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STRUCTURAL GEOLOGICAL CONTROL ON THE APPEARANCE OF GEOTHERMAL AREA MANIFESTATION IN GEDONGSONGO, BANDUNGAN, SEMARANG, CENTRAL JAVA BASED ON ANALYSIS OF FAULT FRACTURE DENSITY

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ABSTRACT
Gedong Songo, Ungaran, is a geothermal complex from the part of the Ungaran volcano system which located in the North of the Serayu Mountains as the result of back-arc magmatism during the quaternary period. The presence of surface geothermal manifestations indicates the existence of an active geothermal system in this area. Surface manifestations in Gedong Songo area includes hot springs, fumaroles, steaming ground, and altered rocks. This study uses a lineament analysis on imagery DEM supported by geomagnetic data and geological mapping. The lineament in this area is identified from DEM. Based on geological field observations and mapping, and also manifestations in Gedong Songo area are controlled by northeast-southwest right strike slip faults structures, and the presence of structures is reinforced by geomagnetic anomalies that indicate areas affected by heat experiencing demagnetization.

Keywords: *Fault Fracture Density, Gedong Songo , Geomagnetic,Manifestation*

INTRODUCTION

Indonesia is traversed by volcanoes or known as the Ring of Fire through Sumatra Island, Java Island, Nusa Tenggara Islands, Sulawesi Island and Maluku Islands. These volcanic pathways have the most potential for large geothermal energy (Pratomo, 2006). The sources of geothermal can be formed due to three factors, namely the presence of heat sources, surface water (meteoric water) and reservoir rocks (reservoirs).

Heat energy is formed from a naturally geothermal and stored in the form of hot water or hot steam under certain geological conditions at several depths kilometers in the earth's crust. Hochstein and Browne (2000) define the geothermal system as naturally occurring heat transfer in a certain volume in the earth's crust where heat is transferred from a heat source to the heat release zone. In Figure 1, Conceptual models of young geothermal system (Goff.F and C.J.Janic, 2000) it can show a conceptual model such as the fracture zone and the fracture that is on the surface that allows water to enter the pores of the rock. This water penetrates the bottom and sides as long as there is a gap for the water to flow. When water starts to reach the heat source, the temperature of the water will increase and evaporate partly, and some will remain high temperature water. Hot fluid transfers heat to the surrounding rocks by the process of convection, if the temperature increases it will result in increased volume and pressure.

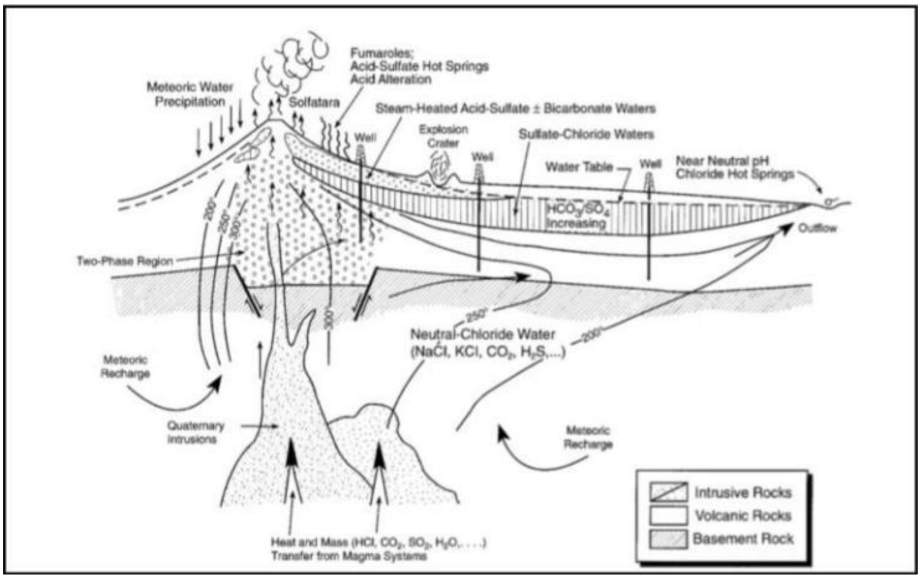

Figure 1. Conceptual models of young geothermal systems hosted on andesite stratovolcano. (Goff.F and C.J.Janic, 2000)

To make optimal use of Indonesia's geothermal potential, efforts are needed to improve the mastery of geothermal technology. One of them is by using Geological Information System (GIS) technology such as Globalmapper and Arcmap, geothermal potential can be mapped based on faults and fractures through remote sensing. In the principle, hydrothermal solution as a source of geothermal energy will flow through fields in the form of faults and fractures which can be seen in DEM image data. Making a Fault Fracture Density Map (FFD) by utilizing remote sensing technology and Geographic Information Systems can be an easy way to map geothermal potential in Indonesia that has real potential and is supported by Indonesia's geographical situation which can be developed as a renewable and environmentally friendly energy in the midst of a fossil fuel crisis.

This research area located in Gedong Songo , Central Java Ungaran and this research discusses control over the emergence of surface geothermal manifestations in Gedong Songo , Ungaran, Central Java and interpretations of the DEM map with the alignment assumed to be a weak zone that controls the discharge of surface fluids.

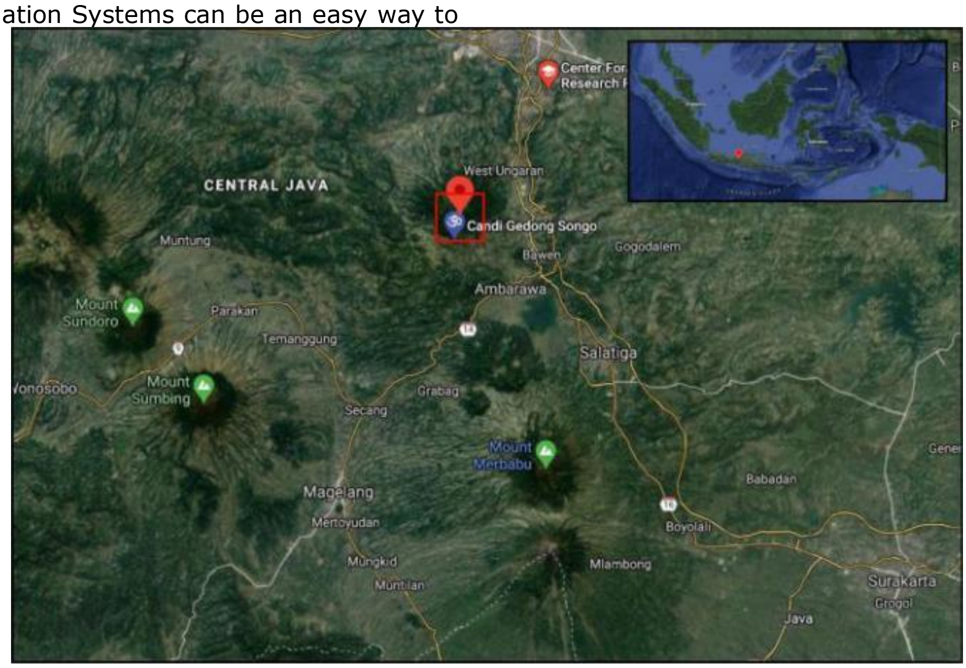

Figure 2. The Gedong Songo reseach area. (Courtesy by Google Earth)

RESEARCH METODOLOGY

The research method in the Gedong Songo area, Ungaran, Central Java based on the analysis of the lineament at the DEM to produce a map of the alignment and structure or fault fracture density (FFD) processed with Global Mapper and Arcmap software and primary data collection data such as field data collection including outcrop observation, observation of geothermal manifestations, structure measurements taken from the field of the Gedong Songo Geothermal complex, Ungaran, Central Java. Then the addition with previous research data such as water geochemical data (Nguyen Kim Phuong et al, 2005) and magnetic geophysical data (Agus Setyawan et.al, 2015) are expected to support this research.

LOCAL GEOLOGY

Gedong Songo and surrounding area composed by several rocks like Sandstone (QTp1), Claysand (Qa), Andesite hb-ag (Qhg1), Lava hb (Qks), Marls, Tuffaceous sandstone (Tmpk), Claystone, Marls, Volcanic breccia (Tmk), Andesite ag-hb (Qls2), Pyroclastic volcanic (Qp1), Andesite bx ag-ol (Qpk1), Lava bx (Qpkg), and Andesite ag-hb (Tma1).

The manifestations in this area are found in severals area involve, Gedong Songo , Diwak, Kendalisodo, Kaliulo, Benaran, and Nglimut. The research area is located in Gedong Songo area that controlled by major structure northwest-southeast trending.

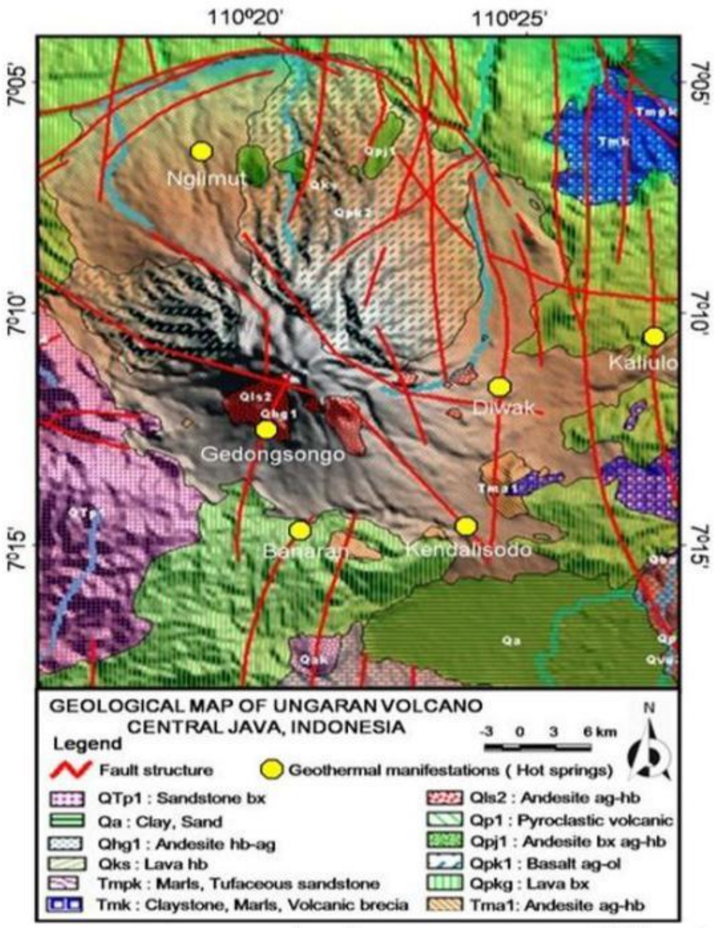

Figure 3. Modified Geological Map modified from Thanden RE et all 1996 based on 1995 Landsat TM satellite imagery (Setyawan, A et all 2007)

RESULT AND DISCUSSION

FAULT FRACTURE DENSITY

The Fault Fracture Density map is created using the line density method. Line density is a feature that calculates linear feature density around each output raster cell (Figure 3.A), density is calculated in units of length per unit area (ESRI)

Based on the Fault Fracture Density map (FFD), it shows that manifestations (Fumaroles, Steamground, Hotspring) are found at high densities (Figure. 3) And the alignments associated with structures in the study area and can be a topographic representation of river straightness, straightness valleys, fault and fracture structures, rock contact and the appearance of geothermal manifestations. Trend line in Gedong Songo area has general direction with northwest-southeast dominant direction.

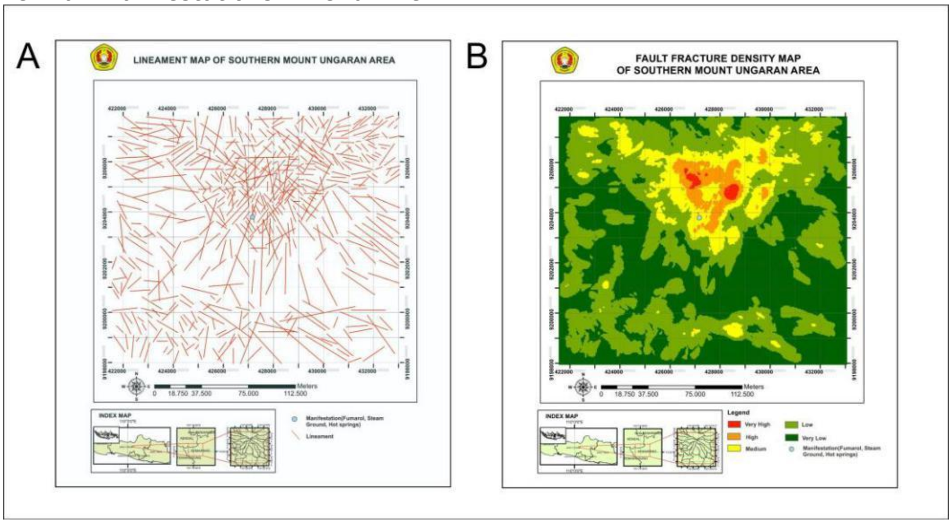

Figure 4. Linement Map of Southern Mount Ungaran Area, B. Fault Fracture Density Map of Southern Mount Ungaran Area

GEOMAGNETIC

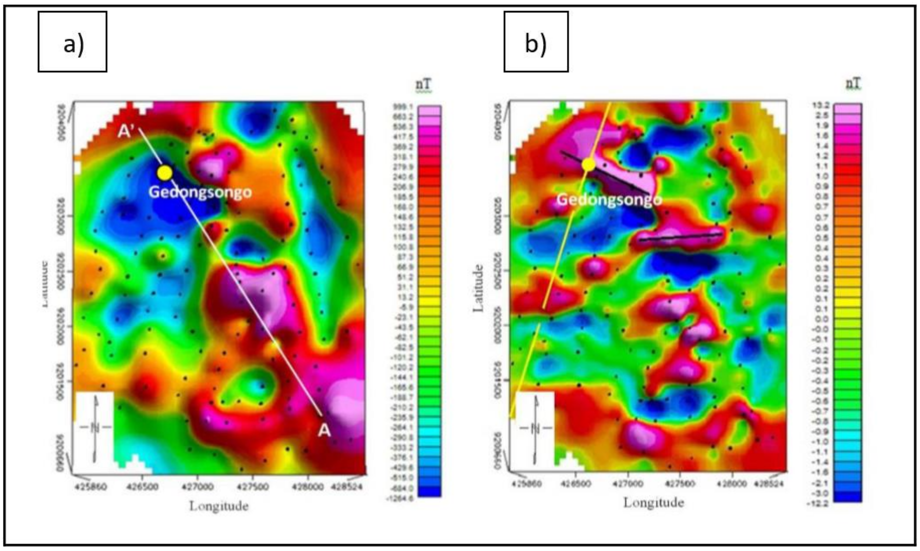

Figure 5. The total magnetic anomaly map, b) The horizontal gradient map of the magnetic data for Ungaran (Agus Setyawan et.al, 2015)

In this Fault Fracture Density map cannot be used only but also needs to be correlated with other data such as geomagnetic geophysical data.

Figure 4.a. The magnetic data was corrected for IGRF, annual correction, pole reduction, and upward continuation. The total magnetic anomaly map south of Ungaran volcano shows manifestations (Fumarole, Steam ground, Hot Spring) in Gedong Songo which have low magnetic anomaly values; which shows the existence of an active geothermal system in the region. The results correlate well with geochemical analysis.

Figure 4.b. Figure shows the HG map obtained from magnetic data that is processed using equations used to determine the structure that is located at the maximum value of the horizontal gradient map. The yellow circle shows the location of the manifestation, the white line shows the direction of the incision (here is not displayed further read Agus Setyawan et.al, 2015) the yellow line shows the interpretation of the geological fault, while the black line shows the fault interpretation of the HG.

GEOTHERMAL MANIFESTATION OF GEDONG SONGO AREA

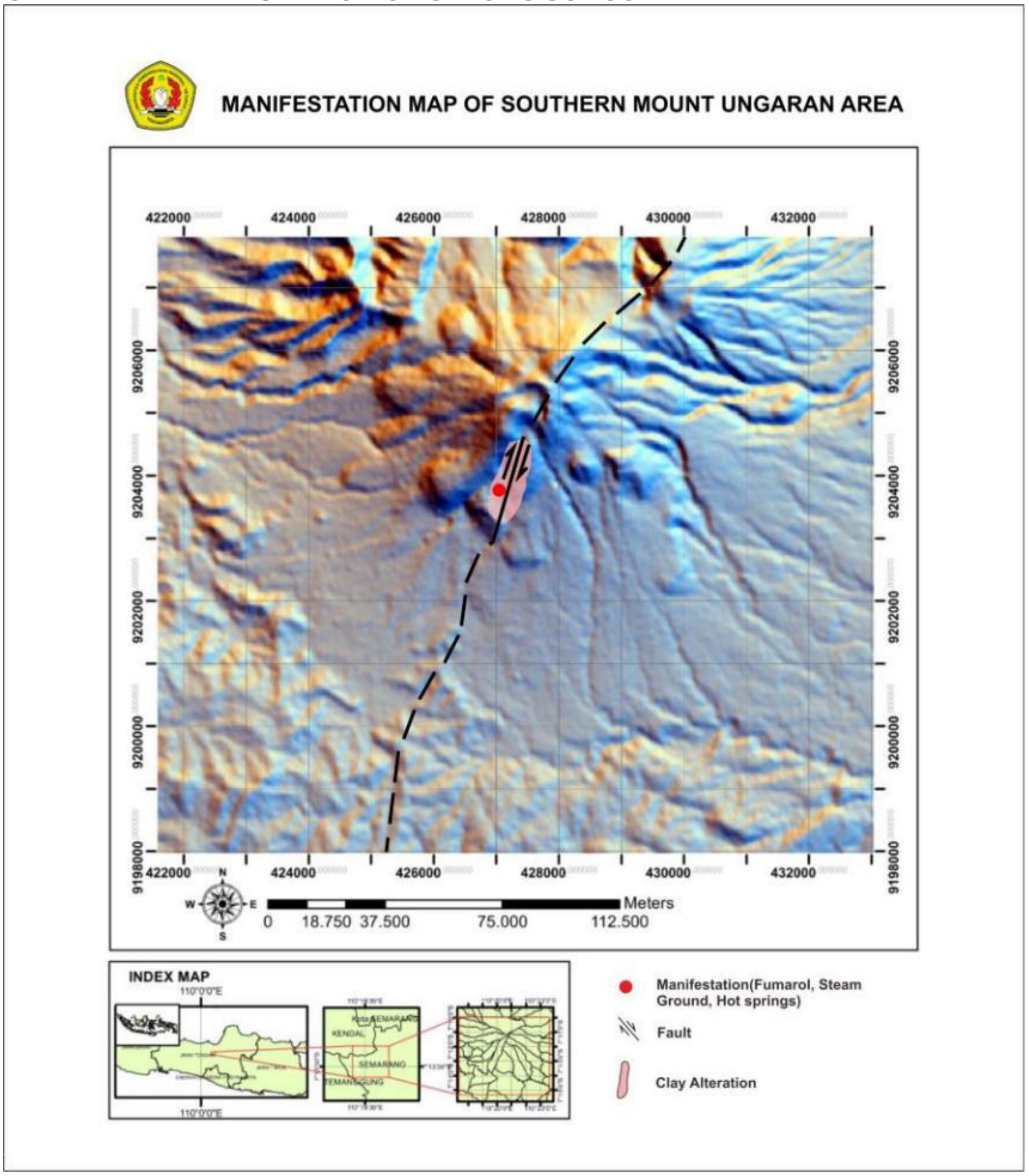

Figure 6. Manifestation Map of Southern Ungaran Mount Area

Based on Figure 6, Geothermal manifestations found in Gedong Songo area are fumaroles, hot springs, and clay alteration rocks. Manifestation of geothermal is controlled by a fault northwest-southeast trending. From the Magnetic Map (Figure 5.a), show that the geothermal manifestation area is symbolized by low magnetic anomaly values. The loss of magnetism or demagnetization is caused by destruction of rock which controlled by the presence of geological structures such as faults, which will later be used as a channel way for hydrothermal fluid discharge. Hydrothermal fluid that passes through the rock causes changes in the rock/alteration rock, in the field obtained clay alteration. Besides, the boiling fluid will change into two phases, the liquid phase will produce manifestations in the form of hot spring while the gas phase will form fumaroles. While the red color is an area where rocks do not experience alteration and the effect on the structure is still minimal, so the magnetic properties remain.

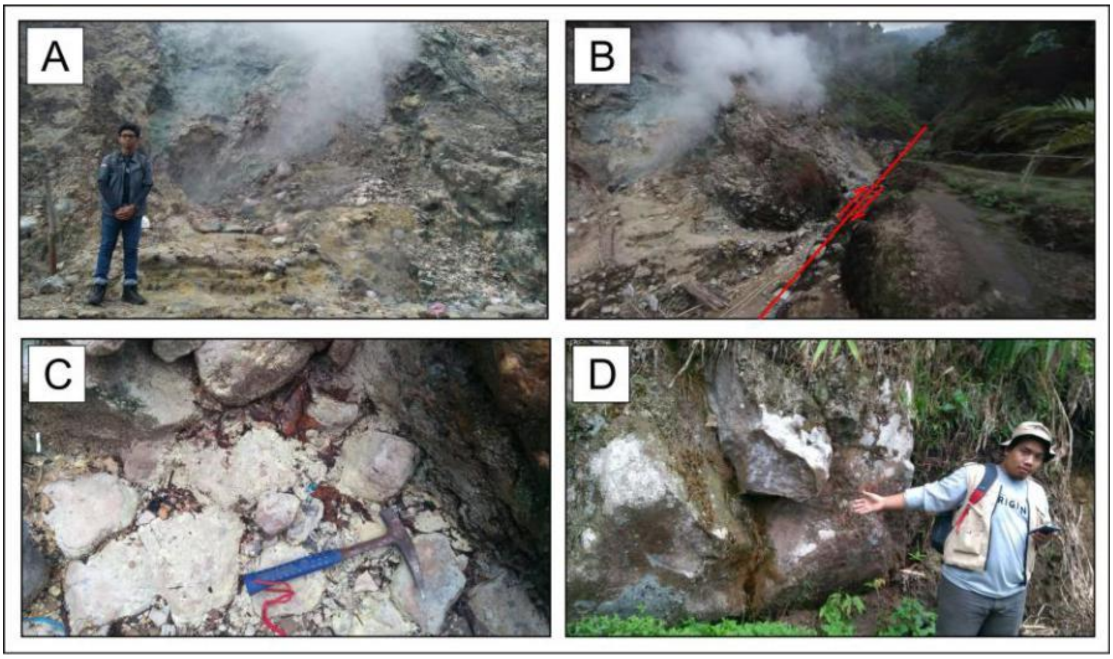

Figure 7. A. Fumaroles B. Steam ground and Fault Indicated C. Clay Alteration D. Andesite Fresh Rock of Southern Ungaran Mount Area

Based on chemical composition of the hot / warm springs and cold springs (well water and river water) collected in Gedong Songo area are presented in Table 1. Nguyen Kim Phuong et al (2005). The Chemical and physical processes that affect water composition and their spatial relationships can be used in ternary diagrams such as Cl-HCO3-SO4 dan Na/1000-K/100-√ , Giggenbach (1988) which show the relative concentrations of water. Based on the samples have taken that showing the conductivity ranges from 0.04 mS / cm to 19.83 mS / cm, the temperature are ranging 18°C to 56°C and in general have neutral pH from 5.36-7.87 except UGW-1 which has an acidic pH of 3,45.

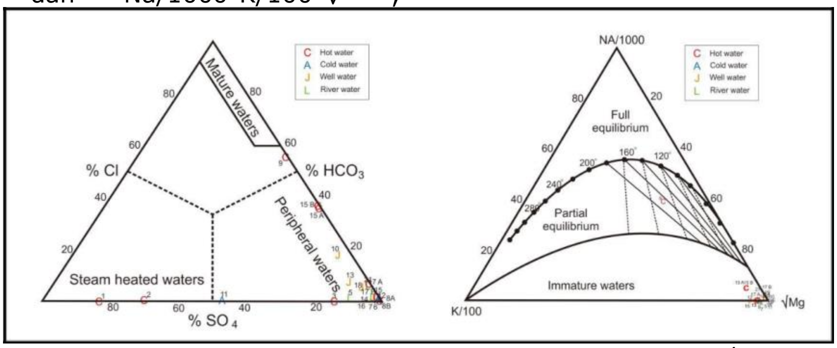

Figure 8. The figure above is a) Cl-SO4 HCO3 and b) Na/1000-K/100-√Mg, ternary diagram Giggenbach (1988)

Based on Figure 8A. the Cl-SO4-HCO3 ternary diagram showed that type fluid of hot springs and cold springs found in the Gedong Songo area generally belongs to the bicarbonate / peripheral waters. Based on chemical analysis of HCO3 / bicarbonate ions is the most dominated anion, with a varies in a wide range from 39 ppm to 465 ppm. This is caused by CO2 gas that dissolves into groundwater or is influenced by limestone in the east of Ungaran (UGW-9, 15A, 15B, 17A, 21) which releases CO2 content and then dissolves in ground water and then forms HCO3. HCO 3 water forms below the groundwater level and is generally weak acidic, which is caused by interactions with local rocks as they flowing into the surface. However, some samples showed a high SO4 content they are 245 ppm (UGW-1), 137 ppm (UGW-2) which included into steam heated sulphate water. Heated sulfated water vapor is associated with boiling process, dissolved gases (mainly H2S and CO2) may separate into the H2O-rich vapor phase as they boil and rise to the surface. A steam heated environment is formed where the H2S is oxidized by O2 in atmosphere, in the vadose zone, forming H2SO4(H2S + 2O2

= H2SO4) which is adsorbed into steam-heated ground water (Schoen et al,1974)

Based on Figure 8B. The ternary diagram of Na / 1000-K / 100--√ showed that the chemical analysis results of hot springs and cold springs are showed that water are generally included Immature water and it have higher Mg than Na and K.The immature waters indicates that the hot waters in the study area did not reach equilibrium or had reaction with other elements when they flowing into the surface. High Mg indicates waters have mixed with meteoric water, ground water or wall rocks that have high Mg concentrations. The UGW-9 plot included the partial equilibrium and can be estimated the subsurface temperature is 160°C.

Table 1. Chemical composition of the hot / warm springs and cold springs (Nguyen Kim Phuong et al ,2005).

Location	Code	Temp (°C)	pH	EC mS/cm)	HCO3-	F-	Cl-	NO3-	SO42-	Na+	NH4+	K+	Mg2+	Ca2+
Gedongsongo	UGW-1	21.9	3.45	0.56	-	0.12	0.84	0.08	247	14.26	0.43	5.04	13.44	42.45
Gedongsongo	UGW-2	40.0	5.36	0.39	5.86	0.21	1.16	TR	136	25.31	0.64	8.63	10.34	32.55
Gedongsongo	UGW-3	56.0	6.10	0.33	200	0.12	0.77	TR	31.8	14.09	0.5	7.9	15.14	37.13
Gedongsongo	UGW-4	32.2	6.00	0.3	465	0.05	0.76	TR	2.61	10.73	0.5	5.46	14.65	35.85
Gedongsongo	UGW-5	-	6.31	0.04	39	0.004	0.66	TR	3.53	2,315	0.02	1.18	0.65	3.54
Bumen	UGW-6	20	6.23	0.32	240	0.01	0.94	0.10	2.59	11.89	0.28	4.56	13.52	44.19
Bumen	UGW-7	19	6.25	0.33	248	0.01	0.98	TR	2.60	12.28	0.29	4.67	14.02	45.71
Banaran	UGW-8A	20	6.04	0.27	207	0.09	2.46	TR	0.11	10.42	0.13	5.58	11.29	37.06
Banaran	UGW-8B	18	6.02	0.29	221	0.01	2.44	TR	0.08	10.30	0.14	5.57	11.18	37.06
Kaliulo	UGW-9	43.5	7.23	19.83	419	0.43	5339	0.16	13.0	5147	TR	181.9	34.60	50.77
Kaliulo*	UGW-10	21	7.23	0.7	320	0.25	75.30	1.16	15.0	43.95	0.56	3.41	17.37	92.79
Gedongsongo	UGW-11	18	5.42	0.18	57.3	0.01	0.65	0.04	50.3	6.78	0.04	3.14	5.61	18.16
Candi village	UGW-13	18	6.65	0.18	97.6	0.06	9.1	14.55	6.40	8.11	0.11	8.14	4.97	19.37
Gelaran*	UGW-14	18	6.98	0.16	105	0.07	1.80	10.44	2.25	7.81	0.037	4.28	4.96	19.80
Kendalisodo	UGW-15A	35.2	6.84	4.58	1732	0.06	997.8	0.07	0.10	700.2	16.08	44.15	117.7	217.3
Kendalisodo	UGW-15B	38.1	6.78	5.21	1824	0.06	1088	0.11	0.00	746.1	17.01	47.11	126.0	278.4
Kendalisodo*	UGW-16	23.8	7.87	0.51	351	0.08	7.21	3.01	4.43	23.19	0.29	6.35	26.92	62.08
Diwak	UGW-17A	39.5	6.80	2.11	1435	TR	111.4	0.05	0.08	128	147.3	1.90	30.39	134.5
Diwak**	UGW-17B	27.5	7.40	0.5	292	0.12	19.21	TR	1.40	46.2	35.69	0.60	6.92	19.37
Kaliulo*	UGW-18	26.4	7.10	0.29	203	0.12	12.61	4.62	7.24	41.9	12.08	0.10	13	5.25
Tangkil	UGW-19	24.9	7.10	0.31	157	0.07	2.94	2.86	0.52	69.7	15.74	0.18	3.58	10.15
Derekan	UGW-20	25.8	7.00	0.21	145	0.05	1.48	3.52	1.03	69.5	11.99	0.20	3.66	6.01
Derekan	UGW-21	38.5	6.90	2.5	1560	TR	119	TR	0.31	131	155.1	2.20	31.25	144.3

CONCLUSION

1. Based on the Fault Fracture Density map (FFD), it shows that manifestations are found at high densities
2. Fault Fracture Density map cannot be used only but also needs to be correlated with other data such as geomagnetic geophysical data.
3. Geothermal manifestation area is symbolized by low magnetic anomaly values. The loss of magnetism or demagnetization is caused by rock destruction which is controlled by the presence of geological structures such as faults, which will later be used as a channel way for hydrothermal fluid discharge.
4. Geothermal manifestations found in Gedong Songo area are fumaroles, hot springs, and clay alteration rocks. Manifestation of geothermal is controlled by a fault northwest-southeast trending.

5. Based on chemical composition the hot spring at Gedong Songo area are heated steam sulphate water and immature water.

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