

## Drilling activity and subsurface geology of the MTL-1 shallow well in the Mataloko geothermal area

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**Abstract:** A shallow exploration well MTL-1 was drilled in October 1999 in the Mataloko geothermal field of the Ngada District of Flores Island by the Volcanological Survey of Indonesia (VSI) as a part of the Research Cooperation Project on the Exploration of Small-scale Geothermal Resources in the Eastern Part of Indonesia (ESSEI). The drilling encountered a sudden steam flowing at the 103.23 m depth, while the target depth was 250 m. The surface temperature of the steam was 115 °C whereas the wellhead pressure of 3 barg was measured during the well shutdown. The steam generated from a deeper part of the Mataloko geothermal reservoir escaped to the surface throughout the Wae Luja fracture zone near the well. The subsurface stratigraphy varies between andesitic tuff, pyroxene andesite, andesitic tuff breccias and andesite, which are hydrothermally altered to medium temperature (120 - 190 °C) of argillic type with 2 - 15 % swelling clay.

### 1. Introduction

The Research Cooperation Project on the Exploration of Small-scale Geothermal Resources in the Eastern Part of Indonesia (ESSEI), between Indonesia and Japan was carried out on the Mataloko geothermal area for fiscal years 1997 - 2002. As a contribution in this cooperation, the Volcanological Survey of Indonesia drilled a shallow exploration well to determine the down-hole gradient temperature, fracture zone, subsurface stratigraphy and the alteration type. This program was started on October 1999 by drilling a shallow well of MTL-1 with the target depth of 250 m. This paper briefly reports the drilling activity and subsurface data of well MTL-1.

### 2. Geologic setting

Well MTL-1 is located about 50 m north of the Wae Luja River near the Mataloko hot spring at an elevation about 1048 m.a.s.l (Fig. 1) at longitude 121° 03'34.947"E and latitude 8° 50'22.763"S.

Based on a geological map of the Mataloko, Wolo (Mount) Bobo and Nage areas (WestJec and MRC, 2000), the Mataloko geothermal area is composed of the Tertiary Maumbawa volcanic deposits (3.7 - 2.4 Ma) and Upper-Pliocene Green Tuff (Fig. 2). The

Tertiary volcanic rocks are exposed about 3 to 5.5 km SE of the Mataloko geothermal discharge. The pre-caldera Bajawa volcanic deposits (Pleistocene), which unconformably overlay the Tertiary volcanic basement, consist of the oldest volcanic rocks (1.6 Ma) and old volcanic rocks of the upper Pleistocene (1.1 Ma). The old volcanic rocks are widely distributed in Mataloko, strongly altered and alunite, kaolinite and montmorillonite are formed surrounding the thermal discharge area.

The Bajawa caldera is characterized by Pleistocene caldera forming deposits (0.1 - 0.2 Ma). A series of volcanic eruptions was related to the caldera formation, suggesting that the Bajawa caldera is probably the Krakatoa type. The caldera formation seems to be followed by some young volcanic cones such as Wolo Inelika, Wolo Bobo, Wolo Bela, Wolo Sasa, Wolo Pure and Wolo Nawa.

### 3. Drilling activity of shallow exploration well MTL-1

#### 3.1 Site

The well MTL-1 is situated at 9022319 mS and 286602 mE (UTM WGS 84) in southern Belu, (Fig. 3) and required about 200 meters of access road from this village.

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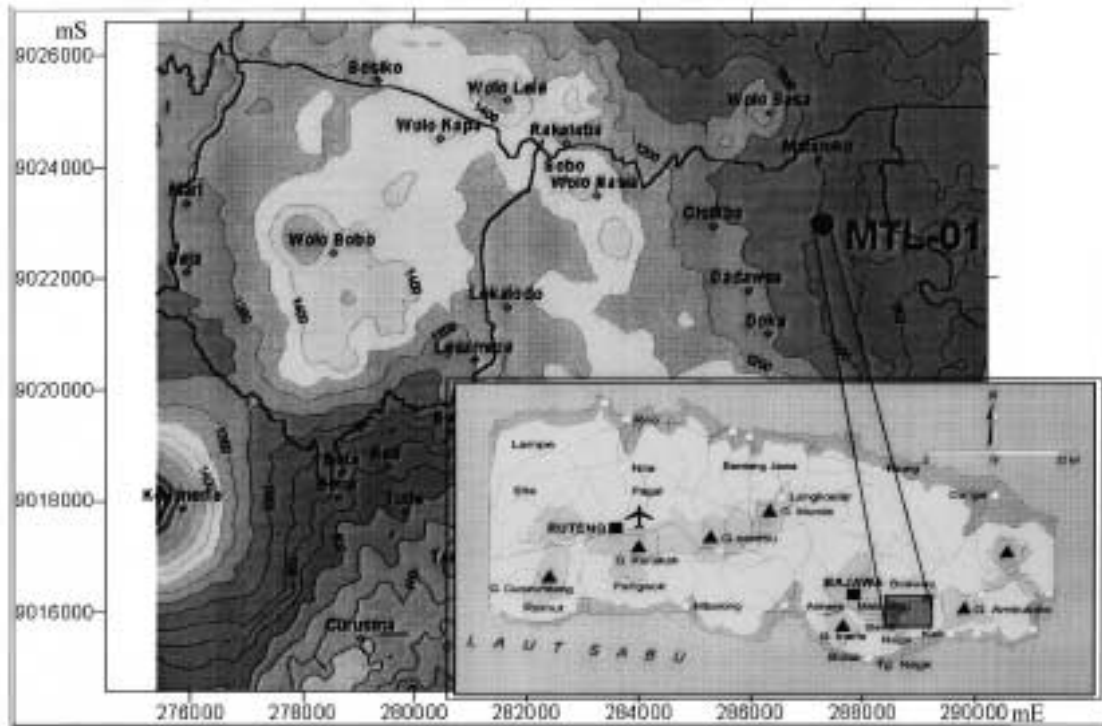


Fig. 3 The location of the shallow exploration well MTL-1.

### 3.2 Drilling activity

#### 3.2.1 Activity

The drilling operation was started on October 14, 1999 using a spindle type drilling machine that drilled a 5 5/8" hole to a depth of 13.8 m. Total lost circulation (TLC) occurred at that depth. The next step was plugging with cement. The hole was opened with 8" bit to 13.8 m and continued with blind drilling to a depth of 18.3 m. Furthermore, the installation of 6" casing was tried in the hole to the 18.3 m depth but the casing did not enter the deeper part because sloughing materials filled the hole up to 7.7 m so this program was abandoned.

After pulling out the 6" casing from the hole, the drilling continued with a 5 5/8" bit until a depth of 98.3 m. Partial lost circulation (PLC) occurred at this depth and steam flowing was killed by pumping cold water. Four-inch casing was installed with a casing shoe at the 98.3 m depth. From the 98.3 to 103.23 m depth, the well was subsequently drilled with HQ-coring ( $\phi=3"$ ). The inlet mud temperature was 70 °C and the outlet mud temperature was 74 °C. (Fig. 4).

#### 3.2.2 Blow-out

Steam flow suddenly occurred while HQ ( $\phi=3"$ ) coring at the 98.3 - 103.23 m depth when the drilling crew pulled out the bottom hole assembly out of the hole. A steam blowout to the surface occurred through the annulus. The temperature of the mud return was 94 °C (Fig. 4). The steam blowout was

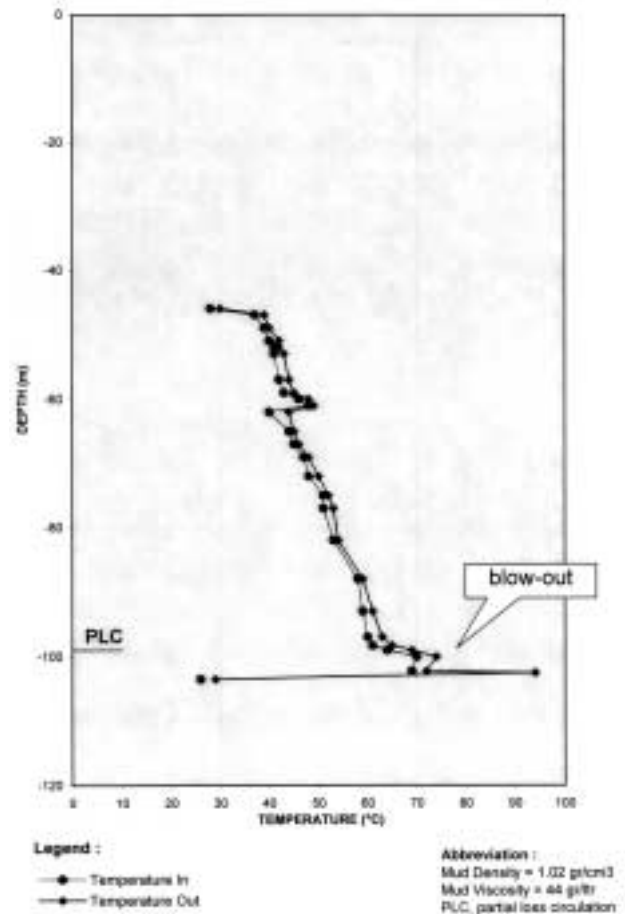


Fig. 4 Mud circulation temperature vs. well depth.

killed with pumping fresh water (10 bar) into the hole. The maximum pressure reading was 3 barg and steam flow temperature was 115 °C.

### 3.2.3 Killing of the well

The total lost circulation at a depth of 13.8 m indicates the brittleness of the subsurface fracture zone so more blowouts could occur. The MTL-1 well is very close to a residential area. For safety concerns of the MTL-1 well, it was decided to terminate the drilling operation at a depth of 103.23 m, and the well plugged with cement on October 25, 1999.

## 4. Subsurface data analysis

### 4.1 Lithology and alteration

At depths of 98.3 - 103.23 m, 33 cutting and core samples were recovered and analyzed by a megascopy in the field. Ten samples were petrographically analysed to determine mineral, textural relationship and alteration intensity with the X-ray diffraction (XRD) method (Fig. 5).

Moderately altered tuff with minor weathered tuff occurs at the surface to the 5 m depth and highly to very highly altered tuff breccias with intercalation of very highly altered andesite are between depths of 60 - 69 m. At the 87 - 103.23 m depth the very highly altered andesite reentered these lithologic units. Probably, these lithologic units are grouped into the old volcanic rocks. The primary minerals in the rock units are plagioclase, pyroxene, hornblende and volcanic glass. The rocks have been hydrothermally altered and produced secondary minerals as replacement products or direct deposition in veins and vugs. The hydrothermal alteration minerals are clay, pyrite, quartz, cristobalite and anhydrite with or without carbonate and zeolite.

In all the samples, clay minerals replace primary minerals and groundmass or fill veins and vugs. Two types of clay are recognized as gray-cloudy clay (smectite) and white clay (kaolinite). The presence of quartz is quite significant showing a devitrification process of volcanic glass and veins. Anhydrite replaces pyroxene, hornblende and volcanic glass, and is found in veins with quartz and clay. Anhydrite replaces mineral and is yellow and blue. Carbonate (calcite) is quite rare and has a dusty appearance due to its association with clay. Iron-oxide (brown to reddish brown) commonly occurs with pyrite and clay, and replaces pyroxene, hornblende and groundmass. Zeolite is in vugs of a cutting sample at the 87 - 90 m depth. It is usually shown by a low relief and fibrous with extension like a fan under the microscope.

The result of eight samples (analyzed by Sitorus, at the Geological Survey of Japan) showed

plagioclase, smectite, kaolinite, quartz, alunite, pyrite, anhydrite (gypsum?), amorphous silica, calcite (carbonate), and hematite.

From the megascopic, petrographic and XRD analysis, most of the rock samples from the MTL-1 well have been affected by moderate to very high alteration intensity of argillic type with 2 -15 % swelling clay.

### 4.2 Fractures

Fractures in the MTL-1 well are recognized from the total lost circulation at a depth of 13.8 m and partial lost circulation at the 98.3 m depth. The presence of the loss zone of the Mataloko surface discharge (hot spring, mud pool, and solfatara) and steam flow are mostly related to the Wae Luja fracture zone.

## 5. Discussion

### 5.1 Estimated subsurface temperature

The logging survey was not performed because of the MTL-1 well condition. Fluid inclusion analysis was not observed due to the limited sample amount. The steam temperature data only represented the presence of steam that flowed from well MTL-1 (115 °C), Mataloko hot spring (94.6 °C) and fumarole (96 °C). The temperature of steam flow and steam column with a wellhead pressure of 3 barg suggested that the downhole temperature is more than 115 °C. The occurrence of the alteration mineral assemblages such as smectite (montmorillonite), kaolinite, alunite, quartz, cristobalite, anhydrite, calcite and pyrite in the rock samples of well MTL-1 are related to acid sulfate water in the temperature range of 120 - 130 °C (Matsuda *et al.*, 2000). The temperature of calcareous silicate minerals in active geothermal systems (Reyes, 1990, Browne, 1991) showed that smectite, kaolinite, alunite, and cristobalite minerals occurred at temperature ranges of 40 - 200 °C, 20 - 200 °C, 40 - 280 °C and 100 - 160 °C, respectively, whereas quartz and anhydrite are in a higher temperature range of 180 - 320 °C. The data suggest that the downhole temperature of well MTL-1 is between 120 °C and 190 °C.

### 5.2 Mataloko geothermal system

The profiles based on the two-dimensional inversion of Schlumberger and magneto-telluric data along the survey lines in the Mataloko geothermal field (Uchida and Andan, 1999) show a resistive layer about 600 - 800 m beneath a clay cap which temperature is low (120 - 190 °C). The resistive layer corresponds to a higher temperature, suggesting that the reservoir temperature is more than 190 °C.

On the other hand, it can be concluded that the increase in temperature with increasing depth shows

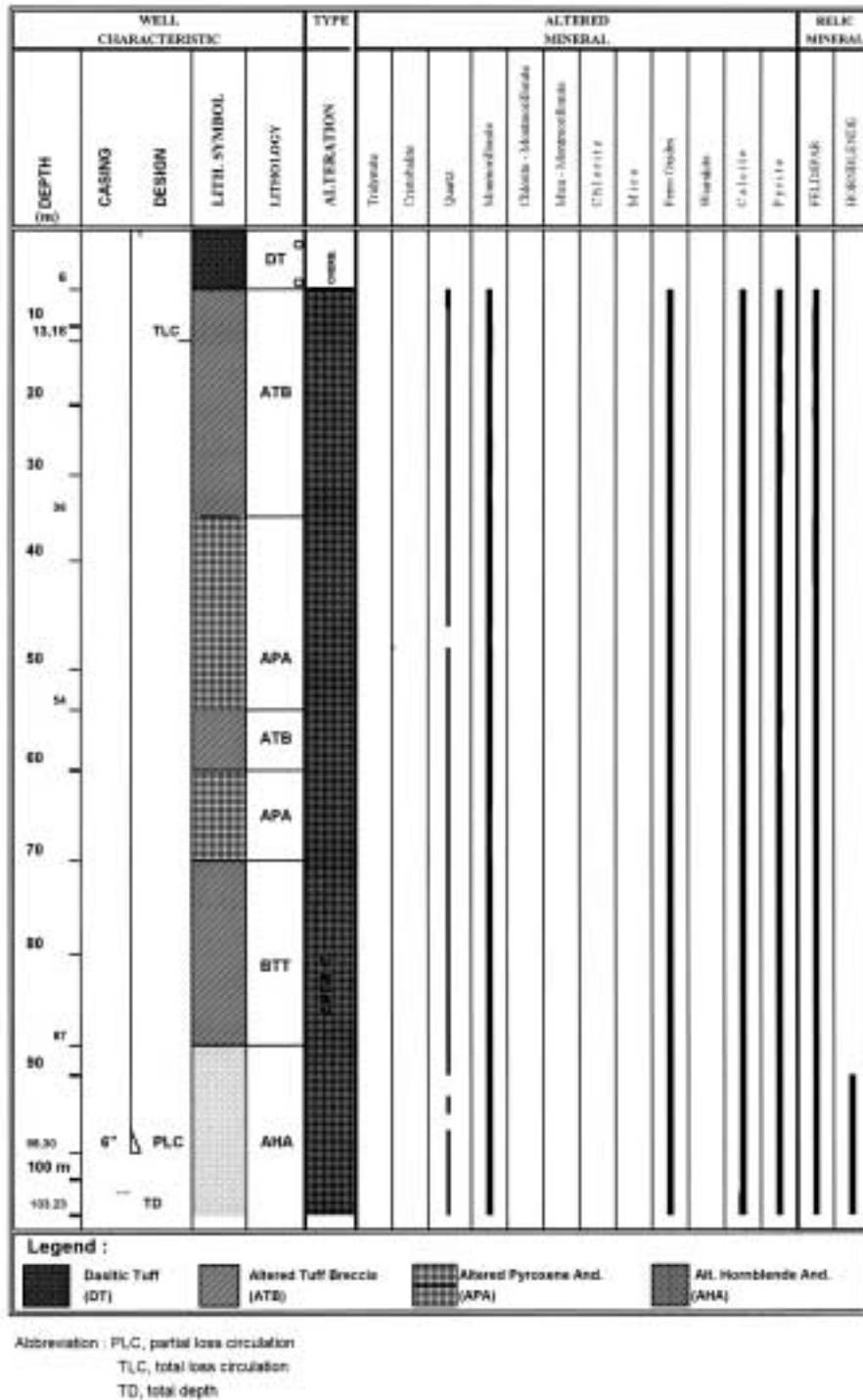


Fig. 5 Lithology and altered mineral distribution of well MTL-1.

the shallow well MTL-1 lies in the upflow zone of the Mataloko geothermal system. In recognition to a heat source of the Mataloko geothermal system, great attention should be given to the young volcanic cones of the Wolo Belu lava dome, Wolo Sasa, Wolo Nawa and Wolo Pure.

The steam cap from the productive fracture zone is not condensed into the fluid phase when it flowed to the surface because the downhole temperature exceeds the boiling temperature. There are three faults

in the N-S direction and one fault in the NE-SW direction between the 500 - 600 m depth that can be concluded from a reconstruction of the two-dimensional resistivity map.

## 6. Summary

- Location of MTL-1 shallow well is situated at 9022319 mS, and 286602 mE (UTM WGS 84).
- Fracture zones in the MTL-1 well are represented

- by TLC = 18.3 m and PLC = 98.3 m depth. The fractures are probably strongly related to the Wae Luja fracture zone.
- The drilling activity of MTL-1 well was stopped at a depth of 103.23 m.
  - Temperature in the steam flow is 115 °C but the lithology of well MTL-1 (total depth = 103.23 m) characterizes a medium temperature (120 - 190 °C) by argillic type of alteration with 2 - 15 % swelling clay.
  - The MTL-1 well steam flow occurrence is almost same as the process of the Mataloko thermal discharges (fumarole and hot spring).
  - The MTL-1 shallow exploration well is most probably located in the upflow zone of the Mataloko geothermal system.

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## マタロコ地熱地域の浅部井 MTL-1 の掘削と地下地質

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### 要 旨

1999年10月、「遠隔離島小規模地熱の探査に関する研究協力 (ESSEI)」の一環として、インドネシア火山調査所 (V S I) によってフローレス島シガダ郡のマタロコ地熱地帯で浅部調査井 MTL-1 が掘削された。掘削予定深度は 250 m であったが、103.23 m まで掘削した時点で突発的な蒸気噴出に遭遇した。坑井をシャットダウンした状態で坑口圧は 3 bar、地表での蒸気温度は 115 °C であった。蒸気はマタロコ地熱貯留層の深部で生産され、坑井近傍のワエ・ルジャ破碎帯を通過して地表に漏れ出ているものである。地下地質は、安山岩質凝灰岩、輝石安山岩、安山岩質凝灰角礫岩および安山岩からなり、中温 (120 - 190 °C) 熱水による変質を受けて 2 - 15 % の膨潤土を含む変質粘土となっている。

(要旨翻訳：安川香澄・水垣桂子 (地圏資源環境研究部門))