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Core Hole Temperature Survey in Central Part of Sulawesi-Indonesia

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ABSTRACT

Geothermal locations in Indonesia are mainly distributed along the Indonesian Volcanic Belts, however some are associated with non volcanic environments (intrusive, plutonic rocks).

Some core holes were drilled in Marana and Pararra geothermal fields by Geological Agency, both of these are located in central part of Sulawesi, characterized as non volcanic geothermal systems.

One of the core holes at Marana field flowed with hot water of a temperature about 95 °C on the surface from well MM-1, which was 185 m in depth. Aanother well,,MM-2 with a depth of 250 m had low thermal gradient (about 9 °C / 250 m). Furthermore, Well PRA-1 which is 251.20 m in depth at Pararra geothermal field had a thermal gradient about 11.44 °C / 100 m. The extrapolation temperature calculated using Horner plot method is about 53.19 °C at 250 m in depth.

1. INTRODUCTION

Indonesia has abundant geothermal resources. which are distributed on 257 locations with the total energy potential about 27.7 GWe, identified until 2008. Geothermal locations in Indonesia mainly distributed along the Indonesian volcanic belt from Sumatra, Java, Bali, East Nusatenggara, Banda islands, to North Sulawesi. However, some are associated with non volcanic environments. There are 203 locations (~80%) associated to volcanic environments and 54 locations (~20%) associated to non volcanic that mostly distributed in Sulawesi, West Kalimantan, and Papua (Figure 1).

Marana field and Pararra field are located in central part of Sulawesi Island which is in Donggala Regency and North Luwu Regency, South Sulawesi and Central Sulawesi Provinces, respectively. Both of these fields are associated with non volcanic geothermal system (granite, sedimentary, and metamorphic rocks). Thermal features of these fields are dominated with hot springs which have temperature about 50 – 90 °C and 44 – 57.5 °C respectively.

Aims of this paper were to know temperatures of core holes in non volcanic geothermal system, especially in the Marana and Pararra fields.

2. GEOLOGICAL BACKGROUND

2.1 Geological of Sulawesi

Geologically, Sulawesi Island and its surrounding area is a complex region. The complexity is caused by convergence. Sudrajat (1981) described that the Palu-Koro Fault stretched from west Palu City to the Bone bay in the southeast for some 250 km long and calculated that the trans current movement was in the range from 2-3.5 mm to 14-17 mm per year.

Based on lithologic association and tectonic development, Sulawesi and its surrounding Islands are divided into 5 tectonic areas between three lithospheric plates: the northward moving Australian plate, the westward moving Pacific late, and the south-southeast moving Eurasia plate. These include: 1) the Tertiary Western Sulawesi Volcanic Arc, 2) Quarternary Minahasa-Sangihe Volcanic Arc, 3) Cretaceous-Paleogene Central Sulawesi Metamorphic Belt, 4) Cretaceous Eastern Sulawesi Ophiolite Belt and its associated pelagic sedimentary covers, and 5) Paleozoic Banda Micro-continental fragments derived from the Australian continent (Hamilton, 1978, 1979; Sukamto and Simandjuntak, 1983) Regional tectonic of Sulawesi is shown in Figure 2. (Metcalfe, 1988, 1990; Audley-Charles, 1990; AudleyCharles, 1991; Davidson, 1991). The contacts between those areas are faults.

2.2 Geology of Marana and Pararra fields

Stratigraphy of Marana area consists of Tertiary to Quaternary rocks (Geological Agency of Indonsia, 2004). The Tertiary rocks consist of metamorphic rock (Triassic age), granite rock (Triassic age), and intrusion of Tertiary granite rock (Miocene age) which intruded into other older rocks. The Quaternary rocks consist of sedimentary rock and alluvium (Figure 3).

Furthermore, stratigraphy of Pararra area can be divided into three groups of rock unit which consists of Metamorphic rocks, intrusion rocks, and alluvium (Figure 4).

3. THERMAL GRADIENT

3.1 Pararra Field

At present, there are two locations of the survey areas which were drilled by Geological Agency in non volcanic hosted geothermal system. These locations are located in Pararra field (PRA-1 core hole) and Marana field (MM-1 & MM-2 core holes) which is 251.20 m, 185.30 m and 250 m respectively in depth. Based on temperature measurement data of these core holes we can calculate thermal gradients and temperature of formations.

Thermal gradient of the PRA-1 of the Pararra field is about 11.44 °C/100 m or higher, which is about four times of the normal gradient of formation(3 °C/100 m),(Figure 5). Then, the extrapolation temperature was calculated using horner plot method, which was about 53.19 °C at 250 m,(Figure 6).

3.2. Marana Field

Furthermore, one of the core holes of the Marana field namely MM-1 was flowed of hot water when drilled to 185.30 m in depth. The temperature of hot water was about 95 °C at the surface with flow rate about 317 liter per minute, (Figure 7). The down-hole temperature is about 103.80 °C at 185 m in depth while MM-1 core hole was flowing. The drilling crossed up flow zone in MM-1 core hole is dominated by hot water.

For MM-2 core hole, the thermal gradient is about 9 °C/250 m. Graphic of the temperature data shows the temperature of MM-2 core hole starting to increase at 170 to 250 m in depth, that is from 33.1 °C to 37.0 °C (Figure 8). The calculated thermal gradient in this range is about 3.9 °C/80 m or 4.78 °C/100 m.

4. INTERPRETATION

Based on temperature logging measurments at 100 m in depth, the obtained maximum temperature was about 33.2 °C . Then logging tool was submerged at down hole for eight hours. Decreasing of temperature occured at down hole of PRA-1 until it reached 32.5 °C, this situation was caused by influx of cold water through fractures into the hole. Furthermore, the temperature logging measurement at 250 m in depth obtained that the maximum temperature was about 41.2 °C and then the logging tool was submerged for twelve hours while increasing of temperature occured at down hole of PRA-1 until 42.6°C. Thermal gradient of the PRA-1 of the Pararra field is about 11.44 °C/100 m or higher about four times of normal gradient of the earth (3 °C/100 m). Then, the extrapolation temperature was calculated using Horner plot method which was about 53.19 °C at 250 m in depth.

Estimation of temperature at 850 m in depth can be extrapolated with the assumption that thermal gradient is 11.44 °C/100 m, the calculated temperature is 121.83 °C. This temperature is smilar to that estimated by chemical geothermometer, which is about 125.91 °C (Team intergrated survey of Pararra geothermal area, 2002).

Furthermore, MM-1 flowed of hot water when drilling reached at 185.30 m in depth. The temperature of hot water was about 95 °C at the surface with flow rate about 317 liter/minute. The down-hole temperature is about 103.80 °C at 185 m depth while MM-1 core hole was flowing.

On the other hand, MM-2 of core hole which has 250 m in depth did not flow hot water as the MM-1. For MM-2 core hole, the thermal gradient is about 9 °C/250 m. Graphic of temperature data shows the gradient of temperature in MM-2 core hole starting to increase at 170 to 250 m in depth that are 33.1 °C to 37.0 °C. The calculation of thermal gradient in this range is about 3.9 °C/80 m or 4.78 °C/100 m. Comparing thermal gradients, the MM-2 core hole is lower than the MM-1 core holes because the reservoir in MM-1 is deeper than the MM-2 core hole (Figure 9).

CONCLUSION

Some conclusions of this paper are given as follows:

- Thermal gradient of MM-2 and PRA-1core holes are 4.78 °C to 11.44 °C per 100 m respectively. MM-1 flowed of hot waters with temperature about 95 °C at the surface with flow rate about 317 liter/minute.
- In the future, the potential of geothermal resources can be developed for electricity and direct use.

ACKNOWLEDGEMENTS

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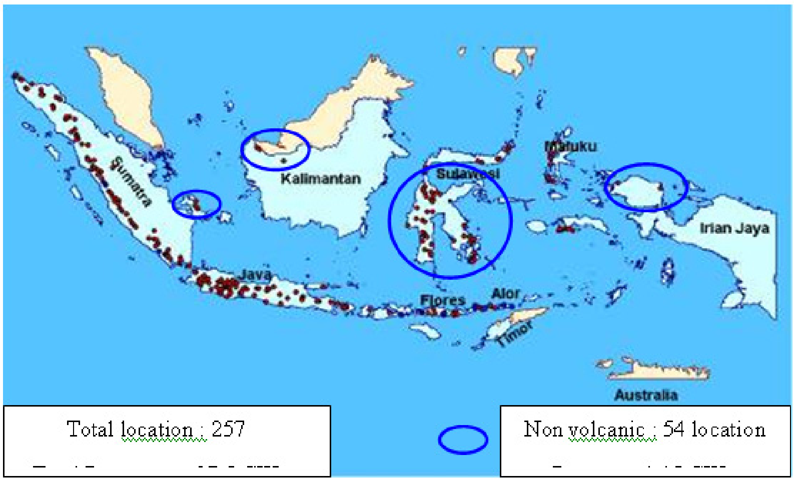

Figure 1: Distribution of geothermal areas in Indonesia

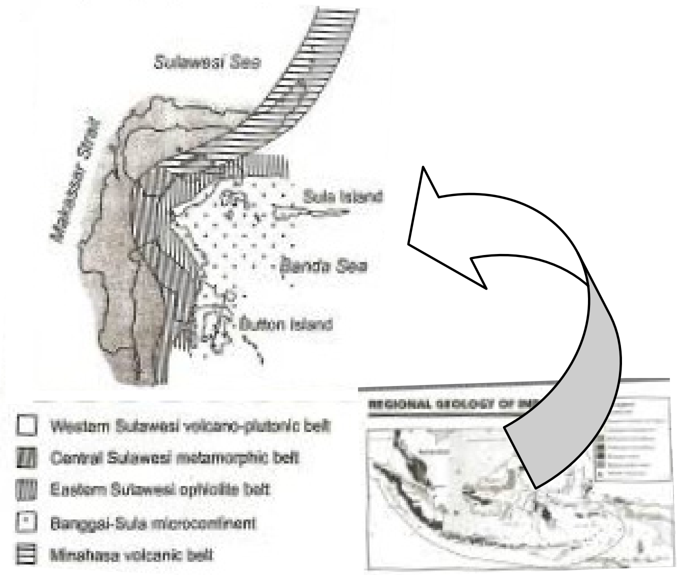

Figure 2: Regional tectonic of Sulawesi – Indonesia, (IAGI, 1989)

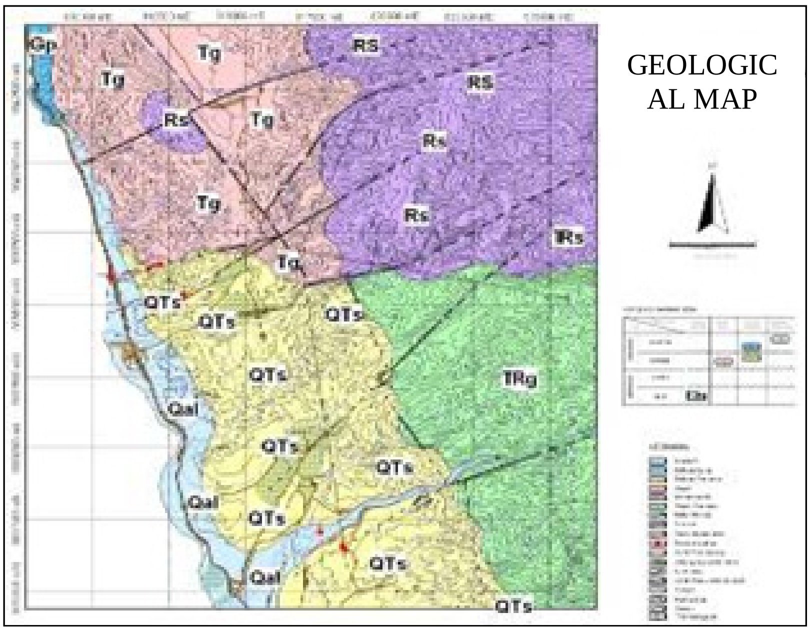

Figure 3: Geological map of Marana geothermal field,Central part of Sulawesi island

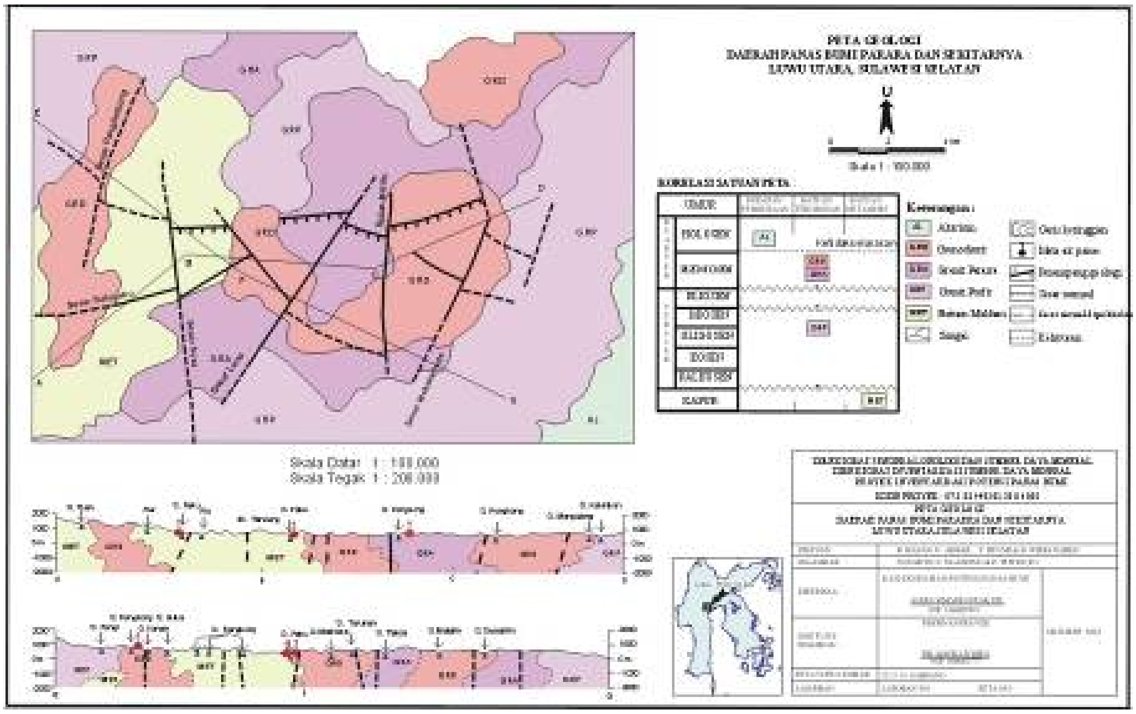

Figure 4: Geological map of Pararra geothermal field, Central part of Sulawesi island

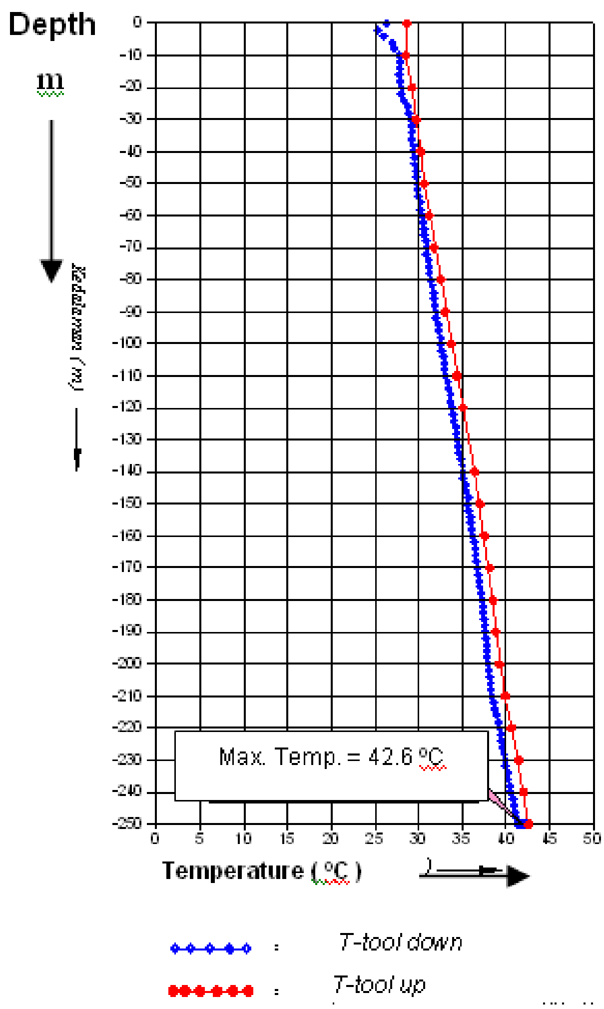

Figure 5: Data of down hole temperture of core hole in Pararra field

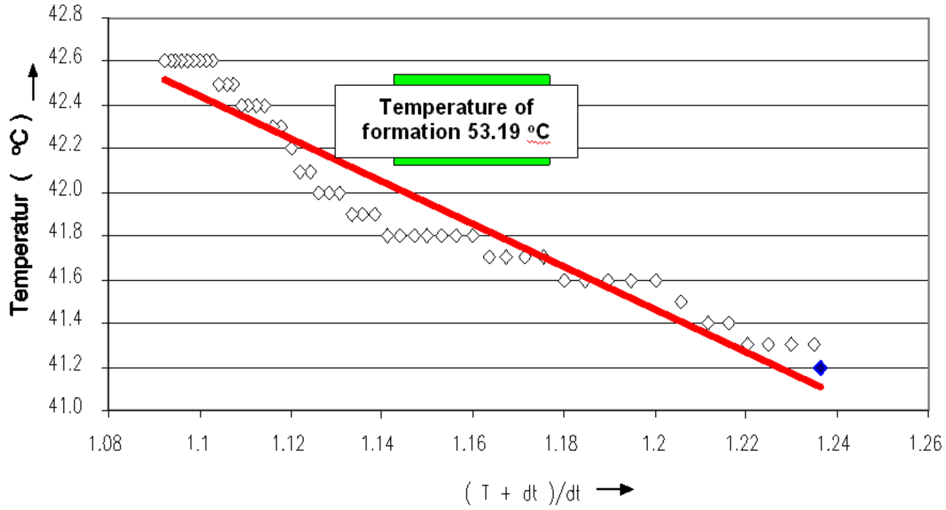

Figure 6: Temperature extrapolation of formation by using Horner plot method

Figure 7: Flowing of hot water of the MM-1 of core in Merana field, Sulawesi-Indonesia

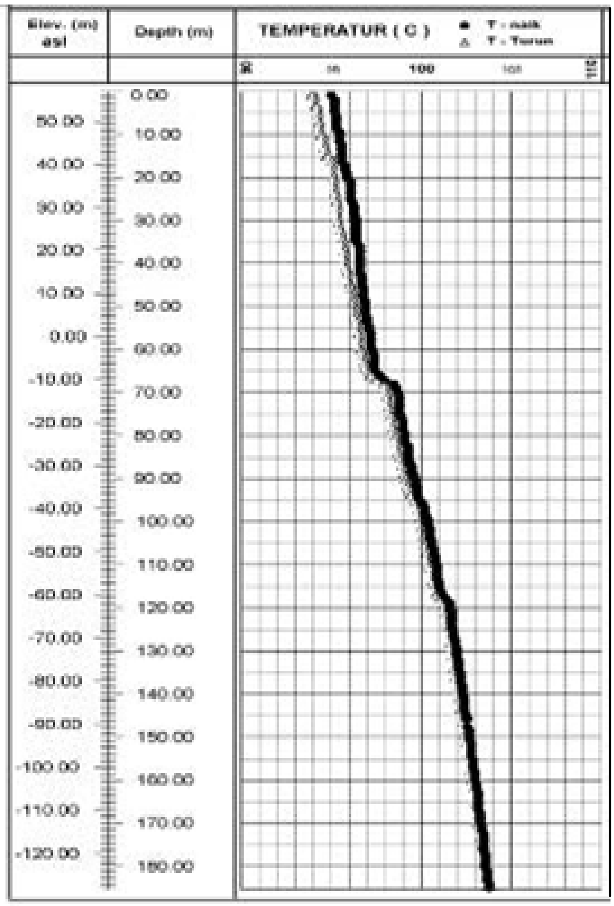

Figure 8: Data of down hole temperture of MM-2 core hole in Marana field

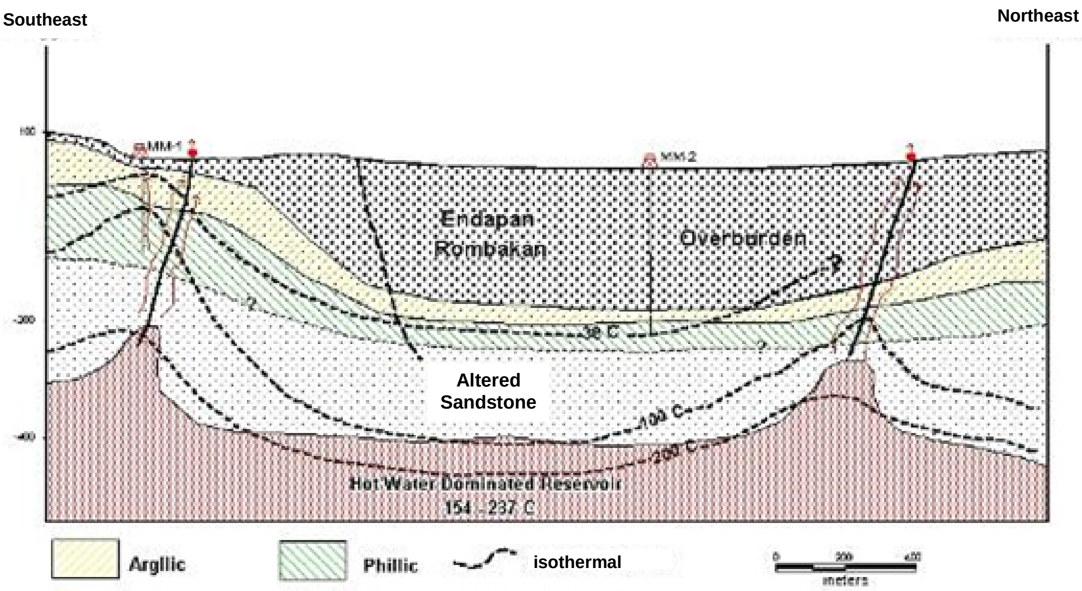

Figure 9: Model of Marana geothermal field, Sulawesi-Indonesia (Fredy et.al., 2005)