Bulletin of the Geological Survery of Japan, vol. 53 (2/3), p. 247-251, 2002

Head-on measurement to locate the Wai Luja Fault in the Mataloko geothermal field, Flores Island, East Nusa Tenggara, Indonesia

Arif MUNANDAR[1], Achmad ANDAN[1] and Janes SIMANJUNTAK[1]

Arif MUNANDAR, Achmad ANDAN and Janes SIMANJUNTAK (2002) Head-on measurement to locate the Wai Luja Fault in the Mataloko geothermal field, Flores Island, East Nusa Tenggara, Indonesia. *Bull. Geol. Surv. Japan,* vol. 53 (2/3), p. 247-251, 4 figs.

Abstract: The Head-on method was developed for mapping of concealed resistivity anomalies in a special array, where a third current electrode C is additionally placed at a large distance but almost perpendicular to the Schlumberger array with current electrodes A and B. In this survey, the Head-on method was used for locating fracture zones in the Mataloko geothermal field, Flores Island, Indonesia. The results of Head-on apparent resistivity profiles have shown that the Wai Luja Fault is a normal fault trending in the NW-SE direction and dipping 53° north. The main geothermal manifestations, i.e., fumaroles, hot springs and altered rocks, in the Mataloko geothermal field are controlled by the Wai Luja Fault.

1. Introduction

The theoretical aspect of the Head-on method was treated by Cheng (1980) and summaries can be read in Mwangi (1982). The Head-on array has the same electrode configuration as the Schlumberger array with a third current electrode, C, added at infinity (Fig. 1). The current is injected at three different pairs: AB, AC and BC. The in-line component of the electric field (i.e., in the AB direction) is measured by the usual MN potential electrodes for three combinations of the current bipoles AB, AC and BC.

Three apparent resistivity values, ρ^{AB}, ρ^{AC}, and ρ^{BC}, are computed as,

$$\rho^{AB}=\frac{(AB)^2-(MN)^2}{4\cdot MN}\pi\frac{V}{I},$$

$$\rho^{AC}=\frac{2\pi}{\frac{1}{AM}-\frac{1}{CM}-\frac{1}{AN}+\frac{1}{CN}}\cdot\frac{V}{I},$$

$$\rho^{BC}=\frac{2\pi}{\frac{1}{BM}-\frac{1}{CM}-\frac{1}{BN}+\frac{1}{CN}}\cdot\frac{V}{I},$$

where (ρ^{AC}, and ρ^{BC}, are apparent resistivities obtained with the current bipoles AC and BC, respectively. V is the voltage difference between electrodes M and N, and I is the current strength that is injected through the current electrodes.

After each set of readings is obtained for a pair of MN electrodes at a station for several different spacings of AB electrodes, the MN electrodes are moved to the next station along the survey line. The C electrode is kept at the same position such that line OC is perpendicular to line AB and $\overline{OC}$ is larger than $2\overline{AB}$. Profiles of ρ^{AC}, and ρ^{BC}, along the survey line often show up with a "crossover". In an ideal condition, a concealed conductive fracture zone lies near the crossover.

The method seems to have a good resolution for locating vertical low and high resistive bodies such

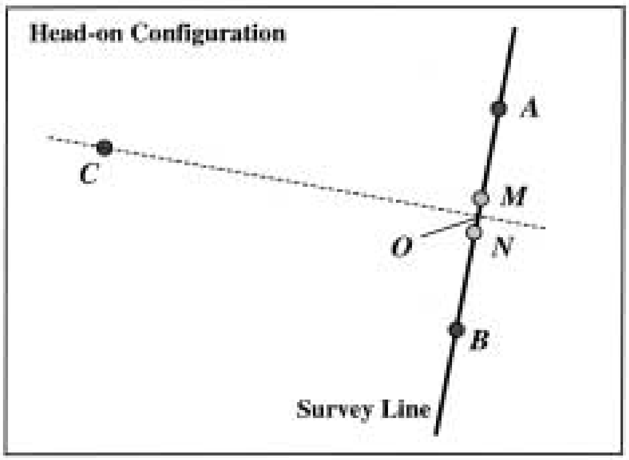

Fig. 1 Schematic of the Head-on array. A, B and C are current electrodes, while M and N are potential electrodes.

[1] Directorate of Mineral Resources Inventory. Jl. Soekarno-Hatta No.444, Bandung, 40254 Indonesia

Keywords: Mataloko geothermal field, Head-on, fracture, fault, geothermal manifestation

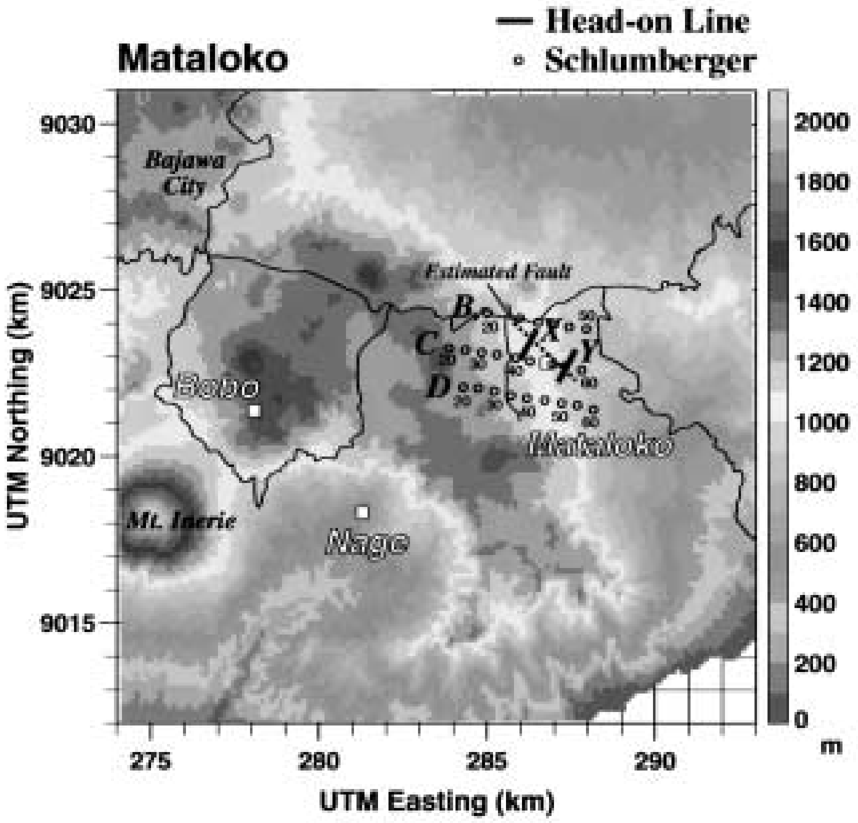

Fig. 2 Location of the Head-on survey lines, X and Y (thick solid lines), in the Mataloko geothermal field. Schlumberger sites on three lines, B, C and D, are also shown by open circles (Uchida *et al.,* 2002). Open squares indicate surface manifestations. The dotted line is an estimated fault.

as dykes and faults. The method has been used successfully to locate shallow faults in a geothermal investigation in the People's Republic of China (Cheng, 1980).

2. Geological Setting

The Mataloko geothermal field is located on the volcanic arc, central of Flores Island, Indonesia (Fig. 2). According to Nanlohy *et al.* (2001), the area is underlain by volcanic rocks of Quaternary and Tertiary ages. In this survey area, numerous volcanic cones can be found, but there are three cones that seem to be very important in this study. They are Wolo Belu (lava dome), Wolo Sasa and Wolo Nawa, which are located near geothermal manifestations, i.e., fumaroles, hot springs, and altered rocks.

There are main fracture systems in the area with a dominant trend in the NW - SE direction. One of these faults is very important in controlling geothermal fluids to flow up to the surface. This fault is known as the Wai Luja Fault. Volcanic lineaments and craters are also recognized in the Mataloko geothermal field.

3. Data processing

The Head-on measurement was carried out for two lines, X and Y (Fig. 2). The length of the lines is 1000 m, and 10 or 11 observation points were arranged on each line. The current electrode spacing AB/2 used was 200 m, 400 m, 500 m, 600 m and 800 m. The potential electrode spacing MN/2 was 80 m, and OC was 4000 m. We calculated ρ^{AB}, ρ^{AC} and ρ^{BC} for each AB/2 spacing at all observation points.

Plotting of $\rho^{(AC-AB)}$ and $\rho^{(BC-AB)}$ versus observation points along the survey line often shows up with a "crossover", which usually indicates a fracture zone (fault). Furthermore, we estimated faults in an apparent resistivity pseudo-section for each line.

4. Result and discussions

Two Head-on survey lines were interpreted in this survey. The main reason for locating the two profiles was to delineate resistivity anomalies caused by geothermal manifestations that are controlled by a fractured system, the Wai Luja Fault. Previous geological (Nanlohy *et al.,* 2001) and resistivity surveys (Andan *et al.,* 1997) in the Mataloko geothermal field indicated the presence of the Wai Luja Fault.

4.1 Head-on curves of Line X

Figure 3A shows curves of $\rho^{(AC\text{-}AB)}$ and $\rho^{(BC\text{-}AB)}$ versus observation points for Line X. For AB/2 = 200 m, the curves have a crossover near the eighth observation point. For an electrode spacing of 400 m, the crossing of $\rho^{(AC\text{-}AB)}$ and $\rho^{(BC\text{-}AB)}$ is at the ninth point. For larger electrode spacings, the curves show crossovers at the first point for AB/2 = 500 m, and between the second and third points for AB/2 = 600 m. For AB/2 = 800 m, the curves cross over near the fourth and fifth observation points. In this case, we interpreted that the concealed conductive fracture zone lies near the crossovers.

4.2 Head-on curves of Line Y

Curves of Line Y cross over at all electrode spacings AB/2 (Fig. 3B). For AB/2 = 200 m and 400 m, the curves of $\rho^{(AC\text{-}AB)}$ and $\rho^{(BC\text{-}AB)}$ cross over near the seventh point. For greater electrode spacings, AB/2 = 500 m and 600 m, the curves cross over between the sixth and seventh points and at the seventh point, respectively. For AB/2 = 800 m, the curves show the crossover between the seventh and eighth points.

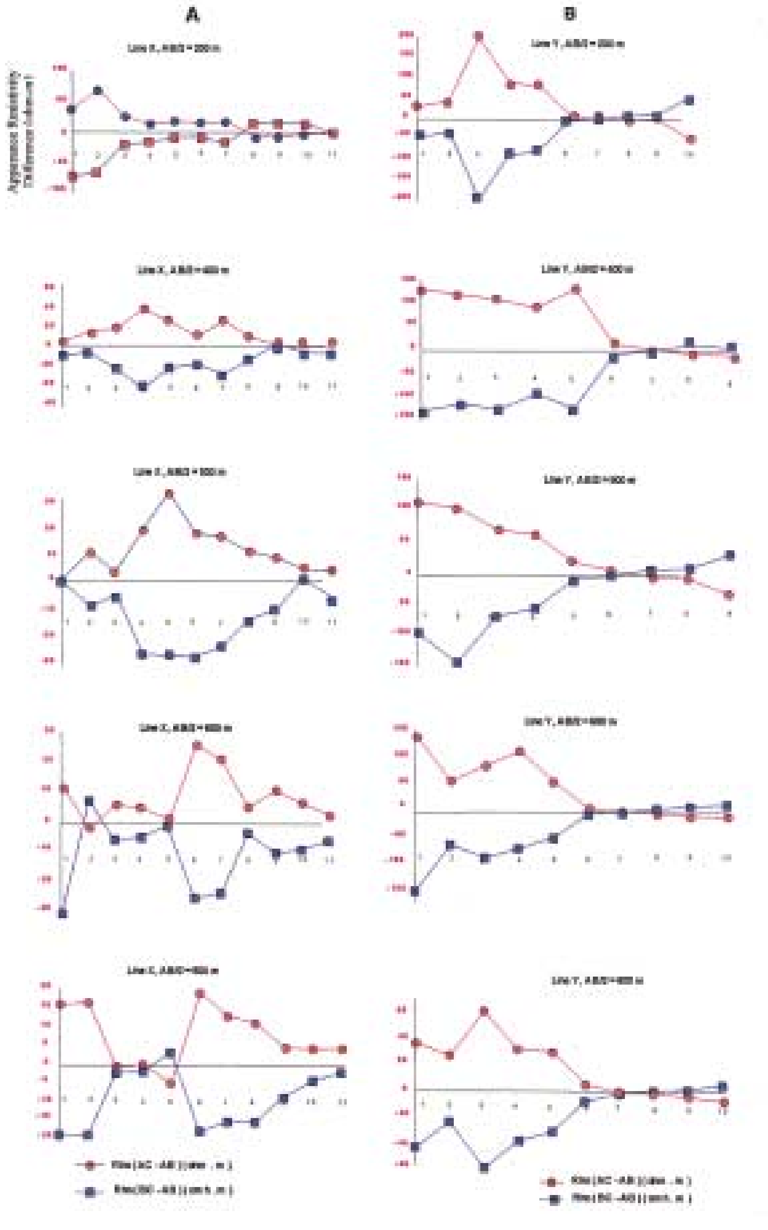

Fig. 3 Curves of (AC-AB) and (BC-AB) of the Head-on data for (A) Line X and (B) Line Y in the Mataloko geothermal field.

4.3 Pseudo-section of Line Y

Figure 4 shows pseudo-sections of apparent resistivity, ρ^{AB}, of Lines X and Y. Based on the processed Head-on data and apparent resistivity pseudo-sections shown in Fig. 4, positions of the fracture zones beneath lines X and Y can be interpreted.

In a section of Line Y, two faults are interpreted (Fig. 4A). The first fault is located beneath point Y7. It is almost perpendicular to the surface. The second fault is found beneath Y5 to Y9, crossing the first fault. The second fault has a dip of 53° calculated from the pseudo-section. This fault is interpreted as the Wai Luja Fault.

4.4 Pseudo-section of Line X

There are two faults in this section (Fig. 4B). The first fault is beneath X7 to X9 and at depths that correspond to the electrode spacings of AB/2= 200 m to 400 m. This fault is interpreted to be connected with the Wai Luja Fault in line Y. The second fault is located beneath X1 to X5 with electrode spacings from 500 m to 800 m. This fault has a dip about 15°.

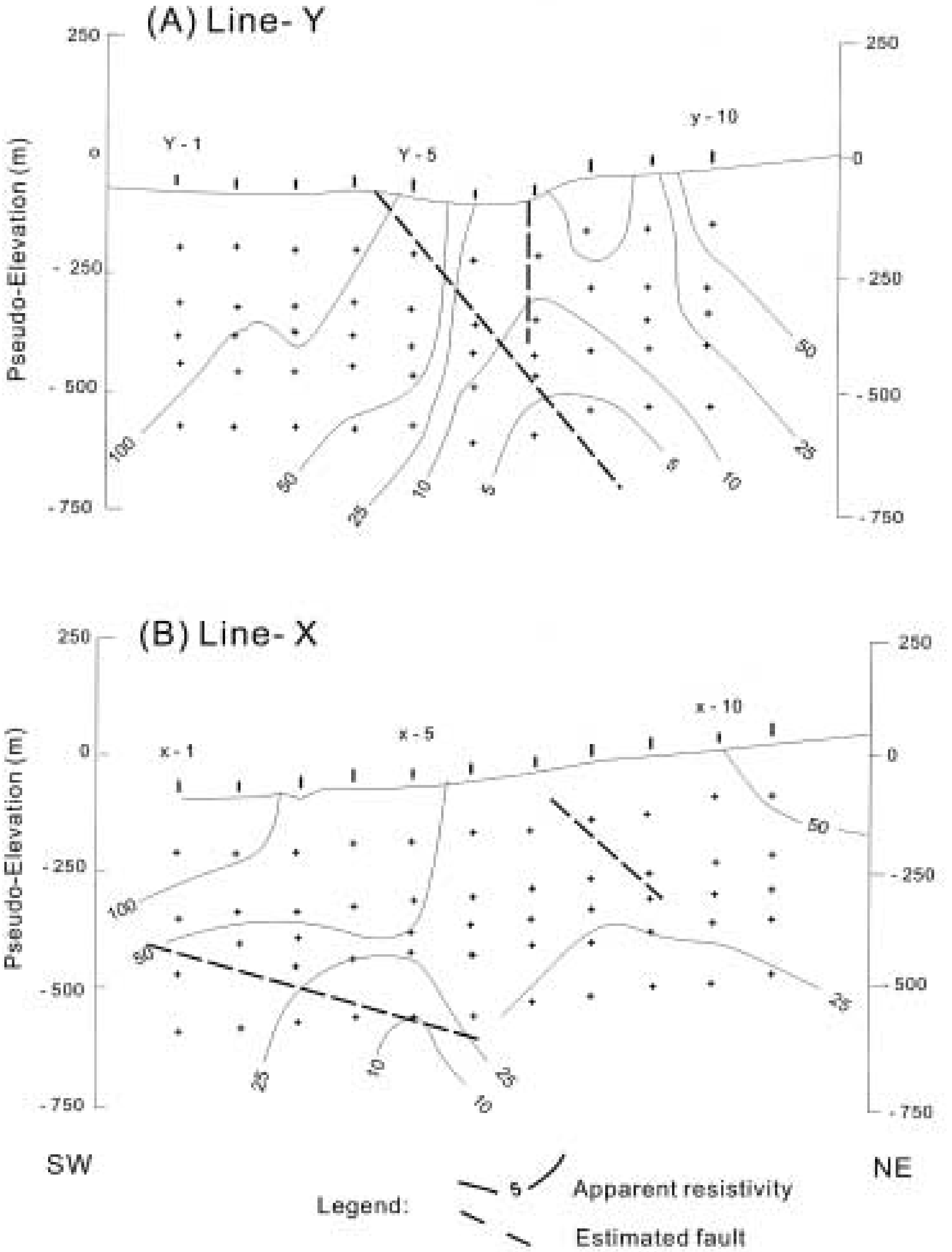

Fig. 4 Apparent resistivity pseudo-sections of (A) Line Y and (B) Line X. Contours indicate the apparent resistivity in ohm-m and dashed lines are faults estimated from crossover locations in Fig. 2.

5. Conclusions

The following conclusions have been derived through this work.

1) The Head-on method has given a good result to locate the Wai Luja Fault in the Mataloko geothermal field, Flores Island, Indonesia.
2) The Wai Luja Fault is a normal fault trending in the NW-SE direction and dipping 53° north.
3) The main geothermal manifestation is controlled by the Wai Luja Fault.

Acknowledgements: The authors wish to express their deep appreciation to the staff of the Geological Survey of Japan for selecting them to participate in this cooperating program. We are grateful to all people who cooperated with the authors. We specially thank Dr. Sjafra Dwipa, Geothermal Division, DMRI, for his guidance on this paper.

References

Andan, A., Suhanto, E., Sukirman, A., Ashari and Usmawardi (1997) *Geophysical survey in the Mataloko geothermal field, Flores, Indonesia.* Volcanological Survey of Indonesia, 48p (in Indonesian).

Cheng, Y. W. (1980) Location of near surface faults in geothermal prospects by the combination of head-on resistivity profiling method. *Proceedings of the New Zealand Geothermal Workshop,* 163-166

Mwangi, M. N. (1982) Two-dimensional interpretation of Schlumberger soundings and head-on data with examples from Lyjut Jorour, Iceland and Olkaria, Kenya. *UNU Geothermal Training Program, Project Report,* 62p.

Nanlohy F., Kusnadi D. and Sulaiman, B. (2001) Geology and geochemistry of Mataloko geothermal field, central Flores, East Nusa Tenggara. *Proceedings of the 5th INAGA Annual Scientific Conference and Exhibitions, Yogyakarta,* 6p.

Uchida, T., Andan, A. and Ashari (2002) Interpretation of DC resistivity data in the Bajawa geothermal field, central Flores, Indonesia. *Bull. Geol. Surv. Japan,* **53**, 253-263.

Received October 5, 2001
Accepted February 21, 2002

インドネシア，ヌサ・テンガラ州フローレス島マタロコ地熱地帯で ワイ・ルジャ断層の位置決定に用いたHead-on 測定

Arif MUNANDAR・Achmad ANDAN・Janes SIMANJUNTAK

要　旨

Head - on 法は，地下に伏在する比抵抗異常をマッピングすることを目的に開発され，特殊な電極配置を用いる．これはシュランベルジャ配置の電流電極A，Bの方向に対してほぼ垂直に，第3の電流電極Cを遠く離れた場所に追加的に配置するものである．今回の調査では，インドネシアのフローレス島マタロコ地熱地帯において，破砕帯の位置を決定するためにHead - on 法を用いた．Head - on 法の見掛比抵抗プロファイルによれば，ワイ・ルジャ断層は北西－南東方向で北に53° 傾斜した正断層である．マタロコ地熱地帯の主な地熱徴候（噴気，温泉，変質）は，ワイ・ルジャ断層に規制されている．
（要旨翻訳：水垣桂子（地圏資源環境研究部門））