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GEOCHEMICAL RESERVOIR ANALYSIS OF THE GUNUNG UNGARAN GEOTHERMAL PROSPECT, SEMARANG DISTRICT, CENTRAL JAVA PROVINCE Karyanto1, 2, Wahyudi2, Suharno1, Ari Setiawan2 dan W. Suryanto2 1. Geophysics Engineering, Lampung University, 2. Geophysics, 6 Gadjah Mada University Email: karyantodjon@yahoo.com ABSTRACT The Gunung Ungaran geothermal prospect situated within the Semarang District, Central Java Province. Geochemical data collected from sixteen location. The geochemical analysis using the ions balance, geothermometer and geoindikator analysis, doe to determine the reservoir characteristic and temperature conditions of the Gunung Ungaran geothermal prospect, Semarang District, Jawa Tengah Province. The tentative result, although the ions balance indicate that not good balance, but the geoindictor and geothermometer indicated that the characteristic 3 of the reservoir should be acid with temperature more than 200o C. The discharge test measurements show that chemical composition of the reservoir water was analyzed by standard methods and subsequently classified using Cl-SO4, HCO3 and Cl-Li-B triangular diagram. A Na-K-Mg triangular diagram was used to classify waters 1 according to the state of equilibrium at given temperatures. The geothermal waters are of sodium-acid type and from a relatively old hydrothermal system. Thermal fluid is in equilibrium with reservoir rocks. The calculated temperatures using Na-K geothermometers suggested the subsurface temperature is more than 325oC and Na-K-Mg geoindicator suggested the subsurface temperature is more than 300oC. Key word: geochemical, geothermometer, geoindicator, geothermal Ungaran 1. INTRODUCTION The Ungaran geothermal field is located on one of the major tectonic belts of the central Java. In addition to this, there are volcanic areas spread throughout northward from Mt.Merapai, Mt. Merbabu, Mt. Ungaran and Mt. Gunungpati. Therefore, the Ungaran has many hot springs with a variety of temperatures ranging up to 95oC. The hot springs are located mainly on major active fractures and volcanic areas one of which is called Gedongsongo and others. The Ungaran geothermal field is located near the Gunung Ungaran Massive, which is Paleozoic in age. This Massive is mainly composed of metamorphic schists, marble and granite, and forms the basement of the geothermal area covered by Tertiary volcanic-sedimentary units assumed to be cap rock. The geothermal manifestation spreads throughout an area including boiling hot springs, travertine and swampy areas formed by hot water emergence and leakage. 1 The results of chemical analysis of hot and cold water samples have been evaluated for fluid using Giggenbach diagrams. Proceedings -

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2. 2 CHEMICAL COMPOSITIONS OF THE WATERS The geochemical study is based on discharge water samples collected from the discharge of six hot water springs. Samples were untreated and included acidified water. Chemical analyses of Na, K, Ca, Mg, B, Li, and SO4, and the SiO2 pH, Cl, HCO3. Table 1. Geochemical data from Ungaran geothermal feild No LOKASI SiO2 Ca HCO3 SO4 Cl Li B Na K 1 Gedongsongo 1 78 18 61 96 35 7 11 4 8 2 Gedongsongo 2 106 6 0 372 164 0 0 5 9 3 Gedongsongo 3 74 16 36 146 59 0 1 3 8 4 Gedongsongo 4 129 22 0 1681 176 0 0 5 14 5 Gedangan 38 10 73 5 6 0 0 1 2 6 Diwak 1 67 182 1416 7 112 3 3 105 29 Figure 1. The diagram Cl-B-Li triangle Ungaran geothermal field. Proceedings -

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Li, Cl and B are conservative elements 1 in the geothermal system. They are fixed in fluid phase and have not equilibrated. The conservative elements are the best geoindicators of the origin of the geothermal system. B/Cl ratio and Cl-Li-B ternary diagram were used to indicate the source of the fluid. A plot of the relative concentrations of Cl, Li and B is shown in Figure 1. All geothermal waters have 3 high Cl content relative to Li and B, indicating that they are from an old hydrothermal system and that fluid migrated from the old basement rock. 2.1 Classification 1 of the thermal fluids The average chemical compositions of the geothermal water from the Ungaran are presented in Table 1. The discharge water from Ungaran hot water are of the sodium and acid. A Cl are predominate cations in gedongsongo 2 and Gedongsongo 4 with concentration more than 164 and 176 mg/l respectively. In contrast, hot waters discharged from Diwak 1 hot spring are acid and concentration of carbonate ions are very high (1416 mg/l). The chemical compositions of the waters were classified on the basis of major ions using the Cl-SO4-HCO3 triangular diagram of Giggenbach (Figure 1). All samples plot to area of mature waters and can be classified as sodiumrich geothermal water which formed by the interaction of geothermal fluids with the host rock and dilution with low salinity water at depth (White and Muffler, 1971). The Ungaran possesses great potentiality for the utilization of geothermal energy. The region has been centre of attraction to a number of visiting national scientists, encouraging them to collect and analyze geothermal water samples at different localities on a sporadic basis. One of such studies has determined the temperature and reservoir characteristic. 2.2 Estimation of Reservoir Even though the above table suggests that none of the springs have a huge mass flow rate, a number of springs emerging in the vicinity could have lowered the flow rate. Average the water containing chloride concentration lower than 100 mg/l. No high concentration of silica is observed relative to discharge temperature in all spring waters. The waters at Ungaran lying in this region have relatively high sulphate, suggesting that the waters are fairly mature as indicated by the Giggenbach's diagram of concentrations of the major anions, Cl, SO4 and HCO3. This is illustrated in Figure 2. The Ungaran geothermal reservoir characterized by sodium rich and acid sulphat. Proceedings - ICP2012 ISBN: 979-95620-2-3 Page 117

Figure 2. The diagram Cl-HCO3-SO4 triangle Ungaran geothermal field. 2.3. Subsurface Temperature Estimation Chemical geothermometers are used in order to estimate the reservoir temperature. The important criteria for chemical geothermometer application to thermal spring are the pH, temperature and discharge rate of the spring. Some of them give unreliable results such as either lower than spring temperature or extremely high temperature. These equations are based on geothermometers for chalcedony and

quartz, which assume that these minerals used in geothermometers, are not in equilibrium with rock – water interaction in reservoir. The silica and cation geothermometers were used for the evaluation of subsurface temperature for discharges (Table 2). 6 The Source of temperature equations: T–measured temperature, T: Na-K– Fournier and Truesdell (1973), T: Na-K – Giggenbach (1988), T- Fournier (1977) were used. These give reservoir temperatures ranging 325 - 700oC. The Na-K geothermometer of Giggenbach (1988) suggested reservoir temperature more than 330oC and Fournier (1977) suggested reservoir temperature more than 325oC. The Na-K-Mg triangular diagram shows the equilibrium between the geothermal fluids and rock and reservoir temperature (Figure 3).

Figur 3. The diagram Na-K-Mg triangle of the 1 temperatures of the Ungaran geothermal reservoir. Table 2. Na-K Fourier and Giggencbach) from Ungaran geothermal feild No LOKASI Na-K (Fournier) Na-K (Giggencbach) Quartz Chalce dony Cristo balite Opal CT 1 Gedongsongo 1 795oC 715 oC 124 oC 96 oC 73 oC 25 oC 2 Gedongsongo 2 689 oC 634 oC 140 oC 114 oC 90 oC 41 oC 3 Gedongsongo 3 834 oC 744 oC 121 oC 93 oC 71 oC 23 oC 4 Gedongsongo 4 872 oC 772 oC 152 oC 127 oC 102 oC 52 oC 5 Gedangan 772 oC 698 oC 90 oC 59 oC 39 oC 6 oC 6 Diwak 1 324 oC 330 oC 116 oC 88 oC 66 oC 18 oC By considering the diagram presented 1 in Figure 2, the Ungaran hot springs plot in the immature water part, so using the chemical geothermometers is not reliable according to the theory used to establish the diagram. In this Na-K-Mg diagram all 2 the samples have not gained equilibrium with rock, presumably due to fast circulation of fluid through the rock fractures. This causes the water to be immature, considering the ion exchange processes that, equilibrium has not been reached

yet with rock minerals because of circulation flow. Figure 3 shows that samples from studied geothermal wells fall on the full equilibrium line, suggested attainment of the

Ungaran 300oC. 3. CONCLUSION 1 The geothermal waters discharged from Ungaran geothermal field are of sodium-acid type with a high concentration of HCO3 and SO4. Chemical compositions of reservoir waters indicate that the reservoir is located in the liquid dominant zone and geothermal waters come from an old geothermal system. The water composition from Gedongsongo and Diwak is carbonate and sulphate. Thermal fluid is 2 in equilibrium with reservoir rocks, which can be the product of waterrock interaction at high temperature. Common geothermometers have been used for estimating the subsurface temperature. The results from Na-K geothermometers and Na-K-Mg geoindikcator, 1 indicate that the reservoir temperature. The calculated temperatures using Na-K geothermometers and Na-K-Mg geoindikcator is more than 300oC. However, compare with measured temperature further. 4. REFERENCES Fournier, R. O.: 5 Chemical Geothermometers and Mixing Models for Geothermal System, Geothermics, 5, (1977), 41-50. Fournier, R., and Truesdell A.: An Empirical Na-K-Ca Geoindicators, Geochim. Cosmochim. Acta, 37, (1973), 1255-1275. Giggenbach, W.: 4 Geothermal Solute Equilibria. Derivation of Na-K-Mg-Ca Geoindicators, Geochim. Cosmochim. Acta, 52, (1988), 2749-2765. Geocemical indicators of subsurface temperature. U.S. Geol. Survey J. R. 2, (1974), 259-262. Giggenbach, W. F. Geothermal Gas Equilibria. Geochemica Cosmochemica Acta 31, (1988). Giggenbach, W.F.: 1 Chemical Techniques in Geothermal Exploration. In: D'Amore, F(coordinator), Application of geochemistry in geothermal reservoir development. UNITAR/UNDP publication, Rome, (1991), 119-142. White, D.E., and Muffler, L.G: Vapour-dominated Hydrothermal System Compared with Hot Water System. Economic Geology, 66, (1971), 75-97.

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