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Grouting program in the Mataloko geothermal field

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Abstract: Grouting program was successfully made to protect a steam leak surrounding the well MT-1, in the Mataloko geothermal field, for a radius of 20 m during a sudden blowout of the well MT-1. Due to the safety considerations, the well was killed and cemented to the top. Then the rig was disassembled and moved to the well MT-2, which was located 35 m northeast of the well MT-1. Considering the unstable ground surrounding the well MT-2, which was almost the same as the surroundings of the well MT-1, a grouting program was also performed surrounding the well MT-2 for a radius of 5 m to protect against leaking, before the rig-up for the well MT-2. The grouting program in the Mataloko geothermal field was very successful in protecting the steam leak from surface fractures through which the blowout of the well MT-1 occurred. The grouting was to make a stable foundation surrounding the well MT-2. No steam leak occurred during the drilling of the well MT-2 until the well was shut-in for a long time.

1. Introduction

The Research Cooperation Project on the Exploration of Small-scale Geothermal Resources in the Eastern Part of Indonesia has been jointly conducted since 1997 by the Volcanological Survey of Indonesia (VSI), Geological Survey of Japan (GSJ), Mitsubishi Materials Natural Resources Development Corp. (MRC) and West Japan Engineering Consultants, Inc. (WESTJEC) in the Mataloko geothermal area in Flores Island.

The Mataloko geothermal field is located about 20 km southeast of Bajawa, the capital city of Ngada District. The geoscientific studies have been successful in locating the promising areas and some geothermal structures and recommended four locations for exploration drilling. But the location of the exploration drilling, the wells MT-1 and MT-2, was decided between the proposed sites B and D (Fig. 1). The purpose of this grouting program is to make a stable foundation surrounding of the wells MT-1 and MT-2.

2. Geoscientific studies

2.1 Surface Surveys

The stratigraphy and geological structure of the Mataloko geothermal area are as follows (Geological Survey of Japan, 1999, 2000):

1) Green tuff, as a basement rock, was found in the Watumanu village, southeast of Mataloko, and interpreted as a reservoir rock of the Mataloko geothermal area.
2) Tertiary volcanic deposits consisting of Watumunu lava were found in the northeast of the Mataloko area and interpreted as a reservoir rock.
3) Quaternary volcanic deposits consist of 11 andesitic cones. Wolo Belu was the youngest of those cones in the Mataloko geothermal area and interpreted as a heat source.
4) Volcanic lineament and structure seem to be controlling the geothermal system of the Mataloko geothermal area.

By integrating the results of the geoscientific surveys, the geothermal structure in the Mataloko geothermal area is characterized as follows:

1) Mataloko is surrounded by high gravity zones, and shows a caldera-like structure that might be an important geologic condition for geothermal activities in the area.
2) The low resistivity layer in the shallower part shows a rough NW-SE trend. On the contrary, at depth, it shows a trend of north to south.
3) Some clear discontinuities of resistivity distribution can be correlated to fractures, which play an important role in controlling geothermal activities in the area.

From the integration of all geochemical and geophysical anomalies, the Mataloko geothermal area can be estimated to be promising and recommended

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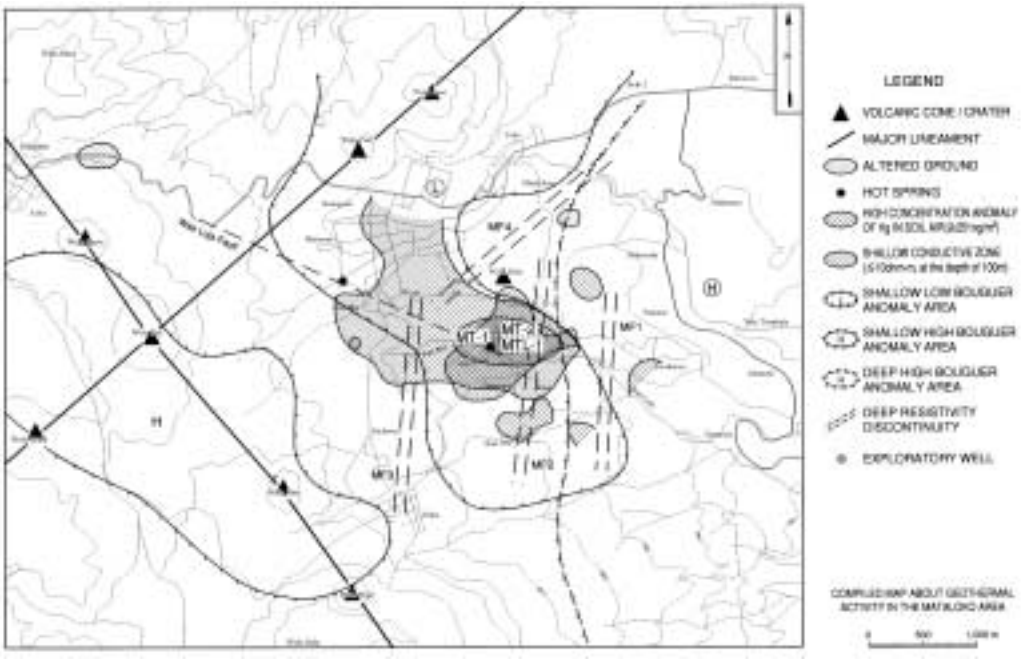

Fig. 1 Map of recommended location for exploration drilling in Mataloko, Flores, based on the geoscentific results.

for future deep exploration drilling to confirm the neutral brine expected at depth. Geoscientific results recommended four locations for exploration drilling in the area (Fig. 1). After further consideration of the data, the location of the exploration drill site was decided between the proposed sites B and D.

2.2 Subsurface geology

Drilling of the first well MT-1 was stopped at a total depth (TD) of 207.26 m because a sudden flowing and blowout of steam with gasses (H_2S and CO) occurred around the collar while drilling a 9 5/8" hole. The 10" casing shoe was set at a depth of 18.10 m. A blowout preventer was planned to be installed after setting the 8" casing to around the 300 m depth. Due to the safety concerns, the MT-1 exploration well was plugged with cement on 19 November 2000 (Sitorus *et al.*, 2001).

The lithology of the well MT-1 consists of tuff breccia, pyroxene andesite and hornblende andesite with minor layers of tuff. All rocks have been altered into the argillic type. Alteration intensity (ratio of secondary minerals to total minerals) varies between 40 % and 90 %, and the rocks contain about 5 % to 50 % of swelling clay.

The second exploration well MT-2 was started by drilling a 12 1/4" hole and continued with the setting of a 10" casing shoe at a depth of 17.6 m. After drilling a 9 5/8" hole to the 104.56 m depth, pressure and temperature (PT) logging was run in the hole. Downhole temperature at a depth of 104 m was 75.8 ℃ on the first measurement and was 112 ℃ after the tool stayed at the bottom for 2 hours. The second run showed a temperature of 130.4 ℃ after 1.5 hours of heat recovery, and downhole pressure of 10.8 bar.

After setting the 8" casing shoe at a depth of 100.12 m, a 7 5/8" hole was drilled to a depth of 162.35 m on 16 January 2001 with a full mud return to the shaker. Very high circulation temperatures, inflow of 53 ℃ and outflow of 60 ℃, were encountered during drilling between the 156 and 162.35 m depths. This was very similar with the circulation temperature of the well MT-1 between the 195 and 207.26 m depths. Therefore, we stopped the drilling at a TD of 162.35 m.

The lithology of the well MT-2 is nearly the same as the MT-1 well. The difference here is that the content of swelling clay in the MT-2 well reaches 60 % of the total rocks.

A flow test using the lip pressure method was successfully done at the MT-2 well. The maximum well head pressure (WHP) was 13.7 barg (bar-gauge) when the well MT-2 was shut-in. Steam flow rates in the 3" flow pipe varied between 10.84 and 10.96 t/h at a WHP of 7.7 barg. The steam temperature was between 126 and 128 ℃. At a WHP of 5.8 - 5.9 barg, steam flow rates ranged from 14.39 to 14.51 t/h with a recorded temperature of 135 to 140 ℃. Chemical analysis during the flow test showed a very low gas content in the saturated steam.

When we used a 4" flow pipe, the steam temperature varied between 125 and 128 ℃ and flow rate was about 14.91 - 15.35 t/h at a WHP of 3.0 - 3.8

barg. When the WHP was to be set 5.7 barg, the flow rate decreased to about 9.05 t/h and steam was slightly wet.

The 6" casing shoe was set at 109.63 m, whereas a 4" perforated liner was run to the 180.0 m depth on 3 February 2001 after drilling a 5 5/8" hole to a depth of 180.02 m. The maximum WHP of 17.7 barg was monitored while the well MT-2 was shut-in during the rig down on 6 - 13 February 2001. A long period flow test was being proposed to characterize the steam quality and an optimum steam flow rate of the MT-2 well.

3. Grouting technique

3.1 Grouting program in MT-1 and MT-2

Grouting is generally defined as cement slurry injection to the underground with high pressure to make the formation condition stable. Grouting work surrounding of the well MT-1 was designed for 24 drilling points with a total depth of 540 m and distribution as below (Fig. 2):

a. 12 drilling points with a depth of 15 m
b. 8 drilling points with a depth of 25 m
c. 4 drilling points with a depth of 40 m

Grouting work surrounding the well MT-2 was designed at 10 drilling points with a total depth of 190 m, because the location of the well MT-2 was only 35 m northeast of the well MT-1. The distribution of the drilling points was as below:

a. 6 drilling points with a depth of 15 m
b. 4 drilling points with a depth of 25 m

3.2 Grouting equipment

The grouting holes with a diameter 4 1/2" or 3 1/2" were drilled by using one drilling machine with the maximum capacity of 200 m depth with a NQ diameter. The grouting work was done by using an electric mixer to mix the cement and water and using a mud pump to inject the cement slurry to the ground through a cementing head and 2" diameter high-pressure hose.

3.3 Drilling and grouting work

By designing the grouting points surrounding the wells MT-1 and MT-2 (Figs. 2 and 3), the drilling was started for the points of the shallow depth (15 m) with a 4 1/2" tricone bit. Then, we installed a stand-pipe of 4" diameter in the hole connecting to a cementing head at its top. Finally we injected the cement slurry, whose specific gravity was approximately 1.7, through the stand-pipe and waited until the cement slurry dried. We continued drilling and grouting for the drilling points of larger depths (25 m and 40 m) using a 3" tricone bit.

During the drilling and grouting, an important thing was to know the lost circulation zones (or fractures). If the formation was not so permeable and large lost circulation was not observed during the drilling, we injected water into the hole through the stand-pipe with pressure until a fluid loss occurred. If a fluid loss did not occur, we did more drilling with a 3" tricone bit and continued to press the formation with water until a fluid loss occurred.

For the case of a 15 m hole, when we encountered

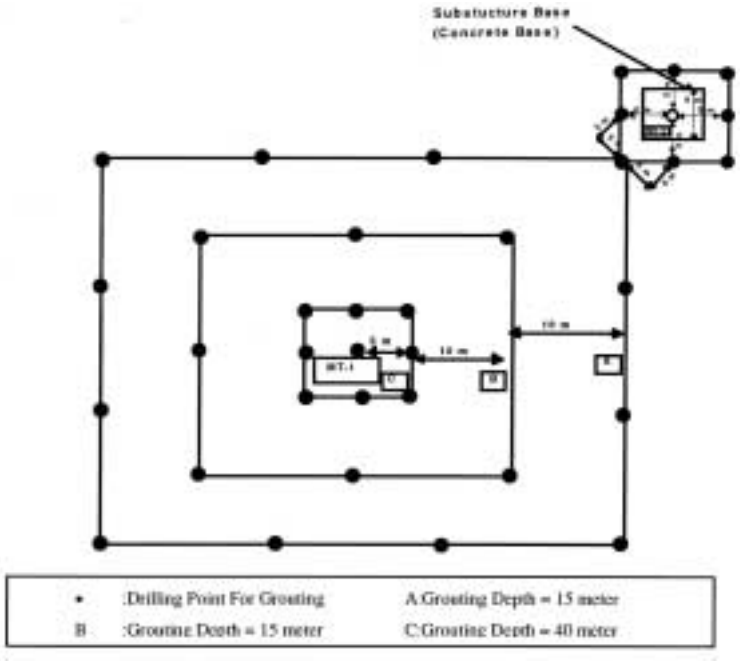

Fig. 2 Grouting points surrounding the wells MT-1 and MT-2 in the Mataloko geothermal field.

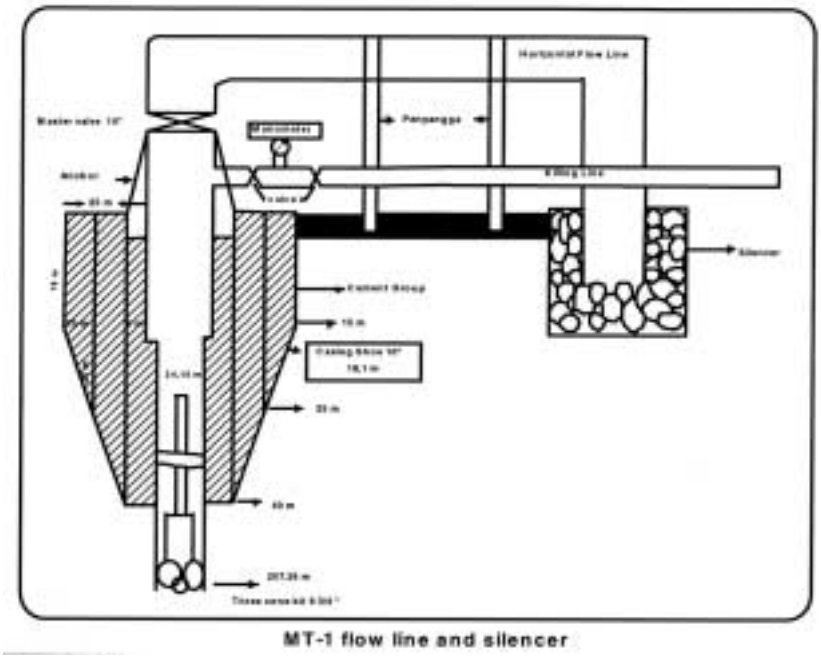

Fig. 3 The target of grouting for MT-1 Well during the blowout.

lost circulation during the drilling work or a fluid loss occurred after injecting water, we injected the cement slurry with a pressure of 2.9 - 4.9 bar into the hole (through the 4" stand-pipe). After the completion of the cement injection to the formation, the well was filled with cement slurry until the cement head reached the surface. Thus the grouting work was completed. The pressures for injecting the cement slurry into a 25 m hole and 40 m hole were 5.9 bar and 7.8 - 10.2 bar, respectively. Grouting work surrounding the wells of MT-1 and MT-2 took 20 days and used 2600 bags of Portland cement.

3.4 Grouting target

During the drilling of the MT-1 well until a depth of 207.26 m, partial or total loss zones were not encountered, but the blowout occurred at the 207.26 m depth once circulation of mud was suspended. Finally the connection of the drill pipe was broken to allow a 10" valve to be closed and prevent steam from coming out of the hole. Much steam leaked during the shutting of the well with the 10" valve. After the break connection, the drill string which consisted of 3 1/2" drill pipes, a 6 1/2" drill collar, a 6 1/2" stabilizer, and a 9 5/8" tricone bit with a total length of 183.11 m was left in the hole as a fish.

After the grouting work finished and the 10" valve was shut, there was no more leaking surrounding of the well MT-1. This meant the grouting program was successful and very effective. From the experience of the well MT-1, the grouting program surrounding the well MT-2 was also done because its location was just 35 m from the well MT-1 and just outside of the border of the well MT-1 grouting zone. By the grouting, we were able to drill the MT-2 well successfully without leaking from the well until the well was shut-in for a long time (Sitorus *et al.*, 2002).

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マタロコ地熱地域における掘削およびグラウチング工程

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要　旨

マタロコ地熱地域の MT - 1 井では突発的なブローアウトにより半径 20 m の範囲で蒸気のリークが起こったが，グラウチングによりこれを止めることに成功した．安全主義に基づき，本坑井は地表までセメントで埋め戻された．次にリグを一旦分解して，MT - 1 から 35 m 北東に位置する MT - 2 井の地点に移動した．MT - 2 周辺の地盤は MT - 1 とほとんど同様に不安定であることを考慮して，蒸気リークを防ぐため MT - 2 から半径 5 m の範囲にグラウチングを実施し，その後リグアップを行った．マタロコ地熱地帯におけるグラウチングは，結果として，MT - 1 のブローアウトを起こした地表断裂からの蒸気リークを防ぐのに極めて有効であった．グラウチングは MT - 2 周辺の基礎を固めることに成功し，MT - 2 の掘削中から長期閉鎖期間まで蒸気リークは全く起こらなかった．

（要旨翻訳：水垣桂子（地圏資源環境研究部門））