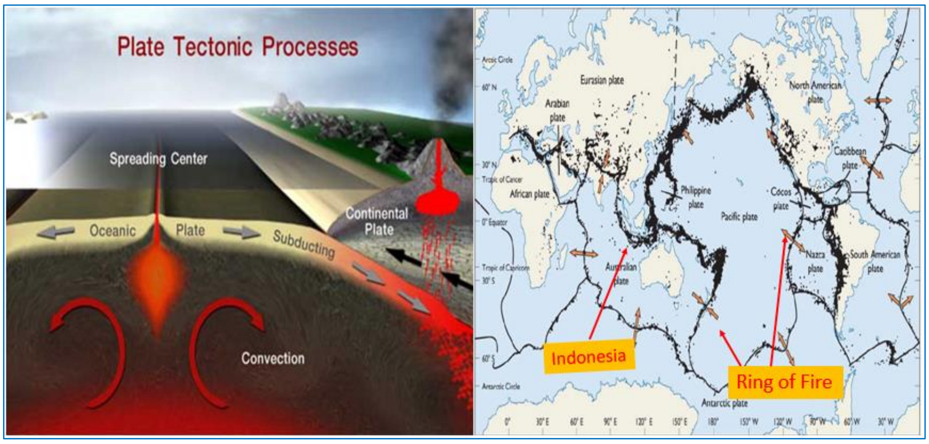


Figure 1. Plate tectonic that controls the formation of “Ring of Fire” (National Geographic Society)

The subduction between Indo-Australian and Eurasian plates occurred in Miocene and Plio-Pleistocene that responsible to the formation of Sumatera Island. A large dextral fault of Sumatra Fault has active movement in Sumatera. The tectonic activities formed significant morphological feature of Bukit Barisan Ridge that has 1600 km extent along the volcanic belt that located in the west of Sumatera. The southern end of Sumatera Island cut by Semangko Fault (Siahaan E.E. et al., 2000) where the geothermal provenance with sufficient heat flow to power electricity generator was observed in the fault zone. According to Clauser and Huenges (1995) and Gupta and Roy (2007), There are four possibilities that any place could have geothermal potential: a. large natural heat source, b. sufficient natural water supply, c. permeable reservoir or aquifer, and d. impermeable rock cover (Figure 2).

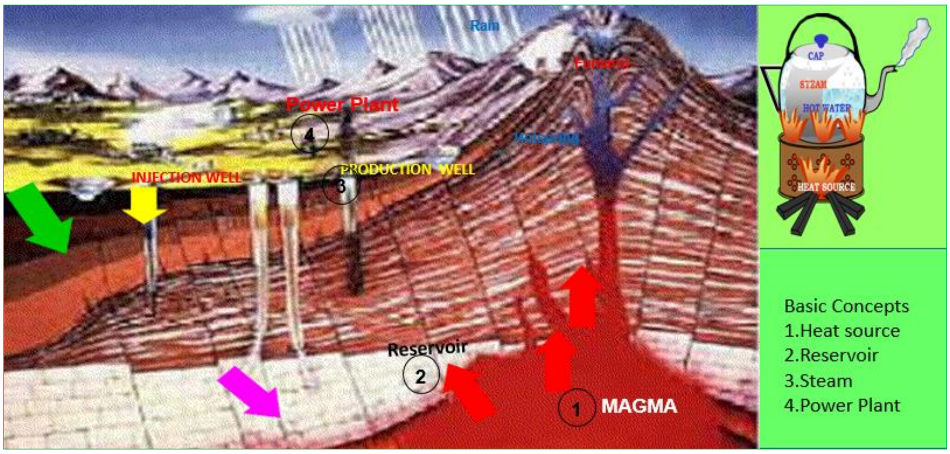
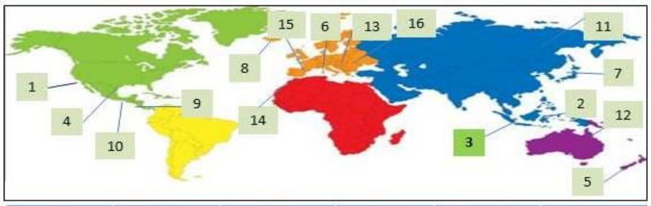


Figure 2. Basic Concept of Geothermal Energy (modified by PT. Pertamina Geothermal Energy, unpublished)

Installed geothermal capacity has reached 12,635MWe globally (Bertani. R, 2015) which equals to 73,549 GWh electricity. In Indonesia has a geothermal potential of 27GWe and now in Indonesia has installed capacity ± 1513.5 MW which equal to 7% of total identified geothermal potential (Figure 3).



No	Country	MWe	No	Country	MWe
1	USA	3,450	9	Costa Rica	207
2	Philippines	1,870	10	El Salvador	205
3	Indonesia	1,340**	11	Russia	82
4	Mexico	1,017	12	Papua N. Guinea	50
5	NZ	1,005	13	Germany	27
6	Italy	916	14	Portugal	29
7	Japan	519	15	France	16
8	Iceland	665	16	Austria	1

***) Real installed capacity : 1,513.5*

Figure 3. 2015 Geothermal Installed Capacity (MW) worldwide (Bertani R., 2015)

2. RESEARCH PURPOSE

The research area has geothermal potential that strongly related by the development of geological structures and the distribution of geothermal surface manifestations. Therefore, the purpose of this study is to evaluate the relation between structural geology and the distribution of geothermal manifestation based on landsat image and topographic maps using micromine software to identify the boundary of geothermal prospect areas. This information is beneficial for further exploration.

3. OBJECT AND METHODOLOGY

The research objects for this study area, the morphology, structural geology based on landsat and topographic map. The research method for this study can be divided into two methods: studio and field observations. Studio method carried out by interpretation of the topographic, landsat maps and application of micromine software. Field method carried out by observation of geological structure, geothermal surface manifestations in the field.

4. DISCUSSION

4.1. Tectonic Setting of Sumatera

Sumatera Island formed by the subduction between Indo-Australian plate and Eurasian Plate in Plio-Pleistocene. According to Hamilton (1974), the plate interaction of western Indonesia formed the subduction zone, increased tectonic, magmatic, and volcanic activities along the Sumatra Island. The plate movement released the pressure gradually, forming the first order of Semangko Fault with dextral slip movement. These activities possibly occurred in Early Miocene, where at this period the tertiary volcanic activities formed as Lahat Formation in the southern part of South Sumatra Basin.

The research area, Tanggamus District is located approximately 18 km to the North East of Semangko Fault. In addition, the earthquake hypocenter points are plotted to define the subduction zone. The measurement result shows that the subduction zone is located approximately 120 km from the surface (Figure 4).

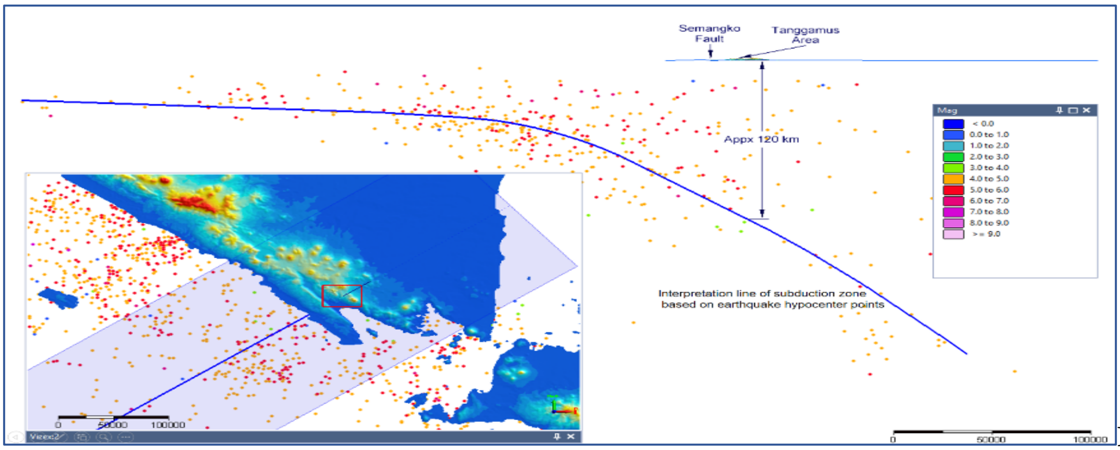


Figure 4. Research area inside tectonic setting of Sumatera.

4.2. Geological Setting

The stratigraphy of this geothermal field (Figure 5) composed by Tertiary volcanic deposit. The oldest rock derived from G. Sula volcanic activity that consisted of andesitic lava and pumice, which interbedded with sandstone and claystone (Tmoh). These rocks overlaying by basaltic andesite lava that produced by G. Kukusan volcanism. The later products are pyroclastic and andesitic lavas that derived from G, Kabawok volcanism. Later products are rhyolitic lava and andesite tuff as volcanic product from G. Korupan, G. Rindingan, G. Tanggamus (Qtry). Beneath these rocks, deposited andesite lava, andesite tuff, and andesite breccia. The dacite porphyry of G. Duduk (Tm), formed afterward. The recent alluvium located on the bottom of this area (Qal).

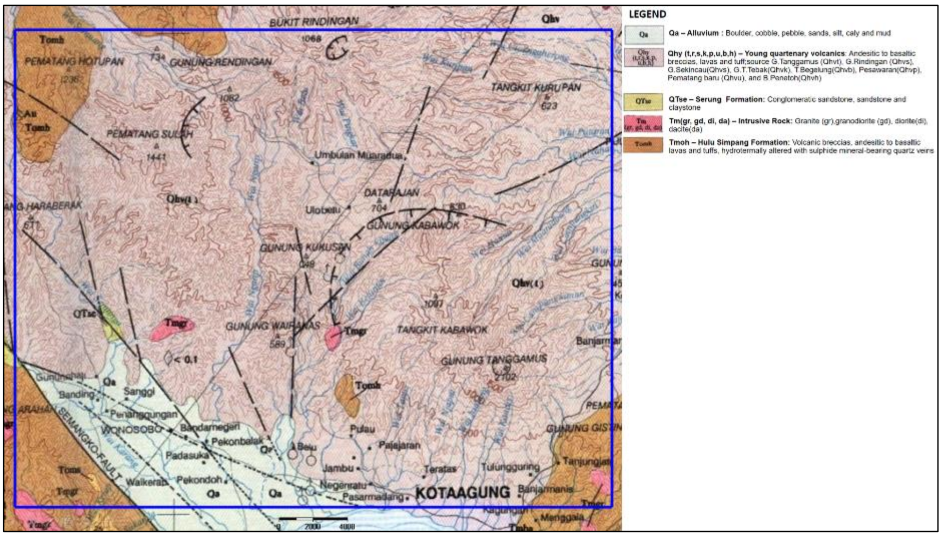


Figure 5. Geological map of Kota Agung (Amin, 1993)

Sieh and Natawidjaja (2000) and Pramuniwijoyo (2008) interpreted that Sumatra Fault in Semangko segment has extensional tectonic regime that dominated by trans tensional faults trending NW-SE. Main structures in Tanggamus areas also follow the NW-SE trend, forming a graben in eastern and western part of the field. The northern part bounded by G.Rindingan while the southern part bounded by W-E fault of G. Tiga. Inside this zone also occurred geological structures with NW-SE trend, founded along S.Muara, S. Karang. These structures also followed by the occurrence of younger volcanic activities.

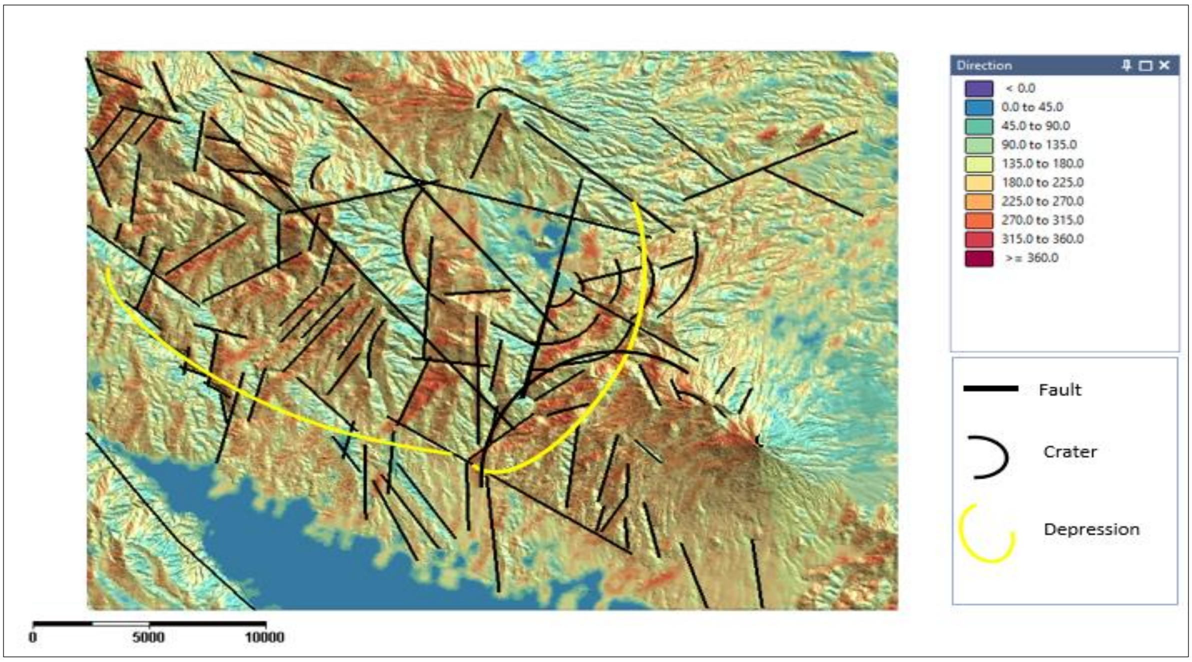


Figure 6. Lineaments interpretation based on 3D digital terrain model generated from RBI contour map.

Lineament interpretation have been made from morphology from RBI topographic contour map. Emphasizing the lineament features, the 3D topographic triangulation model is generated from the contour (Figure 6). In addition, azimuth and dip of every single triangle is calculated to provide numeric values that can be colourized. The orange colour represent triangle that having azimuth N 270^o E – N 310^{o}E. It mean that orange colour area mostly have NE-SW lineaments.

The crater of G. Rindingan opens to the south whereas this crater structure is important as northern boundary of the geothermal system. The circular subsidence structure can be observed on western and southern part as result of Plio-Pleistocene tectonism. This structure controls the geothermal manifestation in Tanggamus area which also controls the distribution of geothermal surfaces manifestation, such as steam heated sulfate water and mud pool (Figure 7).

From field observation, the NW-SE fault inside the semi-circular depression graben also controls the occurrence of fumarole, mud pool, and steam-heated water. The NE-SW fault which in the middle of Tanggamus area controls the occurrence of geothermal manifestation in Pagar Alam and Karang Rejo areas as steam heated sulfate water and mud pools (Figure 8 and 9). The hot springs, mud pool have temperature in ranges 40^o-97.2^{o}C and the steaming grounds have temperature in ranges 74^o-91^{o}C. The evident of fault activities showed by fault scraps and scrap breccia was found at Pagar Alam location.

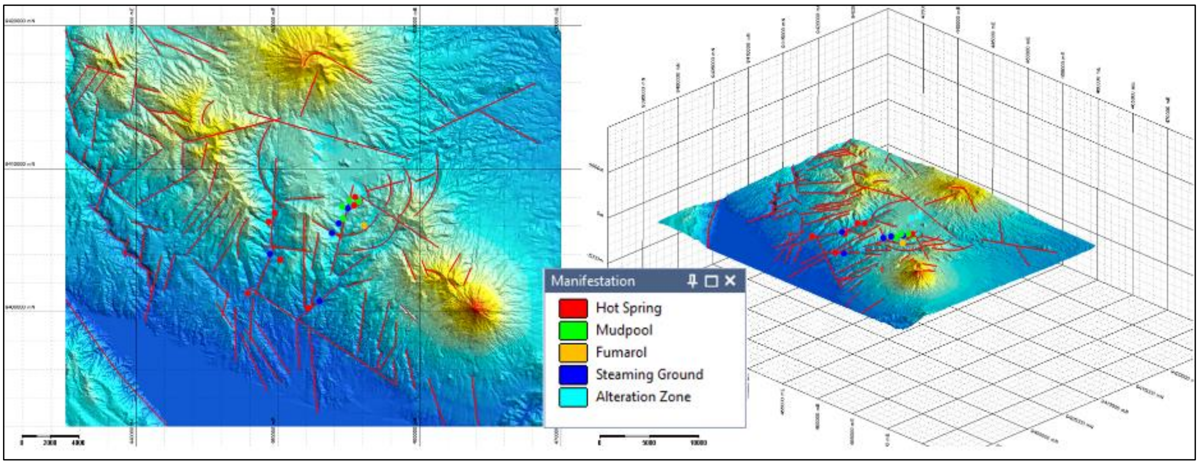


Figure 7. Geological structure controls the appearances of surface geothermal manifestations.

Figure 8. Geothermal surface manifestation Pagar Alam such as altered rock, fumarole, sulfate and steaming ground (left side) and scraps breccia (right side).

Figure 9. Geothermal surface manifestation Muaradua shows hot spring has temperature 97.2^{o}C.

4.3 Landsat 8 processing

Landsat image is used to create land surface temperature. Land Surfaces Temperatures (LST) can be defined as how hot the surface of the Earth would feel to the touch in a location (earth observatory.nasa.gov).The data used for generating LST are Landsat 8 OLI/TIRS corridor 124064 dated 12/June/2016 and 19 November/2016.

LST was calculated using Split-Window (SW) algorithm. The brightness temperature of two bands of TIR, mean and difference in land surface emissivity for estimating LST. Flow chart of Split Window algorithm (Rajeshwari, 2014) shown as Figure 10.

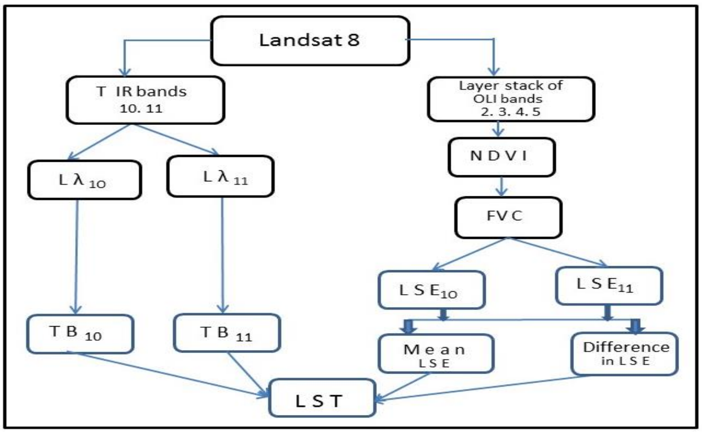


Figure 10. Flow chart of Split Window algorithm (Rajeshwari, 2014).

The formula for calculating LST is,

$LST = TB_{10} + C_1 (TB_{10}-TB_{11}) + C_2 (TB_{10}-TB_{11})_2 + C_0 + (C_3+C_4W) (1- \varepsilon) + (C_5+C_6W) \Delta \varepsilon$

Where:

- LST - Land Surface Temperature (K)
- C_0 to C_6 - Split-Window Coefficient values (table 1) (Skokovic et al, 2014 vide Rajeshwari, 2014)
- TB_{10} and TB_{11} – brightness temperature of band 10 and band 11 (K)
- TB_{10} and TB_{11} can be calculated as $TB = K2/Ln ((K1/ L\lambda) +1)$

  Where:
  - K1 and K2 are thermal conversion constant and it varies for both TIR bands (table 1)
  - $L\lambda$ are Top of Atmospheric spectral radiance (m2*srad*µm). $L\lambda$ can be calculated as $L\lambda = M_L*Q_{cal} + A_L$

    Where:
    - M_L - Band specific multiplicative rescaling factor (radiance_mult_band_10/11) = 0.000342
    - Q_{cal} – value of band 10/ 11 image.

- A_L - Band specific additive rescaling factor (radiance_add_band_10/11) = 0.1

- ε – mean LSE of TIR bands. ε can be calculated as $\varepsilon = (\varepsilon_{10} - \varepsilon_{11})/2$
- Δ ε – Difference in LSE. Δ ε can be calculated as $\Delta\varepsilon = \varepsilon_{10} - \varepsilon_{11}$

Where ε is LSE from band 10 and band 11 with formul $\varepsilon = \varepsilon_s (1\text{-FVC}) + \varepsilon_v * \text{FVC}$

Where:

- FVC is Fractional Vegetation Cover. For every band
  - FVC= (NDVI – NDVIs) /(NDVIv – NDVIs)

Table 1 Constants used for Calculating LST

Parameter	Desc	Value
C0	Split-Window Coefficient C0	-0.268
C1	Split-Window Coefficient C1	1.378
C2	Split-Window Coefficient C2	0.183
C3	Split-Window Coefficient C3	54.300
C4	Split-Window Coefficient C4	-2.238
C5	Split-Window Coefficient C5	-129.200
C6	Split-Window Coefficient C6	16.400
K1 Band 10	Thermal Constant K1 Band 10	1321.080
K1 Band 11	Thermal Constant K1 Band 11	1201.140
K2 Band 10	Thermal Constant K2 Band 10	777.890
K2 Band 11	Thermal Constant K2 Band 11	480.890
ML Band 10	Rescaling Factor ML Band 10	0.000342
ML Band 11	Rescaling Factor ML Band 11	0.000342
AL Band 10	Rescaling Factor AL Band 10	0.1
AL Band 11	Rescaling Factor AL Band 11	0.1
εs Band 10	Emissivity εs for Band 10	0.971
εs Band 11	Emissivity εs for Band 10	0.977
εv Band 10	Emissivity εv for Band 10	0.987
εv Band 11	Emissivity εv for Band 10	0.989

Based on the surface temperature maps produced the average temperature for both samples around 25-29^{o} C with 99.86 % in some areas reaching temperature 74^{o}C. The high temperature is dominated in the volcano areas, although it is covered by cloud. Open depression used as urban area like in Kota Agung is also high. Mountain slope showing less temperatures, as same as the average temperature of the data (Figure 11).

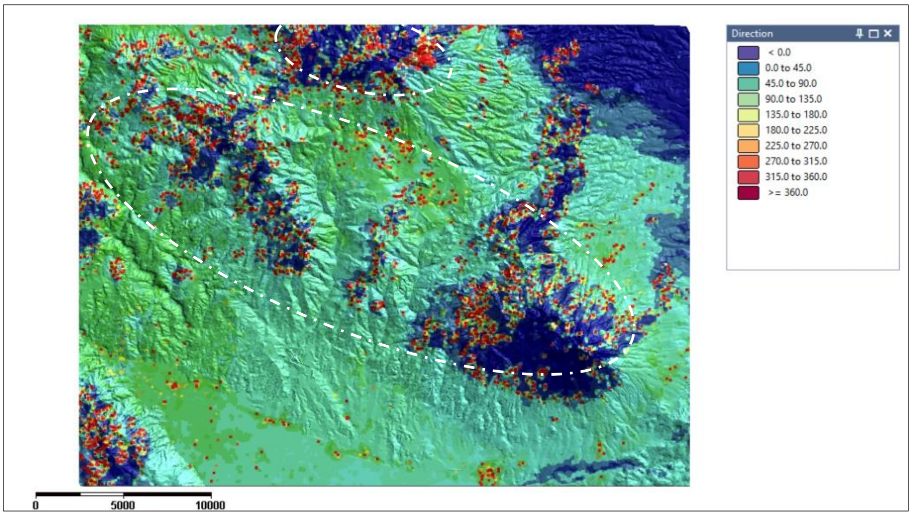


Figure 11. Land Surface Temperature of Tanggamus based on Landsat 8 OLI/TIRS corridor124064 on 19 November 2016. The trend of temperature show NW-SE direction.

The trend of of high temperature inline with the lineament trend. This can be assumed that the source of the heat related to the structure.

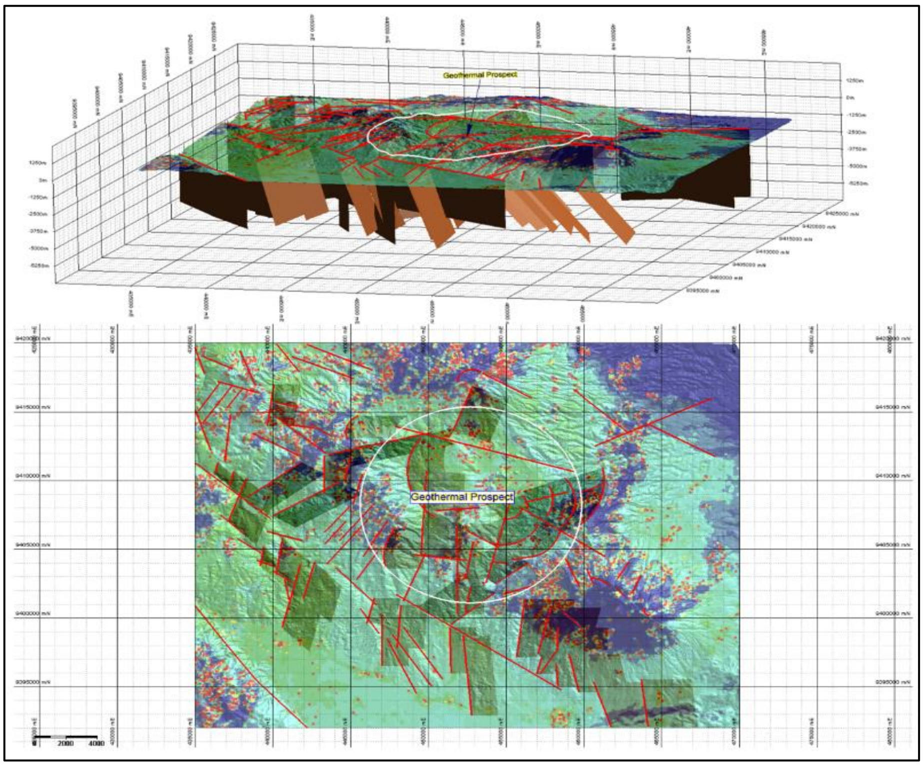


Figure 12. Geothermal prospect of Tanggamus Area.

5. CONCLUSION

From the landsat imaginary, topographic map, field observation and application of micromine software analyses it can be concluded that:

1. Geological structure that developed in the study area especially encountered through G. Rindingan, G. Kabawok and G. Tanggamus formed the geothermal potential belt by having the same trend direction with NW-SE faults and the phenomenon that supports the remnants of volcanic eruption shows the appearances of circular structure.
2. The result of Landsat Surface Temperature (LST) calculation shows the area having surface temperature more than 50^oC related to the trending of geological structure. This is also supported by observations in the field.
3. Tanggamus area is estimated have geothermal prospect with an area of about 66 km^2, where in this geothermal prospect area the surficial thermal manifestations are indicated by the presence of fumaroles, mud pools and steam-heated water which are controlled by a NW-SE graben inside the semi-circular depression. The hot springs have temperatures in range of 40^o - 97^oC, steaming ground with temperatures ranging from 74^o -91^oC. Therefore the SW-NE and NW-SE faults control the occurrence of the Tanggamus geothermal prospects area.
4. Understanding the trends of regional structures, structural developments, dispersal and occurrence of geothermal surface manifestations in the study area may assist in setting up an advanced exploration survey strategy.

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