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GEOTHERMAL GEOLOGY OF THE MATALOKO AREA, CENTRAL FLORES, NUSA TENGGARA, TIMUR, INDONESIA

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ABSTRACT

The Mataloko area, the survey area of this study is located in the central part of Flores, where many alteration zones are found including Nage and Mengeruda, centering around the Mataloko geothermal area. With regard to the generation process of the Mataloko alteration area, it is considered that a low temperature acidic hydrothermal water (about 100℃) has contributed to its generation along with the influence of an alteration cap rock developed deep under the ground. According to this study the following geothermal model is suggested. Geothermal steam and H_2S gas were selectively separated from the hydrothermal water being affected by the cap rock under the ground. This rose toward the surface and flowed into the underground water to generate the acidic hydrothermal water. Consequently it is expected that a predominant geothermal reservoir should exist deep under the Mataloko area. On the other hand, pyrophylite was detected in the central part of geothermal activities of the Nage alteration zone, where many hot springs exist. Pyrophylite is a hydrothermal alteration mineral, which indicates the involvement of a high temperature acidic hydrothermal water (about 200-300℃) in its generation process. Judging from this model, it is considered that the survey area around Mataloko has optimal conditions for geothermal power generation.

1. INTRODUCTION

Nusa Tenggara Timur is located in the east of the Republic of Indonesia, The main islands that make up Nusa Tenggara are Lombok and Sumbawa in the east and Flores and Sumba in the west. Most of them are volcanic islands including some active volcanoes.
The survey area of this study was the central part of Flores where there are many indications of the existence of geothermal sources including active volcanoes and hot springs. However the hot springs have not as yet been used for geothermal power generation. Only a few of them sometimes serve the local resident as baths. The situation of electrification in Nusa Tenggara Timur is still backward. The study is conducted with the purpose to promote an electricity supply plan for isolated islands by geothermal power generation, applying to the Mataloko geothermal field and the surrounding area.
Centering on the Mataloko geothermal area, the survey area includes both Bajawa town in the west and some important geothermal fields eg. Nage and Wolo Bobo in the southwest of Mataloko, Gou and Mengeruda in the north. Two active volcanoes are also included in the survey area; Mt. Inelika (S.L.;1,559m, Date of last eruption:1905) and Mt. Inerie (S.L.;2,245m, Date of last eruption:1882).

2. VOLCANIC STRUCTURE OF MATALOKO AREA

Interpretation of JERS-1/SAR images was adopted in this study. The geological information obtained from satellite imagery is drainage pattern, landform (resistance), tone, texture, and lineaments. The volcanic rocks can be divided into 2 groups in the survey area: Vo (older volcanic rocks) and Vy (younger volcanic rock). Vo is a sub-parallel drainage pattern with high density, rough texture and high resistance, while Vy is a radial drainage pattern consisting of low density, smooth texture and low resistance.
Many lineaments are found along N-S, NW-SE, NE-SW and E-W directions. The lineaments along N-S and NW-SE indicate an arrangement of volcanoes. A steep cliff extending to the N-S can be seen showing the same direction as the distribution of volcanoes in the north of Inerie.

3. VOLCANIC STRATIGRAPHY OF MATALOKO AREA

In the survey area, the stratigraphic units of volcanic rocks can be divided into 5 units: V1, Bc(1,2,3), C(1,2) and Ie in ascending order(Fig.1). The V1 unit is correlated with the Vo by satellite image, while the Bc(1,2,3), C(1,2) and Ie units can be correlated with the Vy.

Ie	:	Inerie Volcanics
C1,C2	:	Cone Volcanics
Bc1,Bc2,Bc3	:	Bajawa Caldera Volcanics
V1	:	Old Volcanics

3.1 Old Volcanics(V1)

The V1 unit, is distributed extensively in the area. This unit consists mainly of px-andesite lava, pyroclastic rocks, lahar deposits and ol-basalt.
Chemical analysis of the andesite lava shows 59-60% SiO_2. K-Ar ages of andesite lava estimated to be 1.1Ma to 1.6Ma.

3.2 Bajawa Caldera Volcanics (Bc1,Bc2,Bc3)

Bajawa Caldera is located in the north of Bajawa City. Bc unit is exposed in Bajawa Caldera. This unit consists mainly of pyroclastic flow and px andesite lavas. The andesite lava contains 57% SiO_2. The K-Ar ages of andesite lava is <0.15Ma.

3.3 Cone Volcanics(C1,C2)

The volcanic cones show a very well-preserved topography, which are distributed in the southern and northern part of Bajawa City and around Mataloko Village. In the south of

Bajawa City, volcanic cones are arranged and extended southward. In the north of Bajawa, the volcanic cones extend toward the north, Mt. Inelika. The volcanic cones run in a northwest to southeast direction around Mataloko. This unit consists of px-andesite lava, pyroclastic rocks and pumice/scoria fall deposits. The andesite lava contains about 59-65% SiO_2. The K-Ar ages of andesite lava is <0.15Ma.

3.4 Inerie Volcanics(Ie)

The Ie units forms Mt. Inerie. The unit consists of andesite lava and pyroclastic flows. Chemically the andesite lava contains about 54% SiO_2.

4. HYDROTHERMAL ALTERATION ZONE

Many alteration zones were confirmed in this area, such as Mataloko, Nage, Wolo Bobo, Gou and Mengeruda (Fig.2). The hydrothermal alteration minerals were determined by XRD. The following minerals were detected as alteration products by XRD:

Clay minerals	: smectite, kaolinite, pyrophylite, zeolites and clinoptilolite
Silica minerals	: quartz and α-cristobalite
Others	: alunite, jarosite, goethite, pyrite and sulphur

4.1 Mataloko Alteration Zone

The Mataloko alteration zone is located in a northwest to southeast direction extending about 1,200 meters long. This alteration zone is characterized by strong argillization, where many high temperature hot springs (acidic SO_4 type, over 77-89℃) are distributed. A number of alteration minerals such as quartz, α-cristobalite, smectite, kaolinite, alunite, jarosite, pyrite and sulphur were indentified.

4.2 Nage Alteration Zone

The Nage alteration zone is situated inside the Nage caldera. The following alteration zones are found from the center to the outside: silicification zone (quartz - pyrophyllite), silicification - argillization zone (quartz, α- cristobalite, kaolinite, alunite), and argillization zone (smectite, pyrite). Many high temperature hot springs higher than 70-80℃ (acidic SO_4-Cl type) are distributed in the central part of the alteration zone.

4.3 Wolo Bobo Alteration Zone

The Wolo Bolo alteration zone is situated at the Wolo Bobo volcanic cones. A spout hole is observed near the top of the mountain and Keli hot springs (neutral SO_4 type, water temperature : 71℃) are distributed on the hillside. Quartz, α-cristobalite, kaolinite and alunite were identified.

4.4 Wolo Rhea Alteration Zone

The Wolo Rea alteration zone is located in the northwest of Mataloko Village, which is characterized by strong silicification (α-cristobalite, kaolinite). This zone is not accompanied by a hot spring.

4.5 Gou Alteration Zone

The Gou alteration zone is situated in the Bajawa caldera. This zone is characterized by argillization (kaolinite, alunite). There are two hot springs (acidic SO_4 type, water temperature : 35-45℃) in this zone.

4.6 Mengeruda Alteration Zone

The Mengeruda alteration zone is characterized by weak argillization (smectite). There are two hot springs (acidic SO_4 type, water temperature : 41℃) in this zone.

4.7 Others

Many other alteration zones were discovered around Mataloko area, with the following characteristics:

North of Mataloko	: kaolinite, α-cristobalite
East of Mataloko	: smectite, kaolinite, alunite
South of Mataloko	: α-cristobalite
Maumbawa	: smectite, kaolinite, alunite
Soka	: α-cristobalite

5. GEOTHERMAL MODEL

A geothermal model for the survey area is examined on the basis of geological structure, distribution of alteration zones and the generation mechanism of hydrothermal alteration minerals. Kaolinite, alunite, sulfur and α-cristobalite are predominantly found entirely in the Mataloko, Wolo Bobo, Wolo Rhea and Gou alteration zones. The existence of these alteration minerals indicates that a low temperature acidic hydrothermal water (about 100℃) had contributed to the generation process. This applies to the low-sulfidation type suggested by Hedenquist and Lowenstern(1994) and the hydrothermal water is slightly reduced and shows neutral (Hedenquist and Lowenstern, 1994).

It is also considered that an alteration zone cap rock developed deep under the ground should have been involved in the generation of the low temperature acidic hydrothermal water represented by the Mataloko field. Under the influence of cap rock, the underground hydrothermal water did not rise directly up to the surface, but only permeable components, i.e. geothermal steam and H_2S gas selectively separated from the hydrothermal water, rose toward the surface and flowed into the underground water to generate the acidic hydrothermal water. Consequently it is expected that a predominant geothermal reservoir should exist deep under the Mataloko area.

Pyrophylite was detected in the central part of geothermal activities of the Nage alteration zone, where many hot springs are distributed. The existence of pyrophylite indicates that a high temperature acidic hydrothermal water (about 200-300℃) had been involved in its generation process. This applies to the high-sulfidation type suggested by Hedenquist and Lowenstern (1994) and the hydrothermal water is slightly oxidized and acidic. It is considered that in the Nage alteration zone a high temperature acidic hydrothermal water was generated by the hydrothermal water flowing directly into the underground water. Moreover the existence of any hydrothermal water and reservoir of geothermal steam can not be expected under the ground because Mengeruda is situated at a distance from active

volcanoes and is only affected by low temperature volcanic gas influences. Judging from this model, it is considered that the survey area around Mataloko has optimal conditions suitable for geothermal power generation (Fig.3).

The same geological setting as the Mataloko and Nage fields is also found in the Sengan district of Japan. Centering on the active volcano Mt. Yakeyama, a geothermal field is located in the east of Hachimantai including the Tamagawa area with some hot springs (acidic SO_4-Cl type, water temperature : over 90℃; Noda et.al.,1987) and the Sumikawa-Onuma area where now the geothermal power generation is in practical use.

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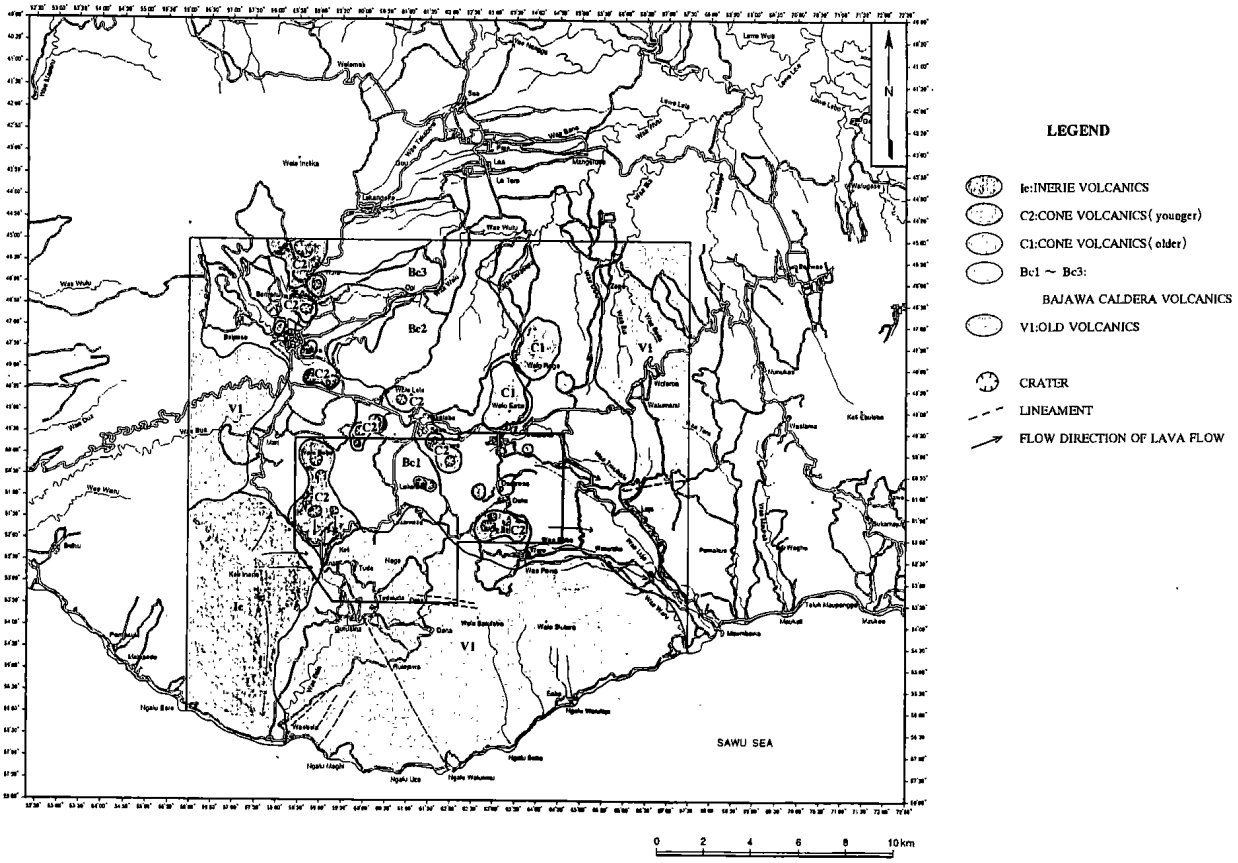

Figure 1. Geologic map of survey area

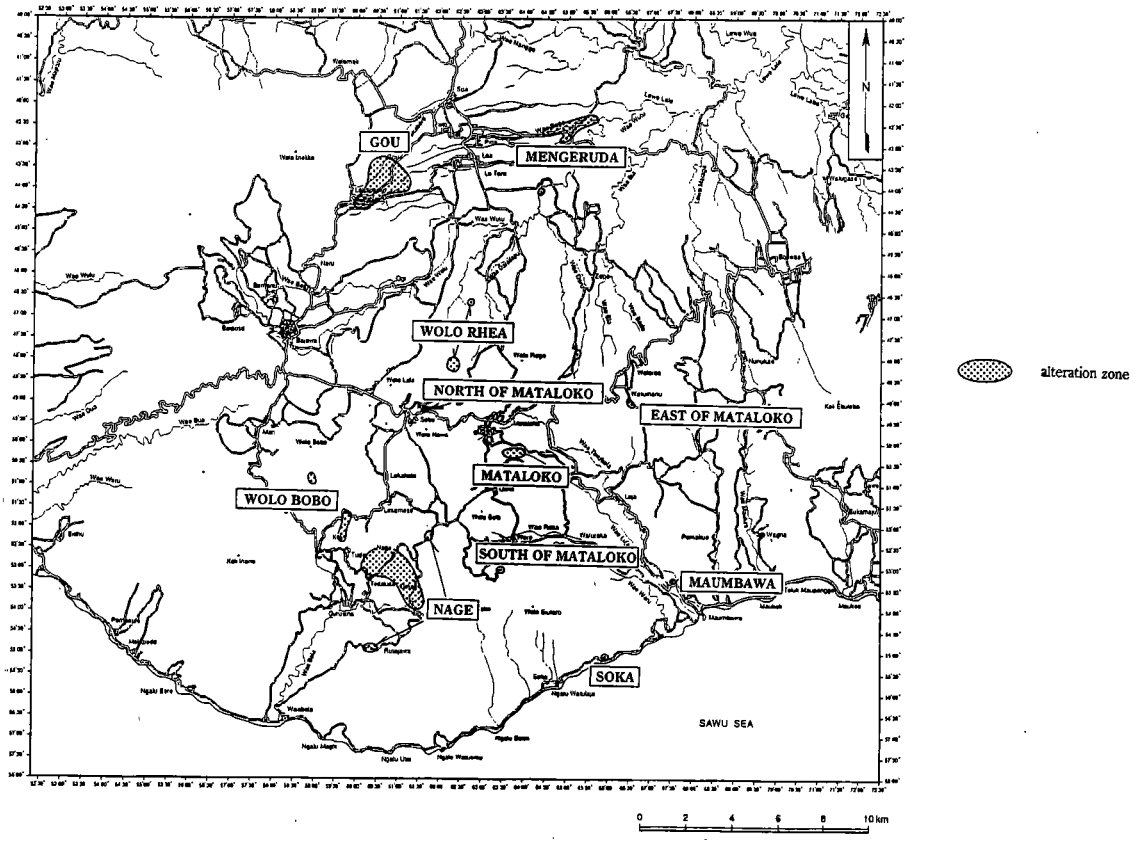

Figure 2. Distribution map of alteration zone

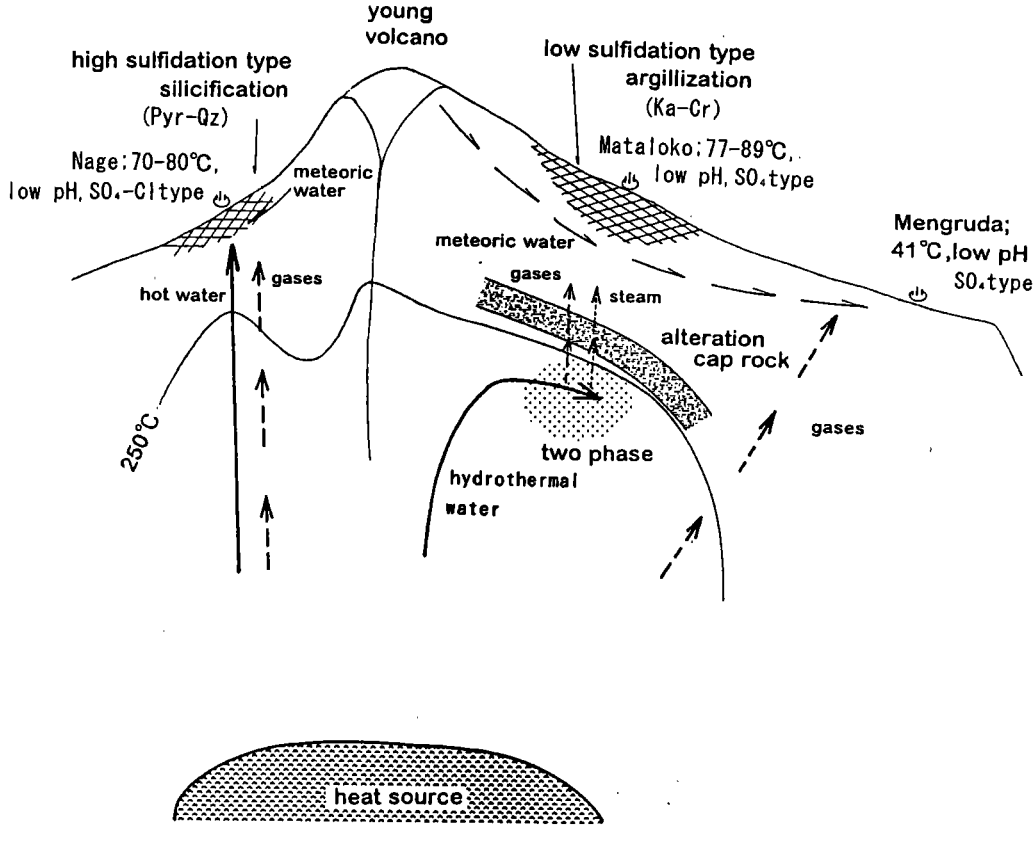

Figure 3. Geothermal model of the Mataloko area