Geothermal Potential in a Small Volcanic Island

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Abstract. In this paper we report the continuation of previous observation of hot spring phenomenon in northern Ternate island. The hot spring distribution spread unevenly with temperature ranging from 29 °C to 35.5 °C along shore line. Geomagnetic measurements, chemical and physical water properties have been carried out to find the caused of unevenly hot spring distribution. This research intends to reveal geothermal potential in a small volcanic island. The result of geomagnetic measurements, showed low magnetic anomalies as demagnetization rock by heat. Magnetic anomaly map shown any fault structure alignment with the northeast – southwest. The fault structures create path of heat. The result of chemical and physical water properties also agree with geomagnetic measurement that show indication of geothermal system. The heat source comes from magma chamber and passes through rock fractures (fault) as known as up flow geothermal system.

Key words: Geothemal; Geomagnetic; Small volcanic island

1. Introduction

Geothermal energy, is known as renewable energy and environmentally friendly, will be targeted as an alternative national energy that supplied about 5% until 2025, or about 9500 MW [1]. This policy should be followed by data supporting and technical readiness. [1], records about 203 geothermal areas associated with quaternary volcanic pathways. Generally, geothermal area is dominated by large islands in Indonesia, such as Sumatra, Jawa, Sulawesi and Papua. A small volcanic islands (in the island arcs) also has the potential of geothermal or hydrothermal.

Ternate island as a small volcanic island, become the study area is a part of unseparated tectonic system of eastern Indonesia. Ternate island is situated above the oblique subduction path to the east with a small angle. Gamalama as a strato volcano with a height about 1715 m above mean sea level and 11 km in diameter [1],[3]. As physiography, cone-shaped volcanoes can be divided into: Central Zone, Proximal Zone, Medial Zone and Distal Zone. [6]

The existence of Gamalama volcano indirectly provided geothermal potential in Ternate Island. The manifestations evidence of geothermal is the presence of hot springs. Geothermal potential mapping is done by geomagnetic measurements to determine variations in magnetic susceptibility of rock.
below the surface. Physical and chemical properties of groundwater are also measured to support geothermal properties.

2. Material and methods
This research was conducted around hot springs site, northern of Ternate island (see Fig.1). The average temperature of groundwater at ranging from 26 to 28 °C. At the site of hot spring temperature ranges from 30 to 35 °C. Geologically, the rocks in the northern of Ternate island are young Gamalama (Gm) [6]. Morphologically, in the northern, is generally hilly with a little plain. The dug wells is only found around the shoreline.

Magnetic measurements in this research using a handheld fluxgate magnetometer (It measures the three components of a dc magnetic field vector with a resolution of 1 nT over its range of ± 100,000 nT (± 1 Gauss by MEDA Inc.), which is focused at Tobololo hot springs. Magnetic measurement was carried out in the grid with a distance 150 to 200 m each point. Before interpretation of measurement field results, it should be corrected by daily value of magnetic variation and IGRF. Total magnetic of anomaly map is presented then due to analyze goethermal situation.

Measurements of physical and chemical groundwaters are also carried out along coastline. Data physics and chemistry of groundwater is measured using a water quality checker from Horiba instruments. The depth of groundwater level was measured manually to describe groundwater flow patterns.

3. Results and discussion
3.1 Groundwater Properties
Figure 2 shows the results of the physical measurements of groundwater such as temperature of water distribution and groundwater flow patterns. A small volcanic island has a radial pattern of groundwater flow which means, groundwater flows to the lowest area or coastal areas [7],[9],[12]. Groundwater flow (see Figure 2) was modeled based on phreatic data of dug wells and drilled wells. In general, dug wells are located in the lowest region or near shore line. Groundwater table elevation follows the topography of the mountain. Groundwater table is getting deeper according to the distance of shore line. To describe groundwater position and movement (groundwater flow pattern), the groundwater data then plotted as contour of elevation. According to [5], to described the groundwater flow direction can be used the contour lines and make drawing a line perpendicular to contour lines.
Groundwater flows through the induced rock by geothermal then will become hot water and flowed out to the recharged area. The fault structure with the direction of the northeast - southwest controlled the flow of hot water to the village of Tobololo [3]. Groundwater temperature distribution looks normal except in the village of Tobololo and in the village of Sulamadaha. In these two villages, groundwater temperatures range between 33-35 °C. The pH value of the hot water in the village of Tobolo ranging between 6.9 to 7.6, while the pH value of hot water in the village Sulamadaha ranging between 7.6 - 8.2 with sodium chloride water type. The electrical conductance value (ranging from 3.3 to 4.4 mS / cm) and Salinity (ranging from 1.7 - 2.3 ppt) for hot water near the shoreline, can be under influenced of saline water. Mg²⁺ content of water samples from Sulamadaha higher than the other samples. This indicates of mixing process of meteoric water to geothermal fluid. The dilution volcanic rock by groundwater containing high elements Mg²⁺ [11],[10].

3.2 Geomagnetic Measurement

The results of total magnetic measurements are shown in Figure 3. Residual magnetic anomaly value shows the ranging between 7000 nT to 33000 nT. Magnetic anomaly contour map shows the value of anomaly magnetic rocks can be classified into three groups, namely: low anomaly (less than 12000 nT); moderate anomaly (between 13000 nT to 23 000 nT); and high anomaly (more than 23000 nT). High – Low patterns of magnetic anomaly in the coast, is interpreted as a rock with high susceptibility (andesitic-basaltic lava rocks) and low susceptibility as a rock which has experienced with strong weathering. Some of rocks is seen as outcrop.

Moderate to low magnetic anomaly, which is seen to spread and dominate the research areas, is interpreted as the low susceptibility rocks to non-magnetic rock. These rocks have experienced weathering and demagnetization due to the heat influence and close related to manifestation of hot water presence.
The results of geomagnetic measurement, indicates that the flow of hot water is driven by fault toward to the shore in Tobololo village [4]. Direction of fault is northeast – southwest. Visualization of the geothermal potential in Ternate Island can be illustrated by tentative model as shown in the picture below.

4. Conclusion
In summary, we have studied about hot spring presence and geothermal potential in a small island. Based on the results of chemical analysis and physical groundwater and the results of magnetic measurements can be conclude that Ternate Island also has a moderate geothermal potential. Although energy needs are still far from ideal conditions, further research is needed considering the geological conditions of the island. At least the geothermal potential can still be used for drying by farmers/fishermen and tourism.

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References
[1] Kasbani Suhanto and Dahlan, 2005 Readiness of Indonesia’s Geothermal Potential Data In Supporting the Preparation of Work Areas. Geothermal Research Program Group. Geological Resource Center p 66
[2] Hamilton W 1979 *Tectonics of the Indonesian region*. US Geological Survey *Professional Paper*, 1078

[3] Geology Agency 2011 *Data Dasar Gunung Api Indonesia*, Second Edition, Ministry of Energy and Mineral Resources p 426

[4] Geology Agency 2009 *Geophysical Investigation of Gamalama Volcano in Ternate*, Ministry of Energy and Mineral Resources p 22

[5] Fetter CW 2004 *Applied Hydrogeology*, 4th edition Mac millan Publishing New York,

[6] Bronto S 2006 *Volcanic facies and its applications* Indonesian Journal of Geology Vol.1 No.2: p 59-71

[7] Achmad R 2016 Ternate Island Hydrogeological Study, Dissertation. Faculty of Geography, UGM, p 127

[8] Fournier RO and Potter RW 1979 Magnesium correction to the Na-KCa chemical geothermometer, *Geochim. Cosmochim. Acta* 43 p 1543-1550

[9] Falkland AC 1993 Hydrology and Water management on Small Tropical Island, *Proceeding of Yokohama Symposium*, IAHS p 263-304

[10] Giggenbach WF 1988 Geothermal Solute Equilibria Deviation of Na-KMg-Ca Geo-Indicators. *Geochemica Acta* 52 : 2749–2765

[11] Giggenbach WF and Goguel RL 1989 *Collection and analysis of geothermal and volcanic water and gas discharges*. Report No. CD 2401. Department of Scientific and Industrial Research. Chemistry Division. Petone, New Zealand

[12] Hadi MP Salam R and Achmad R 2019 *Groundwater resources mapping for small island using Geoelectrical Technique* Indonesian Journal of Geography Vol. 51 No. 1 p 49-53