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APPLICATION OF GEOTERMOMETRY EQUATION (SiO_2)p IN THE GEOTHERMAL AREAS BOTH HARUKU AND TEHORU, CENTRAL OF MALUKU

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ABSTRACT

The appearance of the temperature on the surface of Haruku hot springs range 58 - 59°C while on Tehoru hot springs range 60 - 61°C. To estimate reservoir temperature then applied geochemical method based on analysis from compound of SiO_2 that is implemented in geotermometer empirical equation (SiO_2)p. The estimation results indicate that the reservoir temperature of Haruku range between 175 ± 0.9°C to 180 ± 0.9°C and reservoir temperature of Tehoru range between 185 ± 1.0°C to 190 ± 1.1°C. Thus, the geothermal system in Haruku and Tehoru is a medium temperature, containing high concentration of Sulfate ions and has an upflow area through the fractures. For that needed further exploration (pre feasibility study) in the Haruku and Tehoru areas as geothermal prospect areas.

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INTRODUCTION

The boilling process that occurs in the reservoir will form a steam fluid with a relatively high temperature and pressure, so that at the exit through the fracture the possibility of contamination with ground water, and exit in the form of hot water. The pressure generated by the fluid (hot water + steam) is greater than the outside air pressure causing the underground hydrothermal fluid contaminated groundwater to have a high temperature (>188^{o}C), resulting in boiling (reduced fluid density) and then breaking into the surface (upflow) in the form of hot fluid bursts, especially in hot springs (Sulaeman *et al,* 2007).

Geothermal areas in Indonesia is generally a hydrothermal type which has high temperature (> 225^{o}C), some of which have medium temperature (150 - 225^{o}C). One of the geothermal areas in Maluku is in Akesahu-Tidore. It has a pH range 7.4 - 7.9, which is mostly water-chloride type with surface temperatures range 43.9 - 45.1°C. In hot springs found hot water deposits or sintered silica whitish, brownish iron oxide. This indicates that the hot water system emerging in the Akesahu is located in the "upflow zone" and is a type of "heated reservoir" of water reservoir. Typically the geothermal appearance phenomenon in the reservoir type of hot water dominance is characterized by the presence of silica sinter (SiO_2) in the Akesahu region. The estimation results of reservoir temperature in the Akesahu-Tidore area have a minimum temperature range 145 - 185^{o}C using the SiO_2 geothermometer and 165 - 199 ^{o}C using Na-K geothermometer (Sulaeman et.al, 2007).

Marini and Susangkyono (2003) using geotermometer Na-K in the geothermal areas Hatuasa, Ambon. It has reservoir temperature range 230^{o}C - 245^{o}C with the average temperature at the surface is 70°C. The high reservoir temperature in this area is supported by a very high chloride concentration of 14000 ppm. Another application is on the geothermal areas Talang Haha, Ambon. Estimates on the geothermal area with high temperature range 272 - 277°C. This area is very potential as geothermal field (Andayany, 2011).

This research was conducted in geothermal areas in Central of Maluku, namely Haruku and Tehoru. Establishment of a geothermal systems in the Tehoru area, thought to be related to strong tectonic activity resulting from collision of plate Seram with plate Australian continent that trigger the formation of intrusive rocks as heat sources on the Tehoru geothermal system (Tjokrosapoetro et.al, 2003). In situ measurements on the Tehoru hot springs area show that temperature on suface range 60 - 61^{o}C, pH range 6,7 - 7,1 and electrical conductivity of 10,362 to 13.452 μs/m. Other geothermal areas in Central of Moluccas is Haruku geothermal area. Fault structure of Haruku is a normal fault trending Southwestern - Northeast led to the emergence of hot springs manifestations with a surface temperature of the hot water ranged 57 - 58°C with neutral pH between 7,0 - 7,1 and electrical conductivity of 9.350 to 10.450 μs/m.

From the data obtained can be estimated reservoir temperature by using geochemical method based on analysis from compound of SiO_2 that is implemented in geotermometer empirical equation (SiO_2)p. On this research was to compare the empirical geotermometer equation existing ones with new geotermometer equation that successfully formulated with a comparison parameter error on an average root of the square (rms error).

METHODS

Based on the type of fluid production and the main fluid content, hydrothermal can be divided into two types, namely one phase or two phase. The two phases may be water dominance or steam domination. The dominance of steam is a very rare type of geothermal in which its geothermal reservoir has a more dominant vapor phase content than its water phase. The fractures are generally filled with steam and the pores of the rock still retain water. The reservoir of hot water is generally located deep in the depths below the reservoir of its steam dominance. Water dominance is a common type of geothermal in the world where its reservoir has a very dominant water content although "boiling" often occurs at the top of the reservoir forming a vapor layer having high temperature and pressure.

Compared with the oil reservoir temperature, the temperature of the geothermal reservoir is relatively very high, can reach 350^{o}C. Based on temperature, the type of geothermal energy can be divided into three (Saptadji, 2009) namely: (1) Geothermal type with low temperature, which is a type of geothermal reservoir containing fluid at a temperature of less than 125^{o}C; (2) Geothermal type of medium temperature, which is a type of geothermal reservoir containing fluid at temperatures between 125^{o}C and 225^{o}C; (3) Geothermal type with high temperatures, which is a type of geothermal reservoir containing a fluid with a temperature above 225^{o}C.

The silica sinter is derived from an alkaline hydrothermal fluid with sufficient silica content, precipitated when the saturated fluid, amorphous silica cools from 100^{o}C to 50^{o}C. This precipitate can be used as a good indicator for the presence of a temperature reservoir of >175^{o}C. The solubility of various types of silica minerals is a function of temperature. The dissolved pressure and salt have no significant effect on the solubility of silica especially quartz and amorphous below 300 °C. This condition allows the use of silica concentrations in geothermal fluids to be used as geothermometers. However, to use silica as a geothermometer it must be assumed that silica minerals control silica solubility, no mixing with ground water, and correction of boiling effect due to pressure drop or adiabatic cooling. Silica geothermometer is one of the oldest geothermometers applied in the geothermal field (Fournier and Truesdell, 1973).

Mahon, Fournier and Rowe (1977) states that at high temperatures the hydrothermal solution is saturated with quartz. The estimated reservoir temperature from the measurement of silica concentration with temperature measured directly by the physics method is suitable for high temperature geothermal water range 180 - 260°C. Fournier and Truesdell (1973) states that the reservoir temperature can be estimated from the silica concentration (*ppm*) to assume the saturated water with quartz, adiabatic, isoentalpi cooling. The formula expressing the relation with the temperature of the silica concentration is:

$$t\,(°C) = \frac{1533{,}5}{5{,}768 - \log[SiO_2]} - 273{,}15 \qquad (1)$$

with t = calculated reservoir temperature (°C); SiO_2 = concentration of silika (*ppm*).
Geotermometer (SiO_2)p is geotermometer involving elements of SiO_2 (Andayany, 2011). Index p indicates geotermometer on research. Geotermometer equations (SiO_2)p is:

$$t\,(°C) = C_0(\log S_iO_2)^{C_1} - 273{,}15 \qquad (2)$$

Primary data collection stage in Haruku and Tehoru areas, among others: measurements of temperature, pH, and electrical conductivity measured on the surface conducted with monitoring for 48 hours with interval time of a hour. In addition, the sampling of hot water in each station measurement. Hot water samples taken in Haruku and Tehoru areas were analyzed. The result of analysis in the form of silica concentration value (*ppm*) was used to estimate the temperature of Haruku and Tehoru reservoir based on the application of geotermometer equation (SiO_2)p which was successfully formulated, then compared with temperature data (T-borehole) on some geothermal in the world with value comparison parameter Root error at random error (*rms error*). The temperature calculated using geothermometer formulas with an rms-error value of < 2% is possible as the temperature of the Haruku and Tehoru reservoirs.

RESULTS

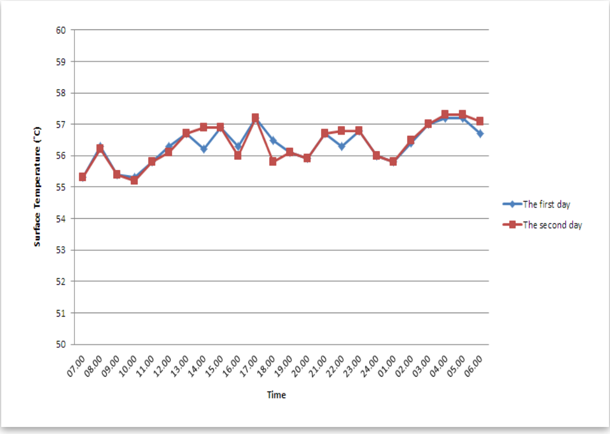

Figure 1. The relationship between surface temperature and the time in intervals of a hour in the Haruku geothermal area (a) the first day; and (b) the second day.

The average temperature on the surface of Haruku hot springs range 58 - 59°C. The temperature range may occur due to the effect of mixing with surface water (rain water) and surrounding air. Figure (1) shows that the average temperature on the first day measurement is 57,5°C. The display of the temperature contour on the second day shows an almost identical appearance to the first day, with the highest average surface temperature of 57,8°C.

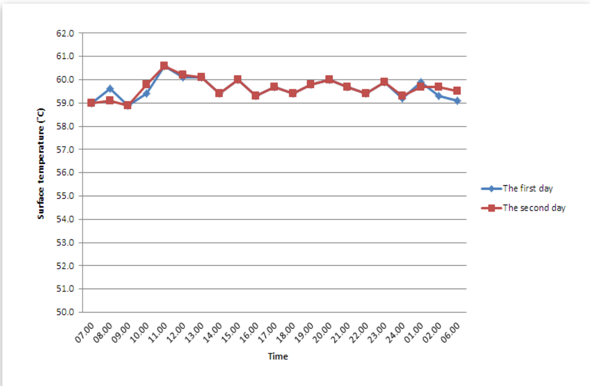

Figure 2. The relationship between surface temperature and the time in intervals of a hour in the Tehoru geothermal area (a) the first day; and (b) the second day.

The average temperature on the surface of Tehoru hot springs range 60 - 61°C. The temperature range may occur due to the effect of mixing with surface water (rain water) and surrounding air. Figure (2) shows that the average temperature on the first day measurement is 60,5°C. The display of the temperature contour on the second day shows a view that is almost the same as the first day, with the highest average surface temperature of 61°C.

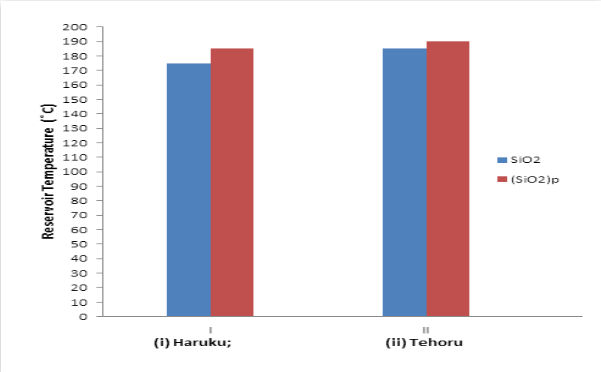

Figure 3. Graph of reservoir temperature both in the Haruku area (1) and Tehoru area (2) which is calculated using the SiO_2 and $(SiO_2)p$ geotermometer equations.

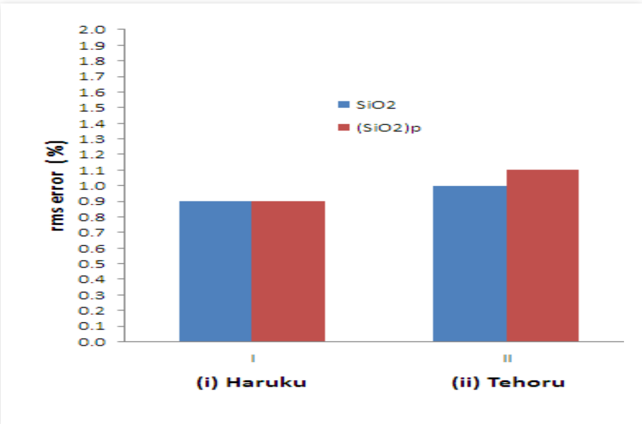

Figure 4. Results of rms error using SiO_2 and $(SiO_2)p$ geotermometer equations for Haruku area (1) and Tehoru area (2).

Based on equations (1) and (2), the reservoirs temperature of the Haruku and Tehoru can be calculated using the SiO_2 and $(SiO_2)p$ geotermometer equations as shown in Figure (3). Thus, the reservoir temperature of Haruku area is 175 - 180 °C. This calculated based on the equation (1) and (2) while reservoir temperature of Tehoru area is 185 - 190°C. Furthermore, the result of calculating the rms value error of the geotermometer formula SiO_2 and $(SiO_2)p$ is presented in Figure (4). Thus, reservoir temperature of Haruku area is possible at temperatures between 175 ± 0.9°C to 180 ± 0.9°C, while on Tehoru range between 185 ± 1.0 °C to 190 ± 1.1°C. The temperature range may be due to hot water circulation within the Haruku and Tehoru reservoir.

CONCLUSION

The appearance of the temperature on the surface of Haruku hot springs range 58 - 59°C while on Tehoru hot springs range 60 - 61°C. Using the SiO_2 and SiO_2 geothermometer equations, it is possible to estimate the reservoir temperature of Haruku range between 175 ± 0.9°C to 180 ± 0.9°C dan on Tehoru range between 185 ± 1.0 °C to 190 ± 1.1°C. This shows high speed, can be estimated reservoir temperature also higher. Thus, the geothermal system of the Haruku and Tehoru regions is a geothermal system. This shows high speed, can be estimated reservoir temperature also higher. Thus, the geothermal system of the Haruku and Tehoru regions is a geothermal system.

For further research, it is hoped that other geothermometers can be used to compare geothermometers $(SiO_2)p$, such as geothermometers of geothermal gases and mineral rock geothermometers. In addition, there is a need for further investigation in Haruku and Tehoru areas as geothermal prospects, such as further exploration (pre feasibility study).

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