

The Role of Sumatra Fault Zone of Dikit Fault Segment to Appearance of Geothermal Features on the Grao Sakti, Jambi, Indonesia

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ABSTRACT

Geothermal features manifestation appears in Grao Sakti, Renah Kemumu, Merangin Regency, Jambi Province and their associated of Sumatran Fault Zone and Barisan Range Zone. It is very important to understand the connection both of geothermal manifestation and fault zone of the Dikit Fault Segment (DFS). Geological survey is early study for understanding geothermal features manifestation. It consists of geological mapping, measurement of geothermal manifestation, and the information physical characterized of geothermal features manifestation. Geothermal features of the Grao Sakti is composed of geyser with temperature about 78.5°C - 94.7°C, hot spring with temperature between of 52°C - 62°C, steaming ground, and hydrothermal alteration. The appearance of the geothermal manifestation linkages to DFS and their part of Sumatran Fault Zone. The existence of geothermal features is controlled by DFS which is orientation of Northwest- Southeast and similarly Sumatra Island orientation. DFS's role as a channel way of reservoir rock geothermal in the direction to the surface geothermal manifestation the formed of outflow zone on the Grao Sakti. DFS is dextral fault system which is narrow graben about 8 - 15 m, composed of hydrothermal alteration of Old Masurai Volcanic Complex dacitic lava and Hulusimpang volcanic breccia. The graben structure is consequence of DFS dextral fault system, where linkage to en-echelon truncation as the result of extensional regime inside DFS system. These is formed of depression zone and their related of pull apart basin. DFS is channel way for the appearance of geothermal features manifestation on the Grao Sakti and its role is significant for geothermal system.

Keywords: *Dikit Fault Segment, Geothermal Features, Grao Sakti, Fault System.*

1. INTRODUCTION

Sumatra is an island located in the western part of Indonesia Archipelago which has experienced various geological processes such as forming of basement terrane Pre-Tertiary of Sibumasu-West Sumatra-Woyla terrane as basement structure and stratigraphy, whereas Tertiary to Quaternary geological processes into volcanism-magmatism, and stratigraphy on Barisan Range [1][2]. It is associated the forming of structural geology in the beginning of continental spreading of Andaman Sea part of Northwestern of Sumatra. These processes is forming of Andaman Fault System continuing to weak zone on the

Sumatra Ridge of Barisan Range and formation of Sumatra Fault System (SFS) [3] [4].

SFS and Barisan Range is complex geological interchanging features. Their associated pull apart basin, volcanism, and geothermal features manifestation [5]. Geothermal features manifestation is appearance on the Grao Sakti of Dikit Fault Segment such as geyser and hot spring. To understand the connection both of geothermal features manifestation and fault zone of the Dikit Fault Segment (DFS), it needs geological observation and fluid geochemistry analysis as early study.

DFS is a part of SFS on the Barisan Range the strike slip formation and related to fault bend basin as connection to en-echelon fault. This research for comprehend of the role DFS to appearance geothermal features manifestation on the Grao Sakti. These is appearance of geothermal features manifestation the lithology formation of volcanic product Oligo-Miocene to Plio-Pleistocene of Old Masurai Caldera and Quaternary Volcanoes of Masurai Volcanic Complex (Masurai Volcanoes, Hulunilo Volcanoes, and Sumbing Volcanoes). The specify of geothermal manifestations on DFS on Western part of Sumbing Volcanoes.

2. REGIONAL GEOLOGY

Indonesia Archipelago is constructed of Eurasian continental plate, Pasific oceanic plate, and Indo-Australia plate. Their linkage to ring of fire along continental margin, both of them Sumatra Island [6]. It is composed of Sibumasu terrane, West Sumatra terrane, and Woyla terrane is a basement on Sundaland of Sumatra [7]. The consequence of different basement terrane in Sumatra during Carbon to Cretaceous, certainly numerous of geological features as basement structure and stratigraphy. Geological processes simplify into 1) collision between of Sibumasu to East Malaya terrane is conduct to Bentong-Raub Suture on Late Permian, 2) transcurrent system with strike slip movement orientation both of West Sumatra terrane to Sibumasu terrane has been produced of Tectonic Medial Sumatra Zone during Early Triassic, 3) obduction during Ealy to Middle Cretaceous between of West Sumatra terrane to Woyla terrane is product of Woyla

Nappe structure, 4) Tertiery - Quarternary the subduction processes of Indian plate to Sundaland were product of Paleogene volcanism-magmatism and stratigraphy of Barisan Range, Neogene processes of counterclockwise Sundaland rotation to activation SFS and then continued volcanism-magmatism, stratigraphy, and Quaternary volcanism, continued stratigraphy, and interchanging structural mechanism (Figure 1).

SFS is one of the major trench parallel strike slip fault and traced of Aceh Simeleum Segment on Nort-Northwestern of Sumatra and continued to Semangko Fault Segment in Lampung of South-Southeastern of Sumatra. The Quaternary tectonic setting trend of volcanism and activation SFS form en-echelon elliptical volcanic clucter common in the oblique-sheared subduction [5]. SFS is composed of pull apart basin, which is fault bend basin and overstep basin, [8]. DFS is forming of fault bend basin which single master fault of Dikit Fault and narrow structural valley. It have en-echelon fault, relative similary fault orientation, and cross cutting to old formation such as Oligo-Miocene Hulusimpang Formation, Pliocene Langkup Granitoid, and controlled the existence of Plio-Pleistocene Old Masurai Caldera product, [9][10][11]. The existence of lithology formation the boundary of DFS and en-echelon fault (Figure 2). Structural valley of DFS is composed of Plio-Pleistocene Old Masurai Caldera product unconformity and structural boundary to Oligo-Miocene Hulusimpang Formation. En-echelon of DFS is forming extension fault[3].

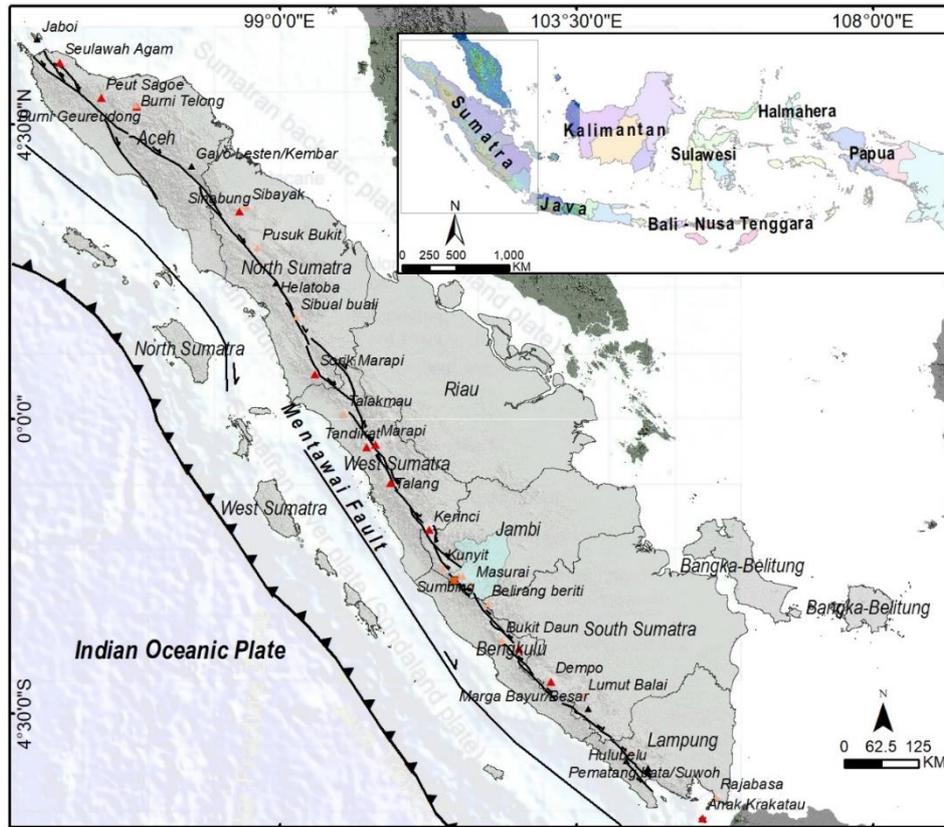


Figure 1 Tectonic setting in Sumatra the slab subduction of Indian Oceanic Plate to Sundaland. These is processes geological forming of SFS the associated to volcanism, geothermal manifestation, and pull apart basin, after [5][6]

DFS and geothermal features manifestation are a part of Masurai Volcanic Complex (MVC) product of the youngest and old eruption. Geothermal manifestation on Grao Sakti related to complex volcanic setting and fault system[9][11]. Masurai Volcanic Complex is B type volcanoes and similarly non-active or dormant Quarternary Volcano.

3. SAMPLE AND METHODOLOGY

Geochemical survey on surface geothermal manifestation sampling into of one water sample of geyser (GS-1) geothermal manifestation with distance location about 6 m to one water sample of hot spring (GS-2) geothermal manifestation. Measured of physical characteristic such as water temperature with air temperature, power of Hydrogen (pH), clarity of water, Total Dissolved Solid (TDS), Electrical Conductivity (DHL), and understanding of sinter deposit surrounding geothermal manifestation (Table 1). Water sample is required 500 ml for anion element and 500 ml of cation element with filtering to used of microfilter 0.45 micron. Water cation sample the pickled with nitrate acidic extend fluid pH to 2 - 4. Sample analysis used method of Atomic Absorption Spectrophotometry (AAS) of cation element

and silica element, Tri Metri for understanding of anion element, Turbidimetri anion element specfy of sulfate element, Spektrofotometri of cation ammoniac and anion fluoride, and Kolorimetri method of cation arsenic element (Table 2). The anion element for understanding of geothermal fluid type, whereas cation element for understanding partial chemical equilibrium of geothermal fluid, and natural element such as silica and sodium/potassium to measured geothermometer for to knowing geothermal reservoir temperature.

Measured of structural geology such as fault on geothermal manifestation cover by fault plane and slickend side of net slip on two fault plane of Dikit Fault Segment. Understanding fault type, orientation, fault continued identification as descriptive, kinematics, and dynamics of fault system. Fault analysis combine to unit rock of geological map and geothermal manifestation, certainly understanding the role of fault to appearance geothermal manifestation. Analysis of digital elevation model include of ASTER-GDEM 30 m and SRTM 90 m (USGS), combine to drainage pattern.

4. RESULTS AND DISCUSSION

4.1. Result

4.1.1. Geothermal Manifestation

Geothermal manifestation on Grao Sakti comprise of geyser, hot spring, hydrothermal rock alteration, and travertine (Figure 2). Geothermal surface manifestation the appearance on Dikit Fault Segment of the Grao River. Geyser have characteristic of fountain fluid persecond which realize about 1 - 3 m, clarity water, high temperature, present to volcanic breccia Hulusimpang and dacitic lava Old Masurai Volcanic Complex. Hot spring have 50l/s rate of flow and medium temperature about 52 °C - 62°C, pH

about 7.5 - 7.8. hydrothermal rock alteration generally the forming of argillic hydrothermal alteration, and travertine produce of deposits geothermal fluids.

4.1.2. Geothermal Fluid Type

Geothermal fluid analysis anion elements obtained chloride (Cl) type of geothermal fluid. Cl ratio content bigger than bicarbonate (HCO₃) and sulphate (SO₄). Chemical geothermal fluid analysis have processing data calculated of the percentage those element. The use diagram for understanding type of reservoir geothermal fluid such as mature water of deep geothermal fluid, peripheral water similarly meteoric water, and volcanic water related to active volcano. The below diagram to show mature water of deep reservoir geothermal (Figure 3a).



Figure 2. Geothermal surface manifestation. It is composed of a) geyser with travertine and related to fault valley of Dikit Fault Segment, b) volcanic breccia with dacitic lava on the surrounding of geyser and associated to fault plane of Dikit Fault Segment, c) hot spring with argillic hydrothermal alteration, d) Grao River (Western) have relatively hot to warm temperature, whereas Nyabu River (Northern) have cold temperature.

4.1.3. Geothermal of Partial Chemical Equilibrium

Geothermal fluid analysis cation element acquire of potassium (K), sodium (Na), and Magnesium (Mg). Ration

between of element to show value magnesium dominantly of potassium dan sodium. Data calculated processing of the percentage those element. The use diagram for knowing partial chemical equilibrium of geothermal fluid. The significance geothermal fluid of boiling to fluid mixing (Figure 3b).

Table 1. Physical characteristic of geothermal surface manifestation

No	Location (No. Sample)	Time	Lithology	Coordinate		Water T(°C)	Air T(°C)	pH	TDS (ppm) and DHL (µm/cm)
				mE	mS				
1.	Sungai Grao (GS-1)	2020 July 27	Volcanic breccia and dacitic lava	794363	9726916	78.5 85.8 94.7	30.5 33.5 37.5	7.2 7.1 7.2	710 and 460 717 and 477 720 and 480
2.	Sungai Grao (GS-2)	2020 July 27	Volcanic breccia and travertine	794363	9726915	77.2 82.7 84.5	30.2 33.7 35.8	7.1 7.3 7.2	715 and 450 720 and 480 730 and 490

Table 2. Geothermal fluids manifestation of geochemical methods analysis

No	No. Sample	AAS Parameter				Tri Metri Parameter		Turbidi metri Parameter	Spektrofotometri Parameter		Kolorimetri Parameter
		Mg ²⁺	K ⁺	Na ⁺	SiO ₂	HCO ₃ ⁻	Cl ⁻		NH ₄ ⁺	F ⁻	
1	Sungai Grao (GS-1)	1.1	30.11	419.33	156.64	63.28	688.60	78.88	0.90	2.59	6.00
2	Sungai Grao (GS-2)	0.66	30.14	385.14	146.52	71.05	669.86	77.32	1.08	0.00	40.00

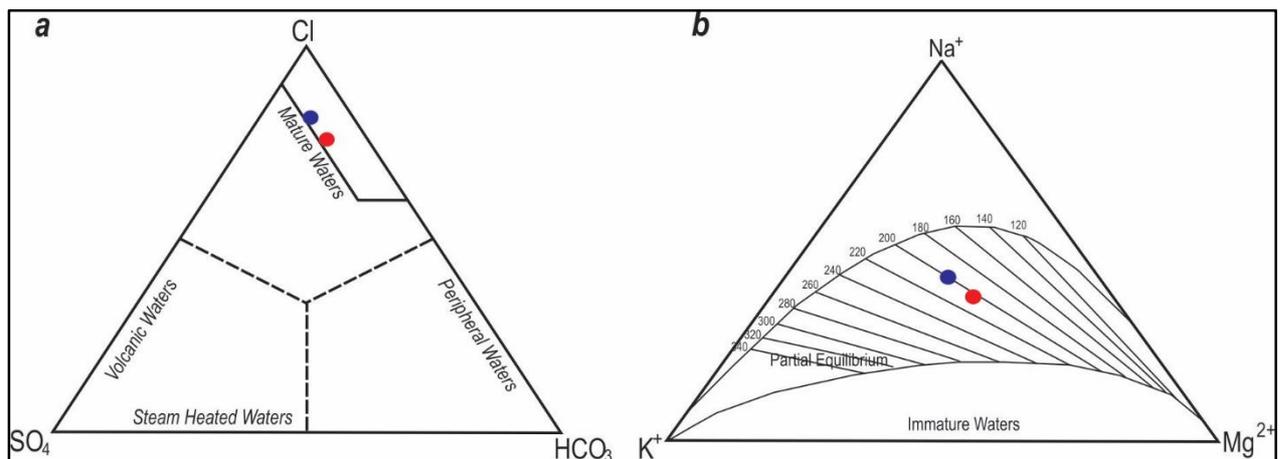


Figure 3. a) Diagram Ternary anion element Cl, HCO₃, SO₄ for determination geothermal fluid type on Grao Sakti and b) Diagram Ternary cation element content of Na, K, Mg on Grao Sakti. the diagram refer to Diagram Ternary [12]

4.1.4. Solute Geothermometers

Solute geothermometer is using geothermometer silica, Na/K of Total Alkali and there are natural element and cation element of geothermal fluid content. Geothermometer enable temperature of the reservoir fluid assesstment. It is valuable tools monitoring the hydrogeology on the geothermal system (Table 3).

Geothermometer silica with interpret quartz, no steam loss, because the geothermal surface manifestation related to volcanic complex and fault system, thus the use equation $T^{\circ}C = 1309 / (5.19 - \log SiO_2) - 273$. Geothermometer Na/K which equation of geothermometer Na/K which equation of $T^{\circ}C = 1390 / (\log (Na/K) + 1.750) - 273$. Geothermometer K-Mg which equation of $T^{\circ}C = 4410 / (\log K / (Mg)^{1/2}) + 14.00) - 273$.

Table 3. Solute geothermometer calculation of geothermometer element

No Sample	Geothermometer Silica	Geothermometer Na/K	Geothermometer K-Mg
Sungai Grao (GS-1)	164°C	207°C	243°C
Sungai Grao (GS-2)	159°C	213°C	232°C

Geothermometer equation based on Giggenbach (1986) and Nicholson (1993)

The result calculation of solute geothermometer of geyser on Grao Sakti is high enthalpy geothermal system refer to classified [13][14]. Specify result of geothermometer silica some classified such as Benderitter and Cormy (1990)[15][12] is moderately enthalpy geothermal system. Generally, compare three geothermometer parameter analysis to indicate of high enthalpy geothermal system with reason such as high temperature surface geothermal manifestation.

strike slip which SSE-NNW, 2) N 160°E/80° (fault plane) and rake 8° strike slip which SSE-NNW. The analysis in the field and studio of fault element obtained of strike slip which dextral fault slip.

4.1.5. Structural Geology

Structural geology on the Grao Sakti comprise of fracturing and faulting. Fracturing as channelway hot spring appear on surface (See Figure 2c). Faulting on the Grao Sakti this characterization of strike slip fault of Dikit Fault Segment. It is part of fault segmented in Sumatra. Fault system of DFS on two fault plane and slicked side of net slip have 1) N 155°E/75° (fault plane) and rake 10°

Fault system on Grao Sakti the formed of structural narrow valley or graben with diameter narrow graben about 8 - 15 m with Old MVC dacitic lava product and Hulusimpang volcanic breccia of andesitic lava. Fault system interpretation of ASTER-GDEM 30 m and SRTM 90 m, combine to drainage pattern for understanding fault system related to DFC. Fault system on the Grao Sakti surrounding have average fault orientation similiary with DFS. En-echelon fault is perpendicular to DFS with orientation NNE-SSW which strike slip, it is continued to Masurai Volcanic Complex, and associated to volcanic structural such as caldera on the peak of Masurai Volcano, crater with debris zone on Hulunilo Volcano, crater on Sumbing Volcano (Figure 6).

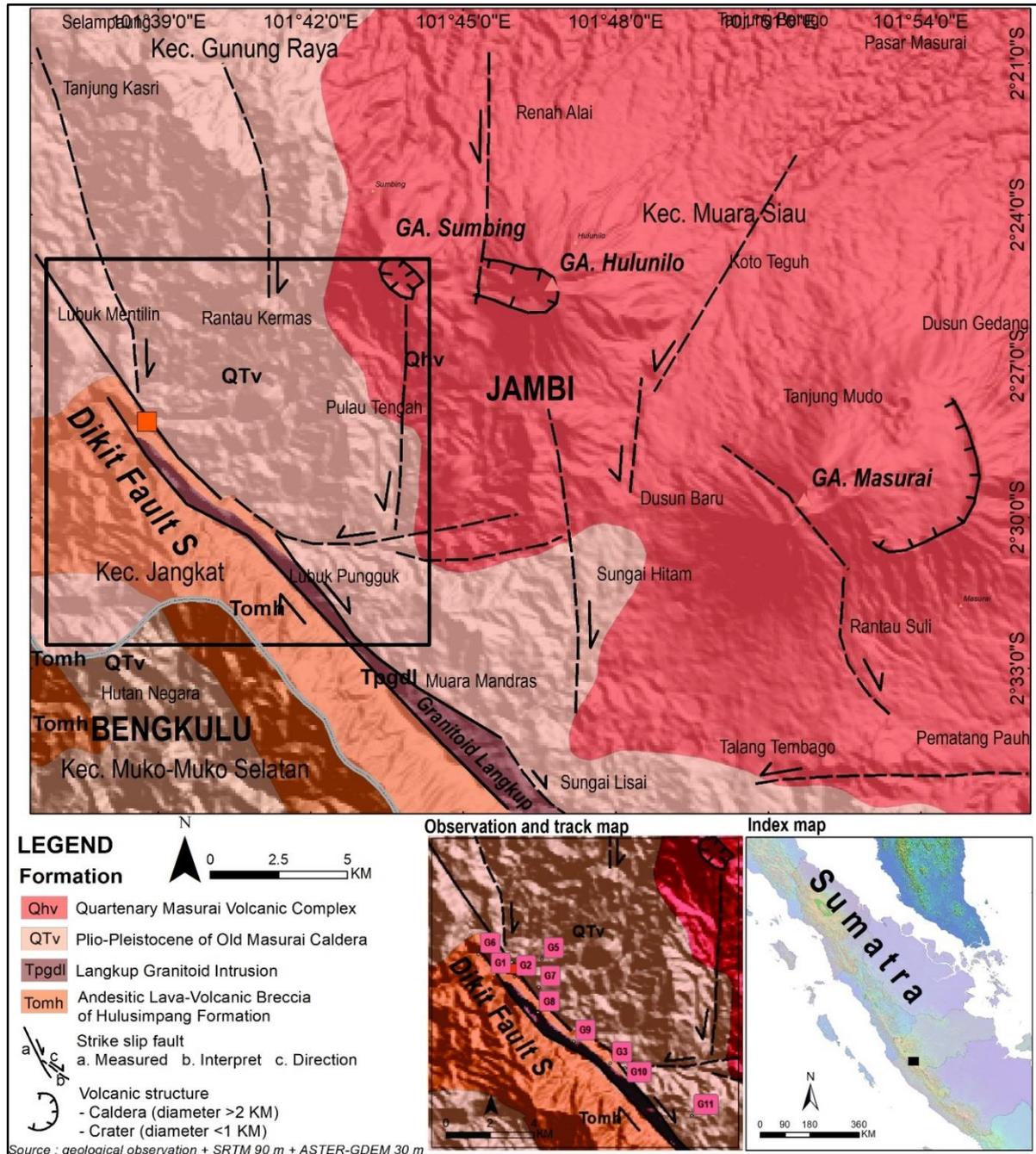


Figure 4. Geological map on Grao Sakti and surrounding. Overlay to digital elevation model [16]

4.2. Discussion

Geochemical analysis of geothermal fluid sample to indicated of chloride type fluid geothermal. It is the meaning fluid of the deep geothermal reservoir and typically of mature water. Partial chemical equilibrium of cation element analysis to partial equilibrium significance partial of geothermal fluid have mixing, meanwhile on

surface still boiling condition with temperature about 94°C. Solute geothermometer of silica, alkali to sodium (total alkali), alkali-magnesium is indicated of high enthalpy geothermal system. It is related to near heat source of Sumbing Volcano. The appearance of geothermal features manifestation on Hulusimpang volcanic breccia and Old MVC dacitic lava the assured appear stratigraphy contact which structural boundary of DS.

Geothermal manifestation such as geyser and hot spring the appearance on the DFS as outflow zone. The existence of Sumbing Volcano, it is part of Masurai Volcanic Complex the youngest episode interpret heat source of geothermal system on Grao Sakti. it have high permeability and recharge area. The appearance of geothermal surface manifestation on Grao River upstream of Sumbing Volcano, wherea if compire of Nyabu River have cold temperature about 21°C. high relief in Sumbing Volcano assured as source of hydrogeology system on Grao Sakti.

The formed DFS since of Miocene continued to orogenic of Barisan Range and their associated geothermal manifestation and also pull apart basin. It have dextral fault system forming of fault bend basin, where geothermal appearance of Grao Sakti. En-echelon of DFS is relatively extension rezime, and so that the formed of graben or basin (Dikit graben). DFS system still active fault continued active volcanism of Quartenary. Interchanging structural on DFS is typically of en-echelon structure.

The appearance geothermal manifestation on Grao Sakti close of relathioship to DFS. It is convinced DFS channelway of geothermal fluid appear on surface manifestation, as recharge area on geothermal system. The existence of geothermal features is assured controlled by DFS which is orientation of NorthNorthwest-SoutSoutheast and similarly Sumatra Island orientation. DFS is role as channelway of reservoir rock geothermal in the direction to the surface geothermal manifestation the formed of outflow zone on the Grao Sakti. DFS is dextral fault system which is narrow graben, composed of hydrothermal alteration of Old Masurai Volcanic Complex dacitic lava and Hulusimpang volcanic breccia. The graben structure is consequence of DFS dextral fault system, where linkage to en-echelon truncation as the result extentional regime inside DFS system. These is formed of depression zone and their related of pull apart basin. DFS is channelway the appearance geothermal features manifestation on the Grao Sakti and the role significant of geothermal system.

5. CONCLUSION

Geothermal features manifestation on Grao Sakti is composed of geyser, hot spring, argillic alteration rock, and travertine. It is appearance of Hulusimpang volcanic breccia Oligo-Miocene with Old Masurai Volcanic Complex (MVC) dacitic lava and the associated to Sumatra Fault System specify Dikit Fault Segment (DFS).

Geochemical fluid of geothermal fluid manifestation on Grao Sakti is chloride fluid type which the deep geothermal reservoir and partical chemical equilibrium to show

geothermal fluid partial have mixing. Based on solute geothermometer silica, potassium or alkali to sodium, and potassium to magnesium, that reservoir geothermal temperature on Grao Sakti is high enthalpy geothermal system.

DFS is part of Sumatra Fault System, typically dextral fault direction. En-echelon produce to extension regime the forming of fault graben of Dikit graben. DFS is the role facilitating the appearance of geothermal surface manifestation as recharge area of hydrogeological system the upstream of Sumbing Volcano. It is a part of MVC the youngest episode.

Geothermal system on the Grao Sakti is composed of heat source hydrogeological system the upstream of Sumbing Volcano of The Youngest MVC as reservoir geothermal, DFS is the role channelway the appearance geothermal manifestation on surface of the Dikit gaben on the Grao Sakti as recharge area outflow zone, dacitic lava of the The Oldest MVC and Hulusimpang volcanic breccia significance caps of geothermal system on Grao Sakti and associated to argillic alteration type.

Based on geochemical analysis and geological survey on the Grao Sakti the required further research use detailed of geological survey and structural mapping, petromineralogy analysis and petrogechemistry analysis. For accurate of temperature geothermal reservoir is required of isotop OH analysis.

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