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DETERMINATION OF TANGGAMUS GEOTHERMAL PROSPECT AREA, LAMPUNG PROVINCE , SOUTH SUMATERA BASED ON REMOTE SENSING AND 3D MICROMINE SOFTWARE

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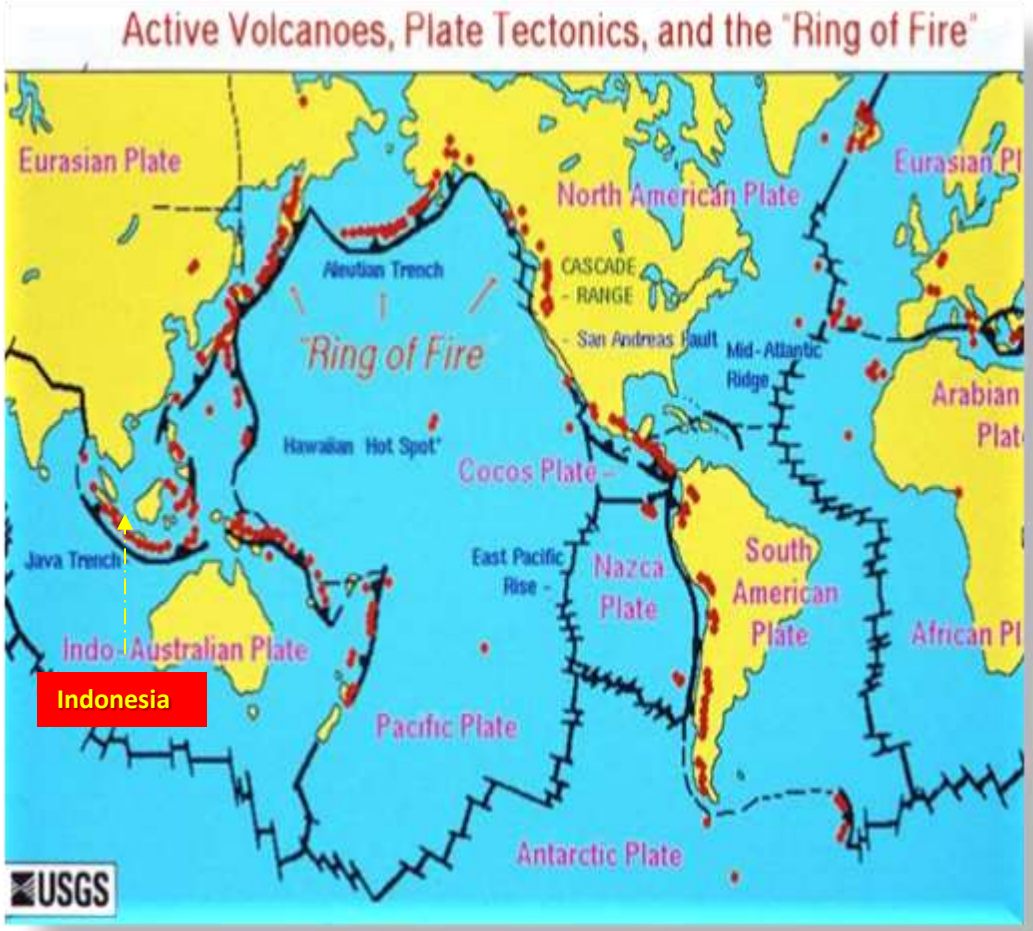
INTRODUCTION

- Indonesia geologically positioned in convergent zone between Indian Oceanic Plate and Eurasian Continental Plate. This convergent zone is seismically active with many actives volcanoes. Around 13 % of global actives volcanoes located in Indonesia as part of "Ring of Fire"

- The development of geological structures that occur in the study area is closely related to the development of tectonic Sumatra Island.

- The area of the research area is Tanggamus in the Southern end of Sumatera Island cut by Semangko fault where the geothermal provenances with sufficient heat flow to power electricity generator was observed in the fault zone



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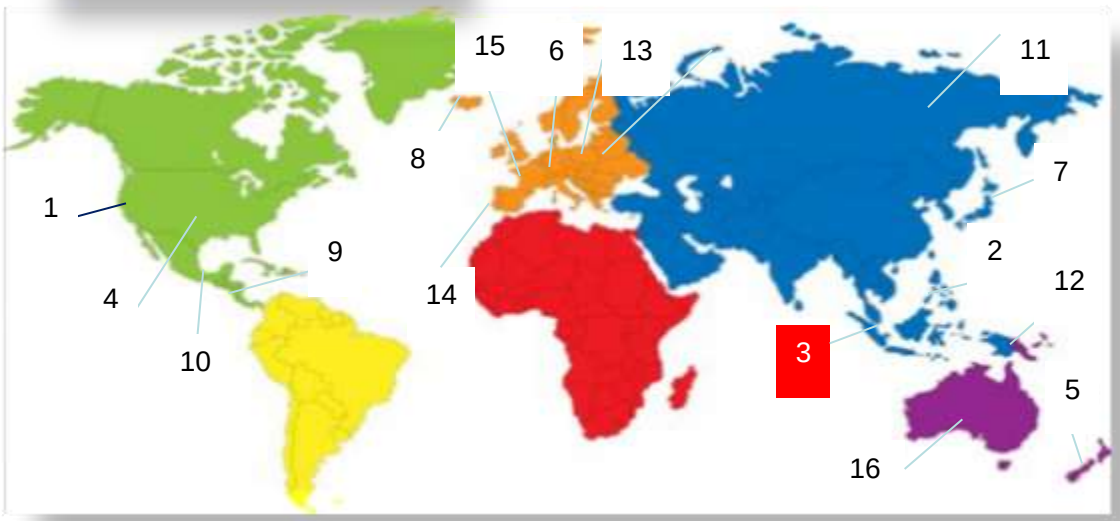
GEOTHERMAL INSTALLED CAPACITY (MW) WORLDWIDE



- Total worldwide geothermal installed capacity in year 2015 are 12,635 MWe which equals to 73,549 GWh electricity.
- Indonesia has a geothermal potential around 27 GW.

Now in Indonesia has Installed capacity ± 1,513.5 MWe which equals to 7 % utilized of total identified geothermal potential.

No	Country	MWe	No	Country	MWe
1	USA	3,450	9	Costa Rica	207
2	Philippines	1,870	10	El Salvador	205
3	Indonesia	1,350**	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	Australia	1

Source : Bertani R, 2015

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BASIC CONCEPT OF GEOTHERMAL

1.Heat source
2.Reservoir
3.Steam (from production well)
4.Power Plant (Turbine and Generator)

Source: Modified by Pertamina Geothermal Energy, 2013, unpublished

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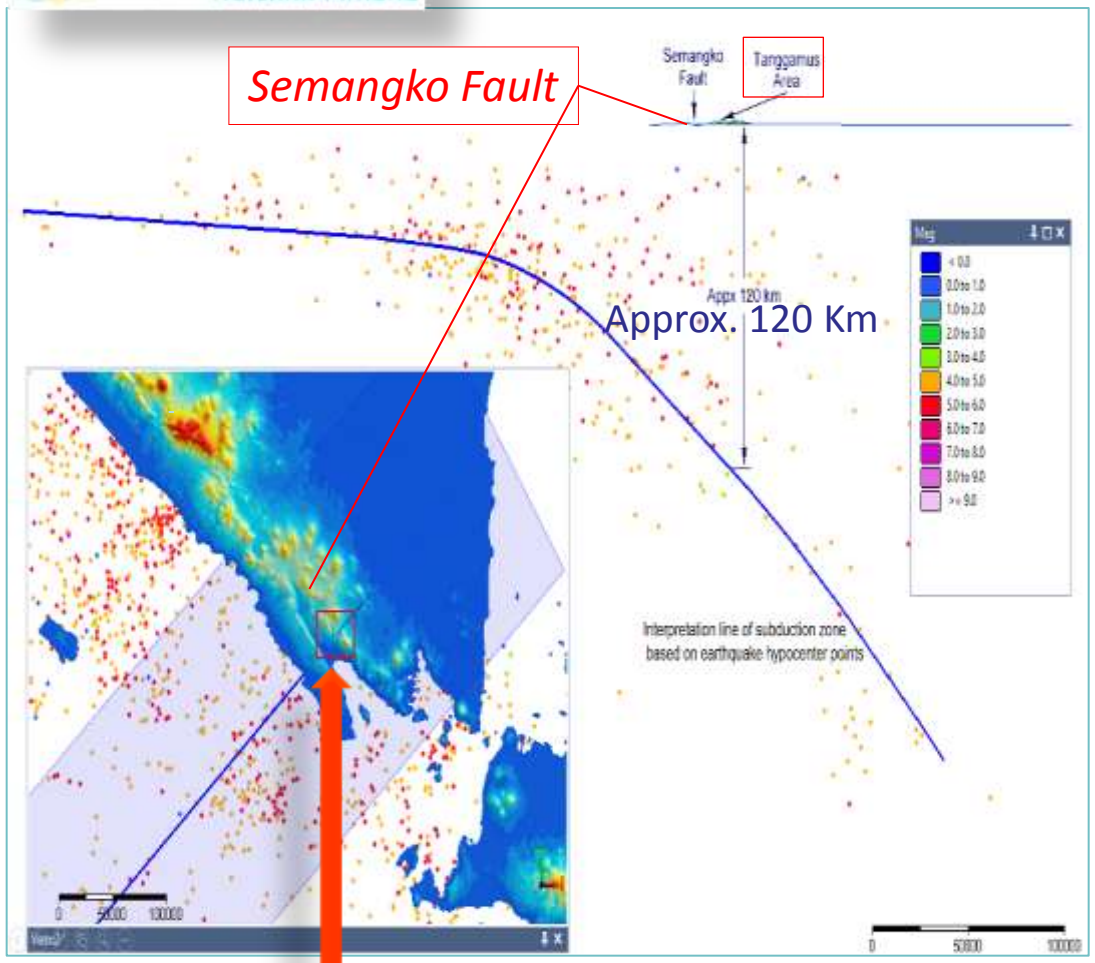
AREA OF STUDY



Location of study area (Southern part of Sumatera Island)

- The development of structures that occur in the Tanggamus is closely related to the development of tectonic Sumatera Island.

- Tanggamus area is located ± 18 Km to the North East of Semangko Fault.

- 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.

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Objective, Purpose and Methodology

- The study area is a geothermal prospect area that has a depression landscape with a very complex geological structure and has a geothermal manifestation on the surface

- Determined relationship between geological structure with the presence, distribution of surface geothermal manifestation and to delineate the large of the geothermal prospect area

Two methods are applied

- **Studio :** analysing topographic and satellite imagery maps, micromine software applications and calculating Land Survey Temperature (LST) is to determine the extent of heat in depth including its spreading.
- **Observation to the field :** to verify studio data with the actual field conditions related to the geological structure development and the appearances of surface geothermal manifestations.

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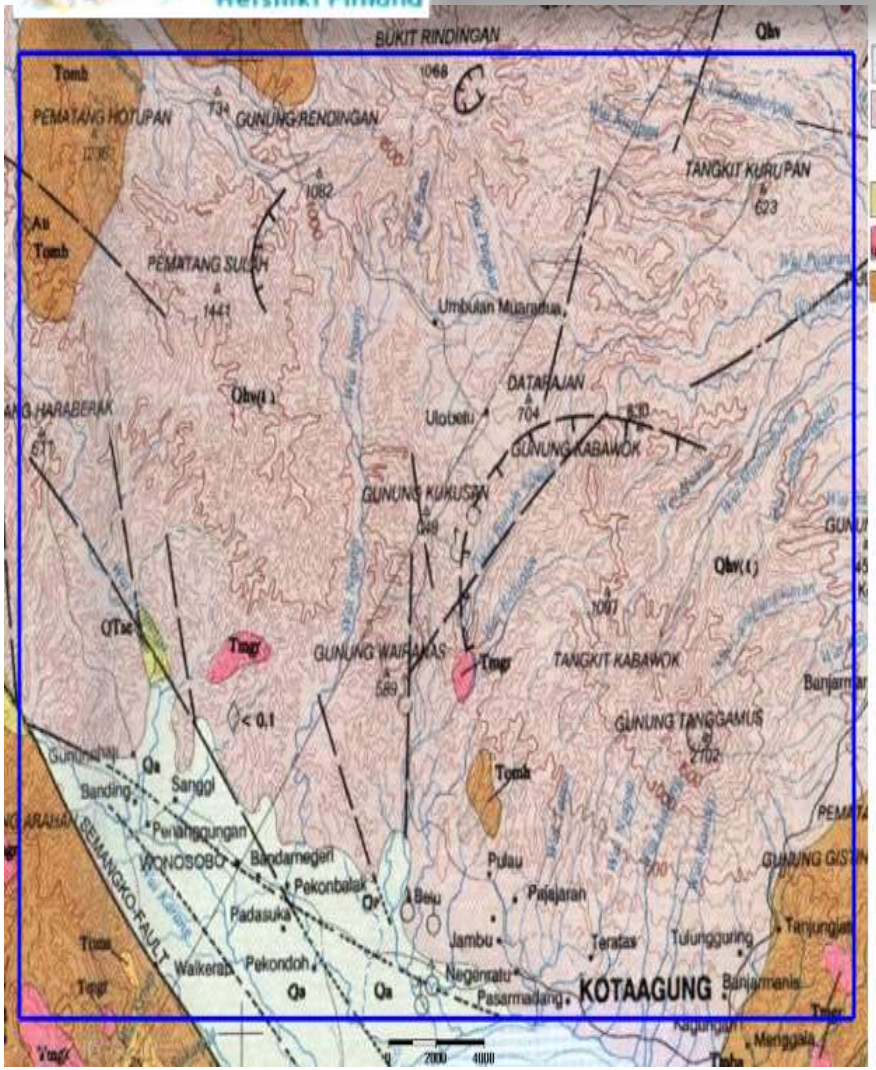
DISCUSSION & Result

GEOLOGICAL SETTING



Source : Geological map of Kota Agung (Amin, 1993)

- The stratigraphy of this study composed by Tertiary volcanic deposit The oldest rock derived from G.Sula volcanic activity that consisted of andesitic lava and pumice (Tomh)
- Quarter products are pyroclastic and andesitic lava that derived from G.Kukusan volcanism (Qtse)
- Latest product are rhyolitic lava and andesitic tuff as volcanic product from G.Korupan. G.Rindingan and G.Tanggamus (Qtry).
- The dacitic tuff formed afterward and alluvium Recent are located on the bottom of this area (Qal).

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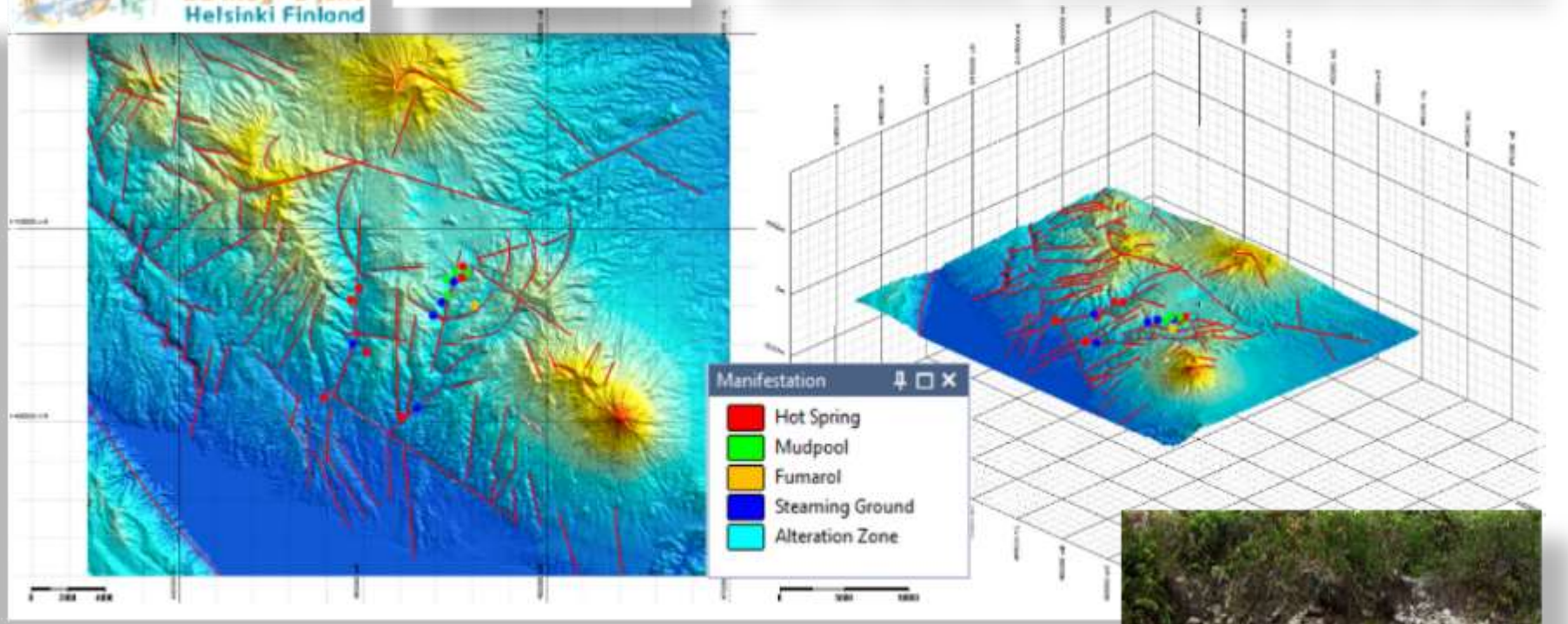
DISCUSSION (cont.)

GEOTHERMAL SURFACE MANIFESTATIONS



- Surface geothermal manifestations were found such as of mud pools, steaming ground, hot springs and alteration rocks, fumaroles scattered in the middle of the study area.
- The emergence and distribution of geothermal manifestations are found in variation regions that have steep slopes up to flat areas, its likely passed by the NE-SW and W-E faults.

Dewi Gentana, May 2017

LINEAMENT INTREPREATIONS

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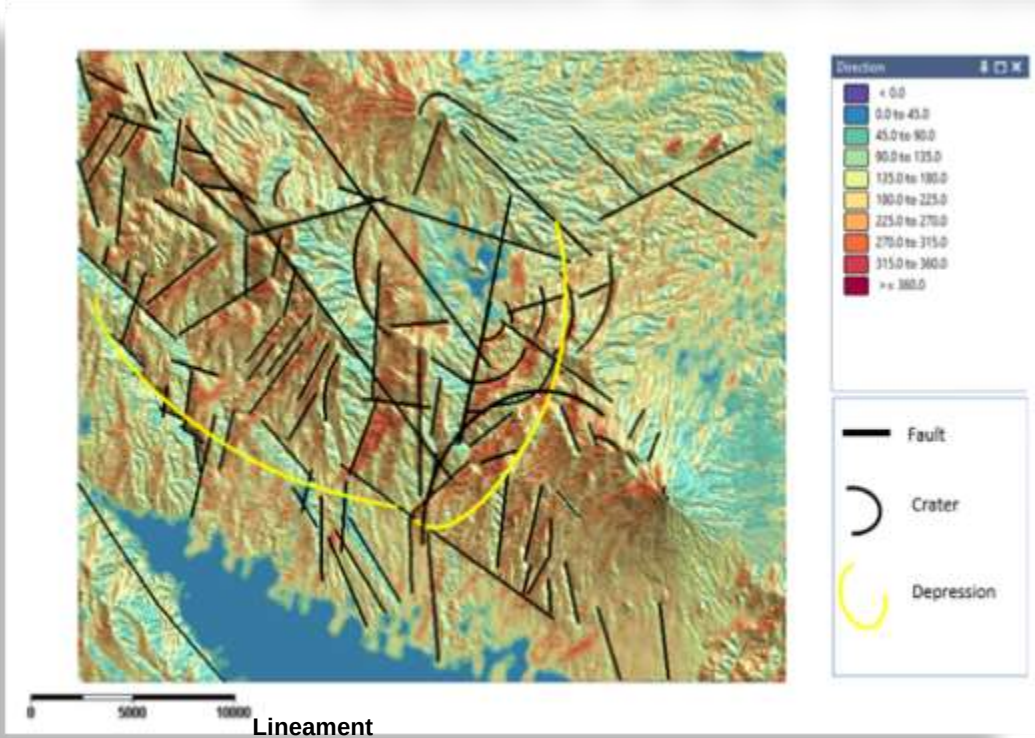
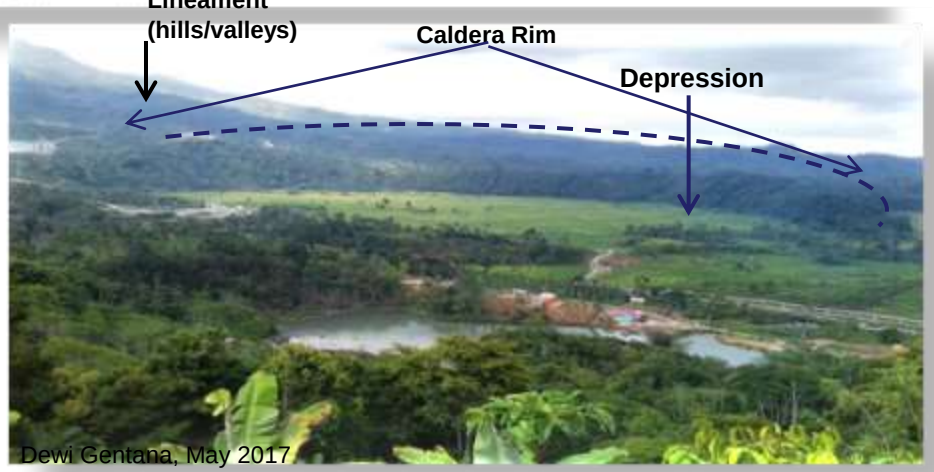
Cont..

- Lineament interpretation based on 3D digital terrain model generated from morphology of RBI topographic contour map which is azimuth and dip of every single triangle is calculated to provide numeric values that can be colorized.
- The orange colour represent triangle that have azimuth N 270^{o} E up to N310^{o}E, it mean that orange colour area mostly have E-W and NW-SE lineament's.
- The circular subsidence structure can be observed on Western and Southern part.
- The NW-SE and NE-SW faults inside the semi circular depression are clearly control the distributions of the geothermal surfaces manifestation encountered at Pagar Alam, Muara Dua and Karang Rejo.





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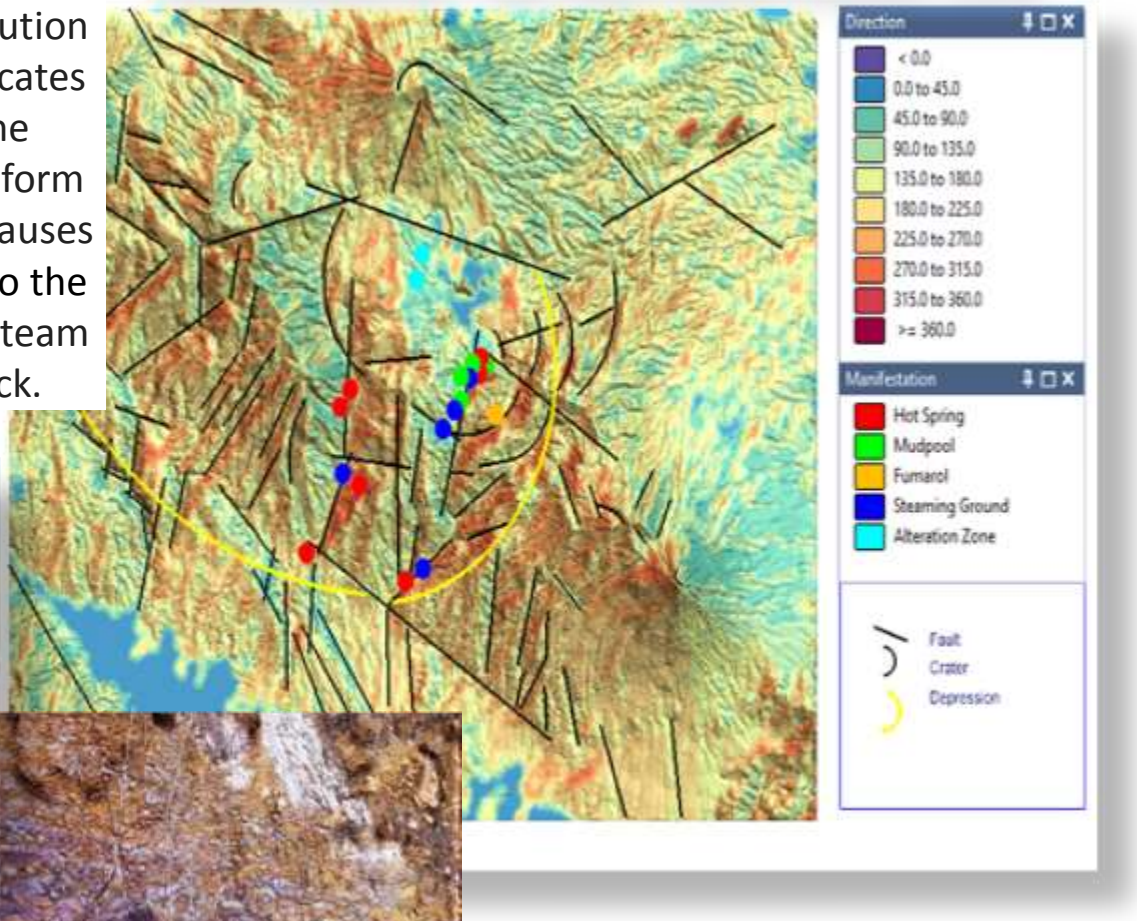
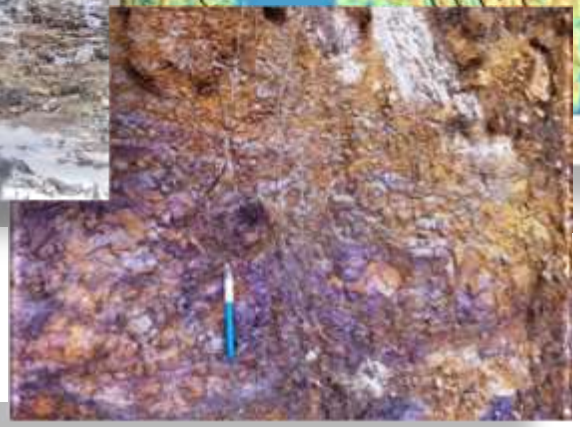
LINEAMENT INTREPREATIONS cont.

By plotting of alignment map with distribution of geothermal surface manifestation indicates that the lineaments contributes to the development of geological structure that form the permeability zone in the rock which causes the hot fluid beneath the surface comes to the surface with its presence by hot springs, steam heated water, mud pool and altered rock.



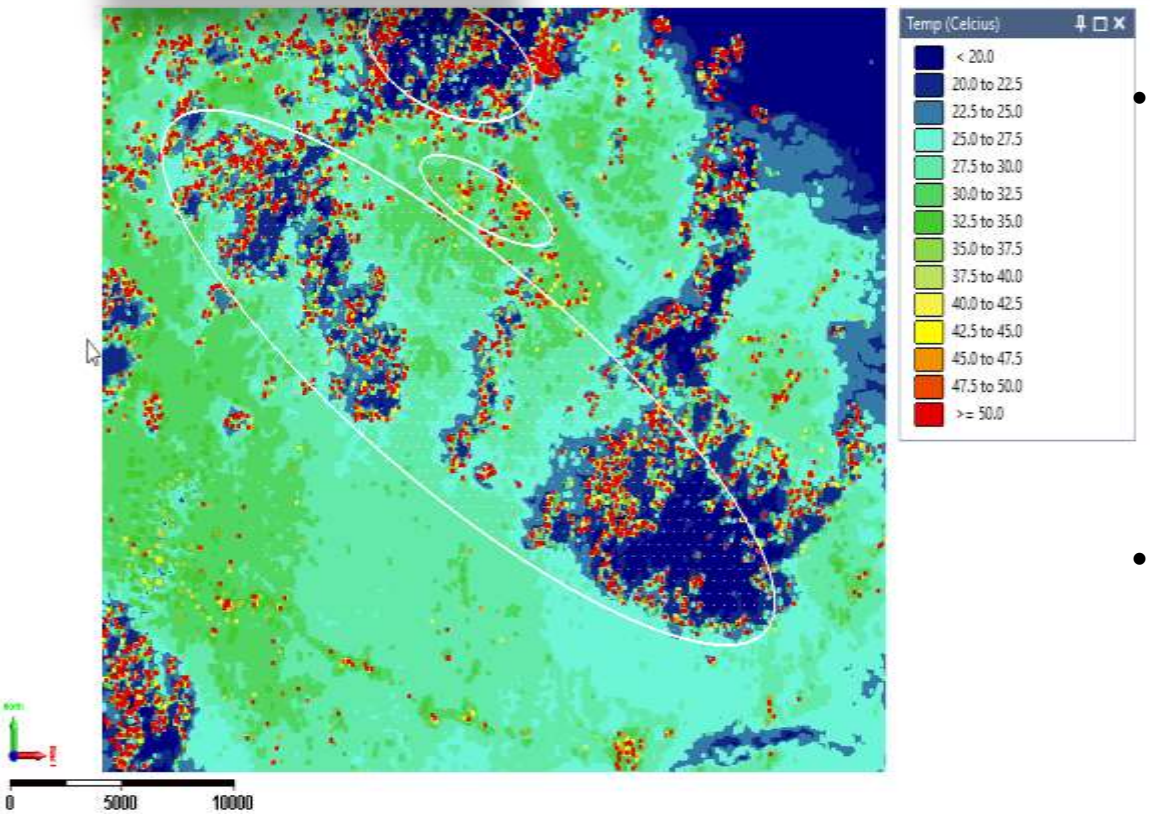
Steaming ground, fumarole , sulfate and altered rock (kaolinite) at Pagar Alam Location



Scrap breccia of Rindingan volcanic product at Pagar Alam location indicates that this area as a fault line area

LAND SURFACE TEMPERATURE (LST)

Cont..



- Land Surface Temperature of Tanggamus based on Landsat 8 OL/TIRS Corridor 124064 on 19 November 2016., shows that the trend of temperatures has NW-SE directions.

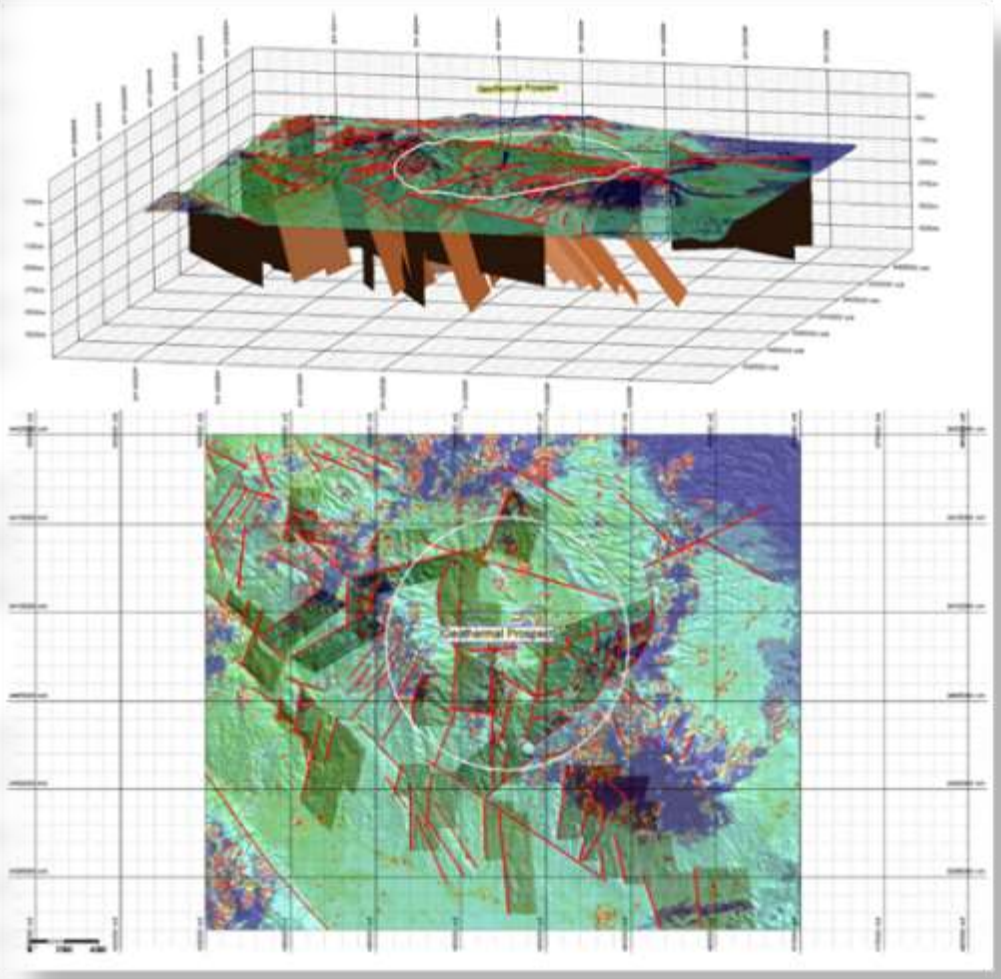
- Interpretation by using topographic, landscape maps and with 3D micromine software applications and surface temperature calculated from Landsat imagery 8 in the study areas have temperature ranges greater than 50^{o}C.

- In some locations have temperatures up to 74^{o}C, related from field observations encountered hot springs have temperature in range 40^{o}-97.2^{o}C and steaming ground have temperatures in ranges 74^{o}-91^{o}C

Cont..

GEOTHERMAL PROSPECT AREA

- Three dimensions illustrate clearly that the development of structures in the Tanggamus geothermal prospect area is indicated as step fault (graben) which have NW-SE,NE-SW and W-E directions with have variation 30-65^{o} slopes. This structure controls the geothermal surface manifestation distributions.
- The micromine software is used to process the topography and Landsat maps to delineate the geothermal prospective areas.
- In this area is estimated to have a geothermal prospect area ± 66 km^{2} (optimistic) but when looking from the distribution of heat features in the whole study area is predicted to have a geothermal prospect area expanded up to 160 Km$^{2.}$



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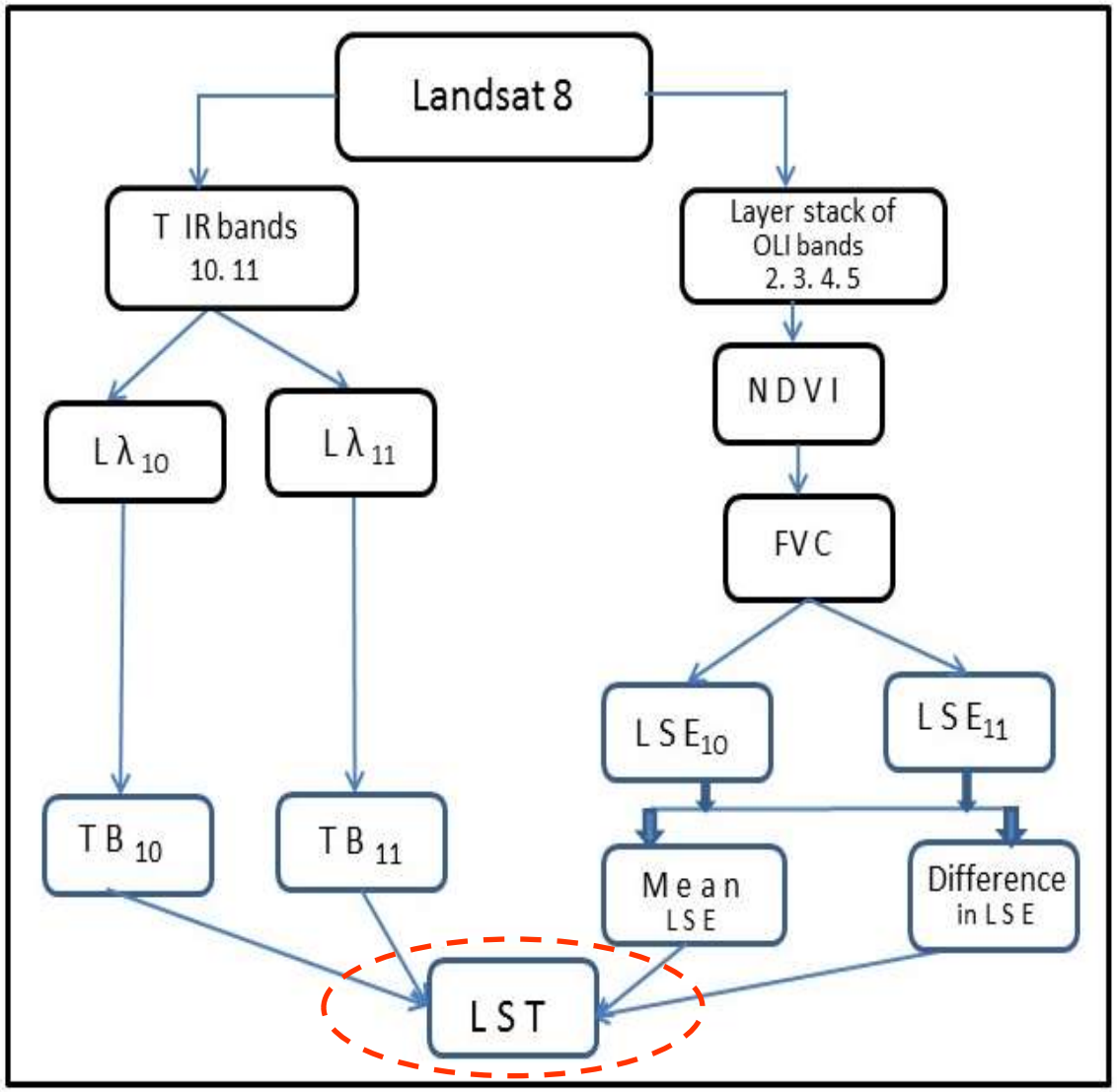
Cont..

Flow chart of Split Window algorithm

(Rajeshwari, 2014).

- Landsat image is used to create land surface temperature. (LST)
- The 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 is calculated using Split-Window (SW) algorithm

LST CALCULATION

The main formula for calculating LST is,

$$LST = TB10 + C1\,(TB10-TB11) + C2\,(TB10-TB11)^2 + C0 + (C3+C4W)\,(1-\varepsilon) + (C5+C6W)\,\Delta\varepsilon$$

Where:

- LST - Land Surface Temperature (K), W is values of atmospheric vapour content
- C0 to C6 - Split-Window Coefficient values (table ; Skokovic et al, 2014 vide Rajeshwari, 2014)
- TB10 and TB11 – brightness temperature of band 10 and band 11 (K)
- TB10 and TB11 can be calculated as TB = K2/Ln ((K1/ Lλ) +1)

Where:

- K1 and K2 are thermal conversion constant and it varies for both TIR bands (table Skokovic)
- Lλ are Top of Atmospheric spectral radiance (m2*srad*μm). Lλ can be calculated as Lλ = ML*Qcal + AL

Where:

- ML - Band specific multiplicative rescaling factor (radiance_mult_band_10/11) = 0.000342
- Qcal – value of band 10/ 11 image.
- AL - Band specific additive rescaling factor (radiance_add_band_10/11) = 0.1

- ε – mean LSE of TIR bands. ε can be calculated as ε = (ε10 + ε11)/2NDVIv
- Δ ε – Difference in LSE. Δ ε can be calculated as Δε = ε10- ε11
- Where ε is LSE from band 10 and band 11 with formul ε = εs (1-FVC) + εv * **FVC**

Where:

- **FVC** is Fractional Vegetation Cover. For every band
- FVC= (NDVI – NDVIs) /(NDVIv – NDVIs)
  - ✓ NDVI = ([B5]-[B2])/([B5]+[B2]), taken from raw data Landsat table
  - ✓ NDVIs = ([B5]-[B4])/([B5]+[B4]), as above
  - ✓ NDVIv = ([B5]-[B3])/([B5]+[B3]), as above

RAW DATA OF LANDSAT 8 OLI/TIRS

LC08_L1TP_124064_20161119.DAT

File Edit Filter Format Records Tools Close

	EAST	NORTH	B1	B2	B3	B4	B5	B6	B7	B8	B9	B10	B11	BQA	B10_TB	B11_TB	NDVI	FVC	B10_LSE	B11_LSE	LSE_MEAN	LSE_DIFF	Celcius1	Celcius6
1	435000.0	9392020.0	12102	11023	9873	9075	16159	10223	8253	9416	5352	23163	21031	3008	295.06988216	294.37867870	0.18894857	2.34	1.008	1.005	1.00673	0.003	22.34	22.42
2	435030.0	9392020.0	12135	11021	9845	9012	16541	10329	8357	9617	5428	23175	21033	2976	295.09977374	294.38461113	0.20027574	2.31	1.008	1.005	1.00632	0.003	22.43	22.50
3	435060.0	9392020.0	12390	11250	10085	9260	16867	10737	8684	9849	5418	23166	21013	2976	295.07735576	294.32527561	0.19977238	2.31	1.008	1.005	1.00637	0.003	22.47	22.54
4	435090.0	9392020.0	12240	11089	10037	9153	17054	10701	8576	9431	5406	23134	20981	2976	294.99761320	294.23028697	0.21195324	2.11	1.005	1.002	1.00351	0.002	22.56	22.60
5	435120.0	9392020.0	12621	11466	10493	9601	17831	11246	8954	10164	5362	23086	20946	3008	294.87789910	294.12631997	0.21725774	2.02	1.003	1.001	1.00230	0.002	22.48	22.50
6	435150.0	9392020.0	13055	11981	10824	10015	17527	11322	9191	10624	5382	23010	20908	3008	294.68810486	294.01335474	0.18794903	2.33	1.008	1.005	1.00669	0.003	21.94	22.01
7	435180.0	9392020.0	13758	12811	11429	10753	17797	11741	9633	11629	5385	22933	20872	3008	294.49550329	293.90625149	0.16289859	2.91	1.018	1.012	1.01470	0.006	21.19	21.35
8	435210.0	9392020.0	14761	13891	12505	11890	18757	12680	10390	12745	5370	22878	20843	2800	294.35773881	293.81991461	0.14904435	3.12	1.021	1.014	1.01762	0.006	20.82	21.01
9	435240.0	9392020.0	14356	13351	12309	11590	18367	12773	10351	11959	5378	22852	20825	2800	294.29255791	293.76629955	0.15814364	2.37	1.009	1.005	1.00716	0.003	21.28	21.36
10	435270.0	9392020.0	14044	13061	12188	11426	18263	12944	10355	11473	5398	22840	20819	2800	294.26246230	293.74842332	0.16607074	2.09	1.004	1.002	1.00320	0.002	21.43	21.47
11	435300.0	9392020.0	14427	13437	12595	11914	18808	13087	10598	11699	5384	22832	20817	2800	294.24239430	293.74246407	0.16656846	2.18	1.006	1.003	1.00449	0.003	21.33	21.38
12	435330.0	9392020.0	13812	12744	11837	11070	17992	12364	9993	10894	5401	22821	20823	2800	294.21479524	293.76034106	0.17074440	2.12	1.005	1.002	1.00365	0.002	21.27	21.31
13	435360.0	9392020.0	12898	11843	10694	9902	16877	11206	9029	10556	5389	22813	20849	3008	294.19471914	293.83778176	0.17527855	2.35	1.009	1.005	1.00694	0.003	20.93	21.01
14	435390.0	9392020.0	12727	11677	10365	9593	16430	10654	8539	10205	5361	22797	20864	3008	294.15455671	293.88243971	0.16910378	2.57	1.012	1.008	1.01003	0.004	20.60	20.72
15	435420.0	9392020.0	12514	11459	9994	9233	15909	10056	8233	10472	5376	22766	20845	3008	294.07670309	293.82587058	0.16259866	2.77	1.015	1.010	1.01276	0.005	20.35	20.49
16	435450.0	9392020.0	12093	10964	9721	8891	15521	9931	8022	9487	5379	22647	20764	3008	293.77736734	293.58445184	0.17205966	2.38	1.009	1.006	1.00733	0.004	20.25	20.33
17	435480.0	9392020.0	14789	13834	12709	12066	18425	12554	10139	11539	5383	22458	20652	2800	293.30038004	293.24995268	0.14231687	2.65	1.013	1.009	1.01115	0.005	19.37	19.50
18	435510.0	9392020.0	19943	19233	18395	18054	23776	18298	14630	19163	5378	22285	20561	2800	292.86206343	292.97758215	0.10562905	3.39	1.025	1.018	1.02146	0.008	18.17	18.41
19	435540.0	9392020.0	21769	21245	20404	20273	25723	20114	16108	20377	5383	22185	20504	2800	292.60794838	292.80670531	0.09534151	7.29	1.088	1.064	1.07602	0.023	14.97	15.82
20	435570.0	9392020.0	22270	21697	21025	20924	26388	20857	16862	20868	5377	22118	20460	2800	292.43738036	292.67465688	0.09755641	7.55	1.092	1.068	1.07965	0.024	14.56	15.45
21	435600.0	9392020.0	22060	21531	20797	20705	26329	20893	17133	20434	5381	22085	20436	2800	292.35327712	292.60257760	0.10025073	8.84	1.112	1.083	1.09777	0.029	13.51	14.61
22	435630.0	9392020.0	21458	20923	20198	20125	25959	20541	17058	20471	5402	22087	20436	2800	292.35837603	292.60257760	0.10741863	10.76	1.143	1.106	1.12467	0.037	12.12	13.52
23	435660.0	9392020.0	19298	18585	17996	17724	24072	19107	15849	17303	5387	22142	20467	2800	292.49850813	292.69567296	0.12863071	3.12	1.021	1.014	1.01770	0.006	17.89	18.09
24	435690.0	9392020.0	17006	16200	15444	14989	21869	16620	13630	15291	5387	22201	20503	2800	292.64864407	292.80370559	0.14891381	2.61	1.013	1.008	1.01052	0.004	18.47	18.59
25	435720.0	9392020.0	15363	14628	13417	12956	20251	14317	11647	12921	5419	22212	20512	2800	292.67661410	292.83070066	0.16121448	3.50	1.027	1.019	1.02301	0.008	17.85	18.11
26	435750.0	9392020.0	17851	17194	15897	15773	22693	15834	12941	16984	5425	22180	20485	2800	292.59522806	292.74969976	0.13786447	11.09	1.148	1.110	1.12922	0.038	12.24	13.69
27	435780.0	9392020.0	20094	19377	18701	18530	24951	18740	15174	18935	5412	22142	20446	2800	292.49850813	292.63261517	0.12574445	4.88	1.049	1.036	1.04229	0.014	16.70	17.17
28	435810.0	9392020.0	20434	19917	19120	19022	25490	19571	15662	19328	5399	22114	20420	2800	292.42718927	292.55450398	0.12273438	8.97	1.115	1.085	1.09961	0.030	13.65	14.77
29	435840.0	9392020.0	21940	21495	20893	20851	27086	20833	16530	20485	5378	22101	20423	2800	292.39406206	292.56351905	0.11508614	15.14	1.213	1.159	1.18601	0.055	9.06	11.15

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Table of Constants used for Calculating LST

(Skockovic Table,2014)

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 11	0.977
εv Band 10	Emissivity εv for Band 10	0.987
εv Band 11	Emissivity εv for Band 10	0.989

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CONCLUSION

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

- 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.

- The result of Landsat Surface Temperature (LST) calculation shows the area having surface temperature more than 50^{o}C related to the trending of geological structure. This is also supported by observations in the field.

- Tanggamus area is estimated has geothermal prospect with an area of about 66 km^2 (optimistic) where in this 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^{o}C, steaming ground with temperatures ranging from 74^{o} - 91^{o}C. Therefore the SW-NE and NW-SE faults control the occurrence of the Tanggamus geothermal prospects area.

- Understanding the trends of regional structure lineaments , structural developments, dispersal of geothermal surface manifestations in the study area may assist in setting up an advanced exploration survey strategy.

THANK YOU FOR YOUR ATTENTION