INTEGRATED GEOLOGICAL, GEOCHEMICAL AND GEOPHYSICAL SURVEY IN JABOI GEOTHERMAL FIELD, NANGRO ACEH DARUSSALAM, INDONESIA

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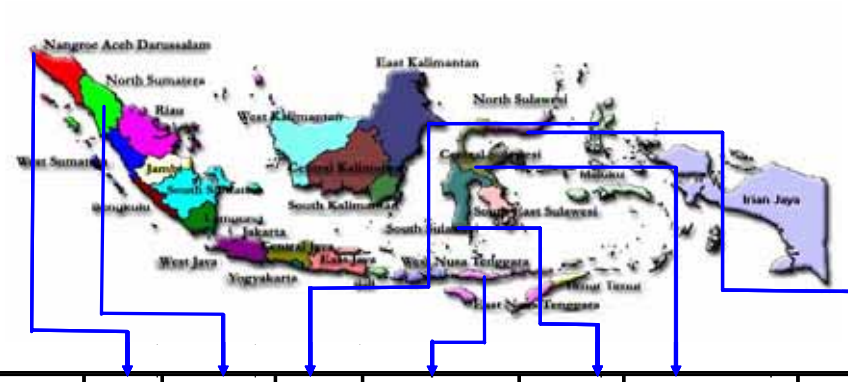
ABSTRACT

Jaboi is located in Weh Island at the northern tip of Sumatra. The existence of geothermal activities in Jaboi is a part of other geothermal activities along the Semangko geological depression in Sumatra. Geothermal manifestations situated in the Quaternary lava (1.1 ± 0.1 Ma) rocks environment. These manifestations are solfatara, fumaroles, hot ground, mud poll and hydrothermal alteration with the temperature between 98°C and 106°C. Hot water temperatures in this area ranging from 95°C to 96.4°C. Integrated geo-scientific data from Jaboi indicated that the prospect area of this geothermal field ± 6 km^2 which controlled by fault systems. Geophysical and geochemical surveys delineated top reservoir at 600 meter below sea level with estimated temperature of 255°C. At least 50 MWe of possible reserve is calculated in the study area.

Keywords: integrated survey, possible reserve, hydrothermal alteration, Jaboi geothermal field, Indonesia

1. INTODUCTION

The exploration stage of 158 out of 253 geothermal areas in Indonesia are still in the preliminary survey. Therefore, more intensive exploration activities are needed in order to inventory the resources data. In the 2005 fiscal year, the Center for Geological Resources (previously Directorate of Mineral Resources) has conducted both surface and subsurface geothermal explorations (Figure 1). Surface explorations were carried out in Jaboi and Sipaholon (Sumatera); Akesahu (Maluku); Lumpio, Suwawa and Pincara (Sulawesi) geothermal fields. Some 390 MWe of possible reserve of geothermal energy potency was estimated from these areas. Sub surface exploration (temperature gradient drilling) was carried out in Marana (Sulawesi) and exploration drilling in Mataloko geothermal fields. This paper presents some geoscientific data from Jaboi geothermal field.



LOCATION / METHOD	N A D	NORTH SUMATERA	NORTH MALUKU	EAST NUSA TENGGARA	SOUTH SULAWESI	CENTRAL SULAWESI		GORONTALO
	SABANG	SIPOHOLON	ARESAHU	MATALOKO	PINCARA	LUMPIO	MARANA	SUWAWA
GEOLOGY	◐	◐	◐		◐	◐		◐
GEOCHEMISTRY	◐	◐	◐		◐	◐		◐
GEOPHYSIC	◐	◐	◐		◐	◐		◐
SHALLOW DRILLING							◐	
EXPLORATION DRILLING				◐				

Figure.1. Exploration Activity

2. PREVIOUS WORKS

Jaboi is located in Weh Island at the northern tip of Sumatra (Figure 2). Weh is a volcanic island of western end of Sunda volcanic. Akbar and Dendi (1983) reported that active hydrothermal activities like solfatara, fumaroles, mud poll and hot water can be found in this island. They group these geothermal manifestations into four areas: Jaboi, Keuneukai, Lhok Pria Laot, and Iboih.

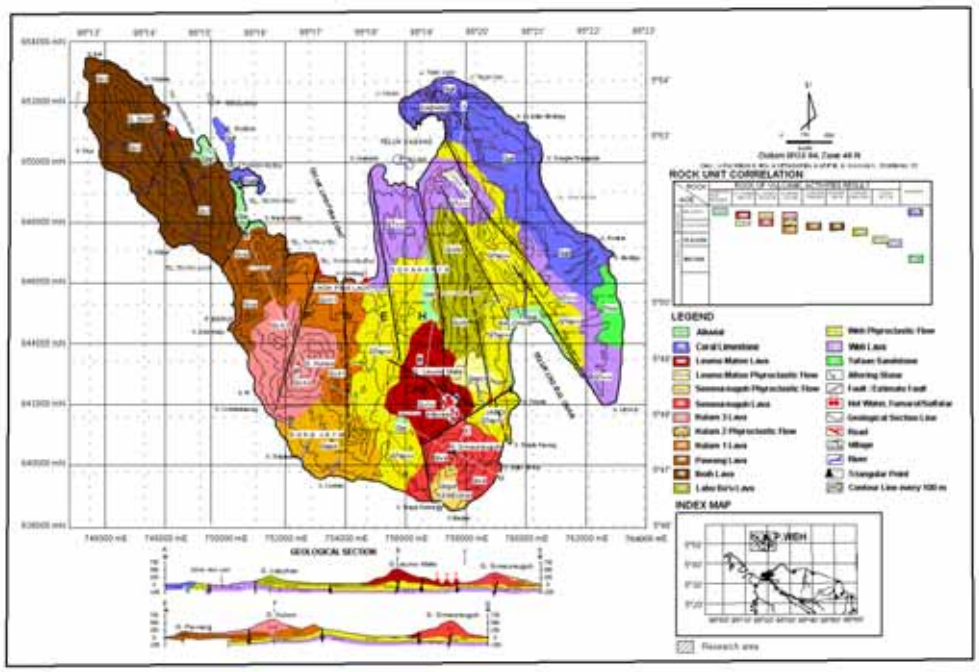


Figure. 2. Geologycal Map of Weh Island

3. METHODS

Integrated survey of geological, geochemical and geophysical was applied to study the characteristic of geothermal system in this area. During the geological mapping, rocks were collected at outcrops and followed by petrography analysis on thin sections. PIMA (Portable Infrared Mineral Analyzer) was used to describe altered rocks. Lava and pyroclastic rocks were sampled for dating C^{14}.

Water chemistry analysis either by using flamephotometry, spectrophotometry or atomic absorption spectrophotometry is necessary to understand the type and origin of water. Soil and soil-air sample analysis were carried out for Hg and CO_2 for studying the possibility of fluid leakage from depth. To estimate subsurface temperature, both methods of SiO_2 geothermometer for hot water (Fournier, 1981) and CO_2-H_2 geothermometer for gas (Taran, 1986) were used.

Sounding and mapping DC-resistivity measurements were conducted to study horizontal and vertical distribution of resistive and conductive layers. Gravity and magnetic methods were applied to study geological structures in this area. Gravity and magnetic data were collected at 223 measuring points.

4. RESULTS OF EXPLORATION

As can be seen from geological map of Weh Island (Figure 2), stratigraphily it consists of four main group of rock units. The oldest rock is Tertiary sedimentary rocks and followed by Tertiary-Quaternary volcanic rocks of Weh, Young/Quaternary volcanic rocks and limestone, respectively. There are nine primary faults with NNW – SSE trending. In addition, secondary faults such as, Leumo Matee, Ceunohot and Jaboi faults are also mapped. Typical altered minerals like monmorilonit, Na and K alunite, poly merkit and kaolinite are found in this area.

Geothermal manifestations situated in the Quaternary lava (1.1 ± 0.1 Ma) rocks environment. These manifestations are solfatara, fumaroles, hot ground, mud poll, hydrothermal alteration with the temperature between 98°C and 106°C. Hot water temperatures in this area are from 95°C to 96.4°C. Triangle diagram plot Cl-SO_4-HCO_3 of hot water derives from fumaroles classified this hot water into steam heated water. Estimated sub surface temperatures were 255°C. High mercury anomaly is concentrated at the Jaboi fumaroles with the area ± 2.5 km^2 (Figure 3). At the same place high CO_2 anomaly is also detected (Figure 4).

Mapping of apparent resistivity rock showed that horizontal distribution of low resistivity (< 10 Ohm-m) zone covering Jaboi manifestation area. This zone is continuously found from shallow (AB/2 = 250 meter) to deeper (AB/2 = 1000 meter) penetration (Figure 5). Sounding resistivity measurements encountered the top of conductive layer between 600 meter and 850 meter depth.

Magnetic anomalies value recorded in this survey area are in the range of -600 nT to 750 nT (Figure 6). These anomalies are classified into three groups: low (-600 nT to -200 nT), inter mediate (>-200nT to 300 nT) and high (>300 nT to 750 nT). Geothermal manifestations at Jaboi are reflected by high magnetic anomaly. This anomaly also located at the western part of the study area.

To delineate geological structure of target area, we extract Bouguer anomaly with second order polynomial plane. Result of this process is a residual gravity map. Residual gravity anomaly map with density background of 2.5 gram/cm^3 shows quite complex pattern of contour lineament with NNW – SSE, N – S and NEE – SWW trending (Figure 7).

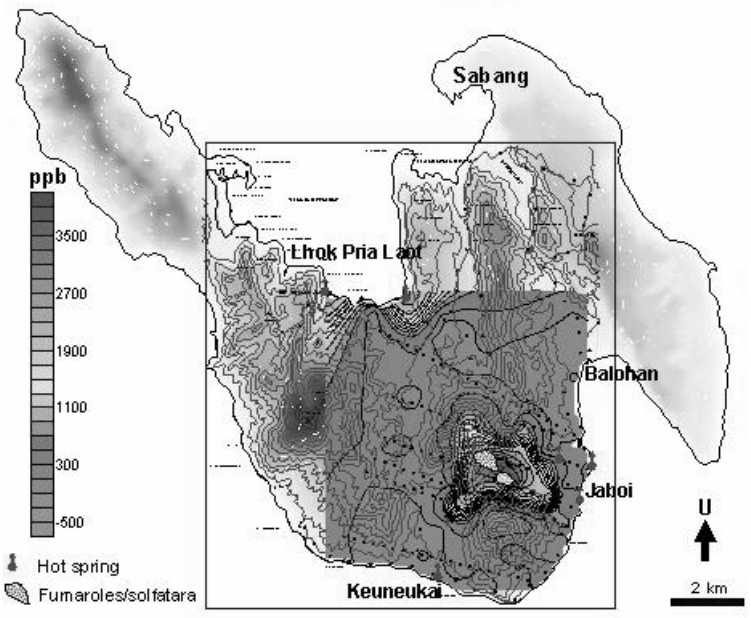


Figure 3. Mercury Distribution Map

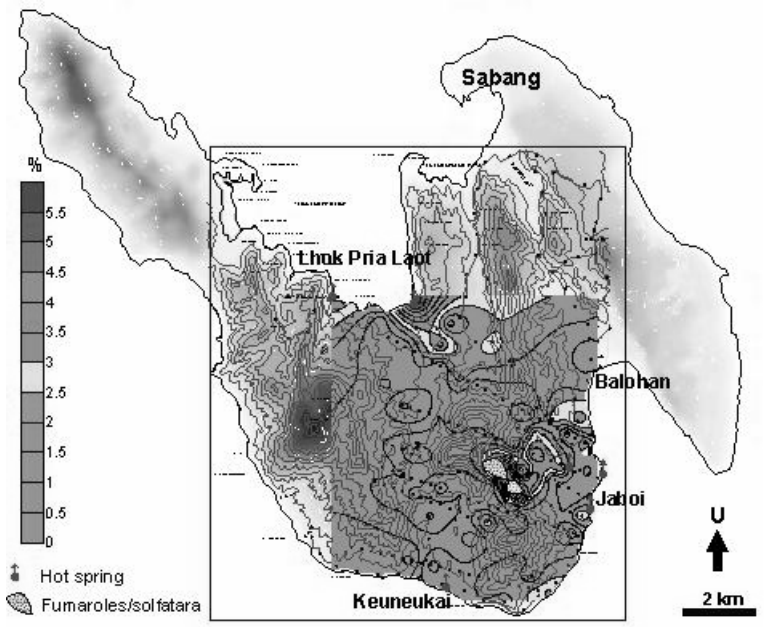


Figure 4. CO_2 Distribution Map

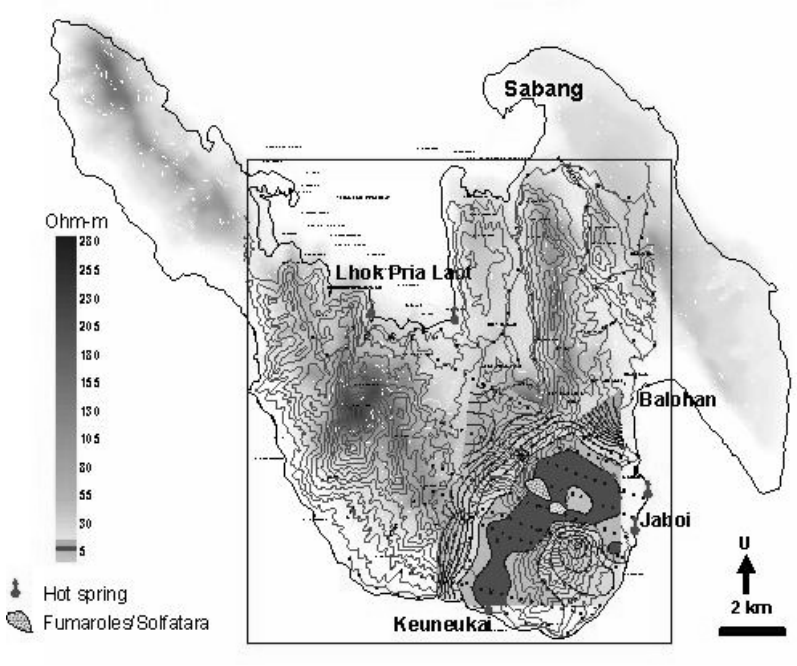


Figure 5. Resistivity Map

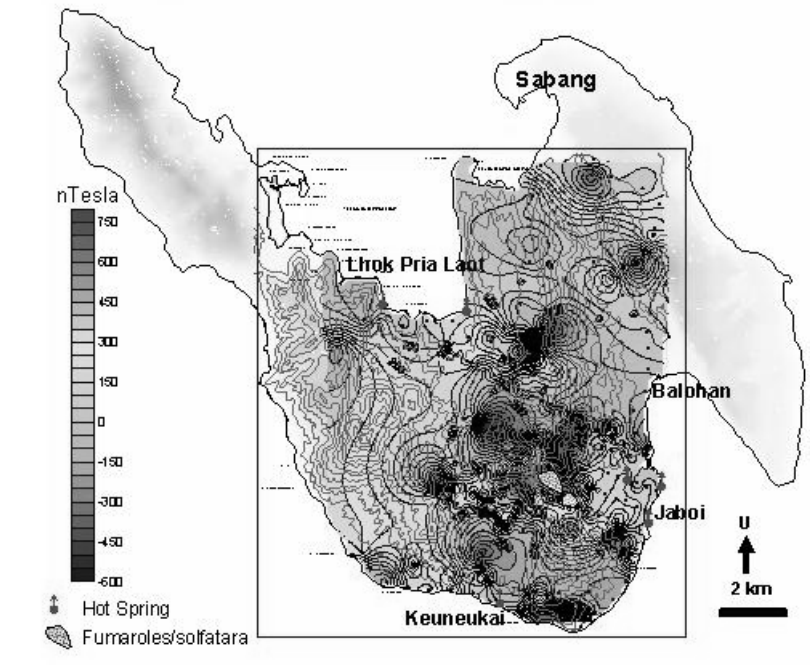


Figure 6. Magnetic Map

5. DISCUSSION

The existence of geothermal activities in Jaboi - Weh Island, is a part of other geothermal activities along the Semangko geological depression in Sumatra (Katili and Hehuwat, 1980). This geological structure is representing by a graben which stretching from Balohan bay to Sabang bay (Figure 2). We believe that Leumo Matee (NNW – SSE), Ceunohot (NE – SW) and other faults delineated by gravity play an importance role in controlling the appearance of Jaboi geothermal manifestations. This hypothesis is supported by seepages of hot water found along the Ceunohot River. In addition, there are plenty of groups or a single vent of fumaroles exists in the eastern flank of Leumo Matee volcanic cone.

Magnetic inclination of primary magnetic field in the study area is ± -6.3° or close to equatorial magnetic. At this area, rock unit which has low contrast susceptibility will responds as high anomaly magnetic field. High magnetic anomalies shown in figure 6 are evidence the presence of demagnetization rocks at Jaboi and Keuneukai. These anomalies also found at the northern part of study area. The causes of these anomalies are still unknown. It is could be reflected by rock susceptibility contrast at the boundary of the graben or by ancient hydrothermal activities in this area.

Probable heat source of Jaboi geothermal system is a magma remnant of Leumo Matee and Semeureuguh volcanic formation. Lava and pyroclastic product of Leumo Matee volcanic is 1.1 Ma years old (Quaternary). Geologically, this magma remnant is classified as young age that has enough heat to heat-up geothermal fluid in the reservoir. Top of this reservoir is estimated at 600 meter to 850 meter depth deduced from resistivity data. Based on chemistry content in water, all of hot water in this geothermal field has been contaminated with surface water. The origin of hot water derives from fumaroles is probably not from reservoir but from steam/gas condensation zone. It is indicated by water pH less than 3 and high SiO_2 content in the water.

Figure 8 is a compilation map inferred from integrated survey (geological, geochemical and geophysical) data. It is shown that high HG, high CO2, low resistivity and high magnetic anomalies are concentrated at Jaboi geothermal manifestations. Referring to these data we are able to draw estimated boundary of Jaboi geothermal system where the total area of ± 6 km^2. By using Volumetric Lump Parameter we calculate geothermal energy potency and we get possible reserve of 50 MWe.

6. SUMMARY

Jaboi is the most active geothermal field in the volcanic island of Weh. Geothermal manifestations situated in the Quaternary lava (1.1 ± 0.1 Ma) rocks environment. These manifestations are solfatara, fumaroles, hot ground, mud poll and hydrothermal alteration with the temperature between 98°C and 106°C. Hot water temperatures in this area ranging from 95°C to 96.4°C. Leumo Matee (NNW – SSE), Ceunohot (NE – SW) and other faults delineated by gravity play an importance role in controlling the appearance of Jaboi geothermal manifestations. Geophysical and geochemical surveys delineated top reservoir at 600 meter below sea level with estimated temperature of 255°C. Integrated geo-scientific data from Jaboi indicated that the prospect area of this geothermal field ± 6 km^2. At least 50 MWe of possible reserve is calculated in the study area.

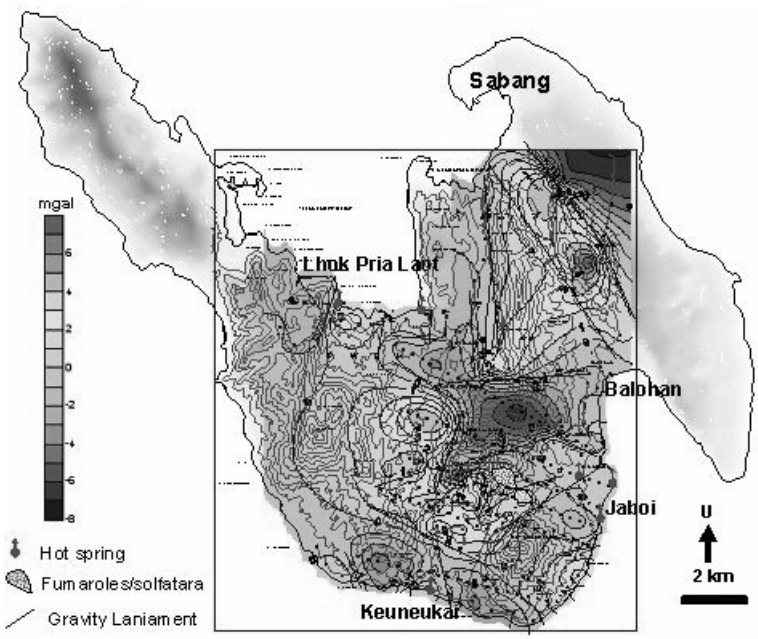


Figure 7. Residual Gravity Map

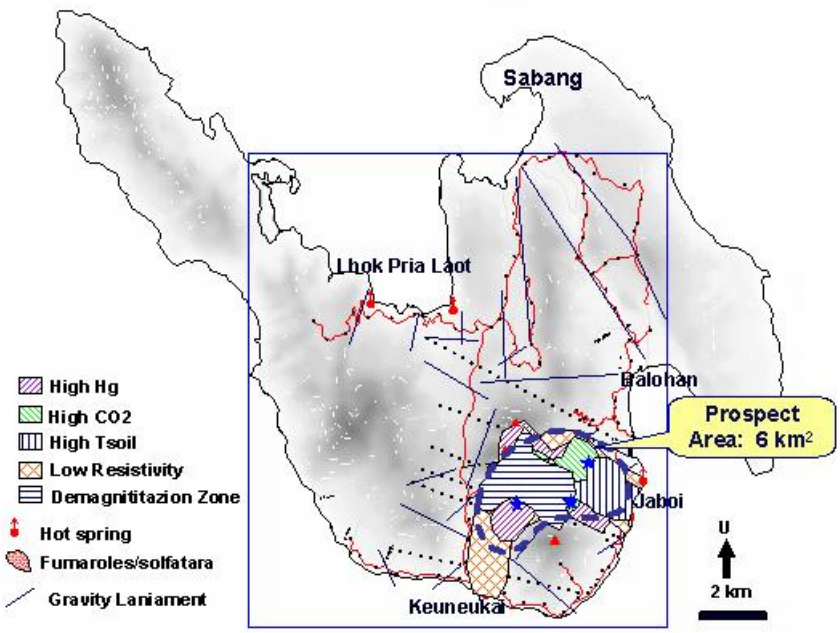


Figure 8. Compilation Map

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