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SEMBALUN BUMBUNG GEOTHERMAL AREA, LOMBOK ISLAND, WEST NUSATENGGARA, INDONESIA: AN INTEGRATED EXPLORATION.

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Abstract

The Sembalun Bumbung area is located in the North – East of Lombok island. This area is a part of a volcano depression, which has formed a caldera structure by a violent eruption of Mt. Sembalun. Geothermal manifestations, including altered rock occur in Sembalun caldera floor (± 1300 asl), and some hot springs discharge along the NE–SW, W–E, NW–SE trending faults, while 4 hot springs are situated at the foot of Mt. Rinjani.

The hot spring waters are of neutral, acid sulphate, and chloride sulphate types. The highest values of Hg, and CO_2 are found in soils at Nanggi hill, in " Sembalun Bumbung".
Results of gravity and geoelectric surveys support the subsurface data interpretation. Gravity data analyzed, suggest that Bouguer, and residual anomalies arround Sembalun represent a caldera structure. Resistivity data for the caldera floor, show low anomaly (< 25 Ω m) contour patterns of AB/2=500m, and AB/2=1000 m and are concentrated at Sembalun Bumbung, on the caldera floor. Estimation of the actual resistivity beneath Sembalun Bumbung on line A show that, the thickness of overburden layers is 185 – 280 m, the clay cap layer is probably about 550 – 1450 m, whereas the thickness of the layer below the clay cap (the maximum penetrated) with resistivity < 10 Ω m couldn't be recorded. The layers beneath the clay cap layer are assumed to constitute a liquid or steam reservoir.

The best area for developing a small scale geothermal power for supplying electricity demand in Lombok island is presumably in the vicinity of "Nanggi hill in Sembalun Bumbung" on the caldera floor.

1. Introduction

The Sembalun Bumbung geothermal area is situated in the North - East of Lombok Island. The surveyed area covers an area of about 18 X 15 km^2 , and lies between 8°12'56"- 8°34'15" S latitude, and 116°27'16"- 116°43'28" E longitude (Figure 1.). Lombok island has a population of about 900.000 people.

The installed electric power generated from diesel is used for domestic energy, such as lighting, industrial, harbour, transportation, hotels/ restaurants/ tourism, hospitals, education etc. The diesel electric power needs an oil supply, which is relatively expensive because it is imported from other islands.
A small scale geothermal power plant is probably the best alternative for meeting the energy demand, but is yet to be developed.
This paper describes an integrated survey for preliminary exploration of the geothermal energy in Lombok island.

2. Methods

During geothermal exploration some surveys have been carried out in Sembalun Bumbung,. Those are: geological, geochemical, and geophysical. surveys They involve mapping, observing, and sampling in the field, but some laboratory work is completed in the office.
The geological survey has been carried out in a large area,but geophysical, and geochemical surveys in a smaller area. Both geophysical, and geochemical surveys are mostly concentrated in the Sembalun caldera floor area

3. Thermal manifestations and surface alteration

Thermal features in Sembalun geothermal area occur in the NE-SW, W–E, NW-SE trending faults, and at the foot of Mt. Rinjani. Features include hot springs, and altered rocks.

The hot springs temperatures are up to 70° C, and the waters are mostly characterized by a neutral pH, but two have a high concentration of acid sulphate, and one contains a chloride sulphate water. Surface alteration of argillitic type is observed at Orok, in the caldera floor area, in the W–E trending fault The argillitic alteration products include gypsum, kaoline, also present are pyrite, iron oxide, and a silica residue. This rock is probably mainly being altered by acid condensate to produce a variety of sulphate minerals

4. Geology

Lombok island is a part of the Banda Island arc, which comprises Upper Cenozoic volcanic rocks with volcanogenic and carbonate sediments (Hamilton,1979).

The volcanic rocks are dominantly of mafic to intermediate calc-alkaline composition, and are uncorformably underlain by Tertiary rocks. The oldest rocks are sedimentary of Miocene age, and exposed in the southern part of the island (Sukardi et.al, 1976). The youngest rocks occur in the western part of the surveyed area.. Aerial photograph interpretation shows a caldera oxbow like structure, open to the North West .

The Quaternary volcanic rocks consist of: Sembalun pre-caldera rock unit, Sembalun syn-caldera pyroclastic rock unit, Sembalun post-caldera rock unit, lava domes, Mt. Rinjani lava unit, Mt. Rinjani pyroclastic rocks, and Mt. Lelonten lava.

These rocks are dominantly of andesitic composition. There are however dacitic–ryolitic rocks exposed mostly on the Sembalun caldera floor. These rocks are Sembalun caldera products (syn-caldera rock unit). The secondary or surfacial deposit is alluvial (Figure 2) The primary minerals present in the Quatenary volcanic are mainly plagioclase, orthopyroxene, clinopyroxene, and volcanic glass.

5. Geochemistry

Seven hot springs discharge to the surface along the above structures. These are:
Aik Kukusan which is controlled by the NE–SW fault, Aik Kalak which is controlled by the W–E fault, Aik Sebau which is controlled by the NW– SE fault, and Segara Anak which is controlled by the Sembalun caldera.

Hot spring samples have been analyzed, and they can be divided into 3 types of hot spring water according to the results, i.e. chloride sulphate type: Aik Sebau; acid sulphate type: Aik Kalak & Aik Kukusan; and neutral type: Segara Anakan I, II, III, IV (Table 1 & Figure 3).

The pH of soil in Sembalun varies between 6 and 7.although values of pH < 6 are concentrated in Bonduri hill, and Nanggi hill. The countour patterns of mercury in soil, show that the highest values, and positive anomaly are concentrated in Anak Dare hill, and Nanggi hill (Sembalun Bumbung).The highest anomalies of CO_2 in soil air are also concentrated arround Sebau hot spring, Batujang hill, and in Nanggi hill (Sembalun Bumbung).

The positive anomalies for Hg & CO_2, and also low pH values are most concentrated in Nanggi hill.. The area arround Nanggi hill is probably a geothermal active zone or a fractures zone. The positive anomalies for mercury, CO_2, and also the low pH in the vicinity of Nanggi hill have suggested, that beneath Nanggi area there may be a prospect area for geothermal energy.

6. Geophysics

Geophysical surveys such as: gravity, and resistivity have also been carried out on the Sembalun caldera floor.

Gravity data analyzed with respect to Bouguer, and residuals of order 3, show these anomalies, and the general structure patterns are positive anomalies, close to the centre of the depression area (Sembalun Bumbung). These positive anomalies, and the closed shape in the centre of the depression support the idea, that in the Sembalun area there is a caldera structure as is indicated by the results of the geological survey.
Resistivity data analyzed for the caldera depression, shows that the contour patterns tend to be North-South directed. The resistivity values are high in the western area, and low in the eastern part. Both low resistivity anomalies (≤ 25 Ω m) of AB/2= 500, and AB/2= 1000 m are located in Sembalun Bumbung. The low anomalies of AB/2= 500 cover an area of about 1×3 km^2, and 1.5×6 km^2 in a deeper area of AB/2= 1000m. Estimation of the actual resistivity arround the Nanggi hill in line A on point A 2000-A 4000 shows these, the thickness of the overburden resistive layers is approximatly 185 – 280 m, the condensate layer or clay cap layer is probably about 550 – 1450 m thick, whereas the thickness of the layer below it (as maximum penetrated) with resistivity < 10 Ω m, could not be established (Figure 4). Below point C 500, the thickness of the overburden layer is between 700-750 m, clay cap layers are probably about 700–1100 m, and the thickness of the reservoir layer below could not be established. Below line D; the overburden layer is between 150 – 200 m, the clay cap is between 530 – 750 m, and the depth of the layer below it could not be established. All layers below the clay cap with resistivities < 10 Ω m, in lines A, C, and D are assumed to be a liquid or a steam reservoir.

The combined data from geological, geochemical, and geophysical surveys have been used to construct a schematic model of the Sembalun Bumbung area (Figure 5)

7. Discussion and Conclusions

The geothermal system in Sembalun Bumbung is presumably controlled by a caldera structure. The surface or near surface rocks are probably being altered mainly by acid condensate to produce a variety of sulphate minerals. The argillitic type alteration minerals include gypsum, kaoline, and also are present pyrite, iron oxide also silica residue.

In the vicinity of "Nanggi hill" beneath the Sembalun Bumbung area there is presumably a prospect area for developing a small scale geothermal power plant in Lombok island. The subsurface geoelectric data in the survey area, suggest that the possible reservoir is approximately 30 to 90 Mwe (average 60 Mwe)

Acknowledgement

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References

Hamilton, W. B (1979). *Tectonics of the Indonesian regio*n. USGS professional paper 1078

Sukardi et al, 1976 *Penyelidikan hidrogeologi di P. Lombok* (un published report

Table 1: Chemistry data for hot springs in Sembalun Bumbung, Lombok island

Constituents	Aik Kalak	Aik. Kukusan	Aik. Sebau	S. Anak I	S. Anak II	S. Anak III	S. Anak IV
pH	8.16	8.30	7.58	8.04	8.01	7.81	7.80
Cl^-	211.55	76.07	549.19	556.40	575.24	547.71	528.87
$SO_4^{=}$	1287.50	1125.0	62.50	600.00	600.00	700.00	775.00
B	2.48	1.66	4.14	18.58	18.23	15.50	15.98
SiO_2	41.0	53.0	33.0	117.0	178.0	168.0	145.0
Na^+	316.66	16.43	208.33	481.25	493.75	493.75	481.25
K^+	5.0	5.71	4.38	86.15	88.46	83.85	80.77
Li^+	0.5	0.5	0.5	2.33	1.80	1.80	1.60
Ca^{++}	332.94	375.22	169.11	200.82	209.63	207.87	251.91
Mg^{++}	8.46	23.25	11.10	155.37	147.45	155.37	141.63
HCO_3^-	89.80	115.46	42.15	531.48	566.30	531.48	619.45
Fe^{+++}	0	0	0	0	0	0	0
NH_3	2.3	1.15	0.75	2.30	2.30	2.00	2.30
As	0.23	0.2	0.2	0.23	0.38	0.33	0.23
Conductivity μhos/cm^2	1970	1900	1550	2500	3200	2750	2600

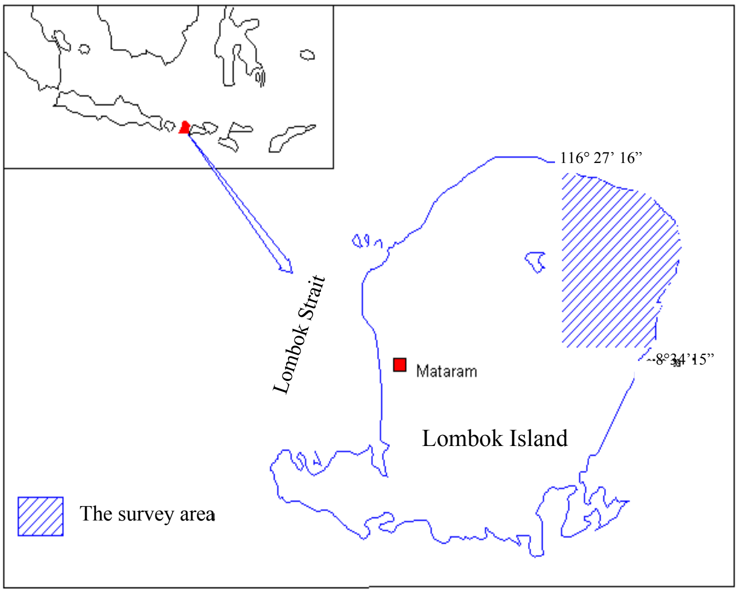

Figure 1: Location map of the survey area

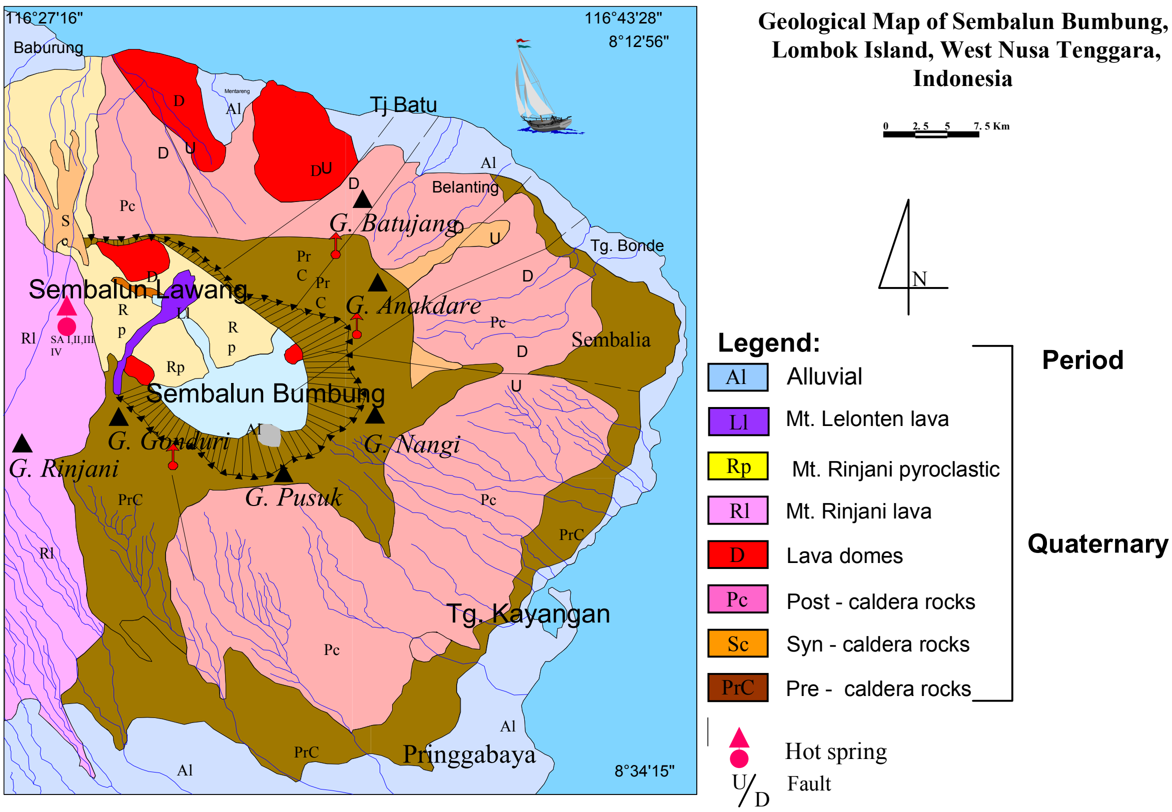

Figure 2: Geological map of the survey area

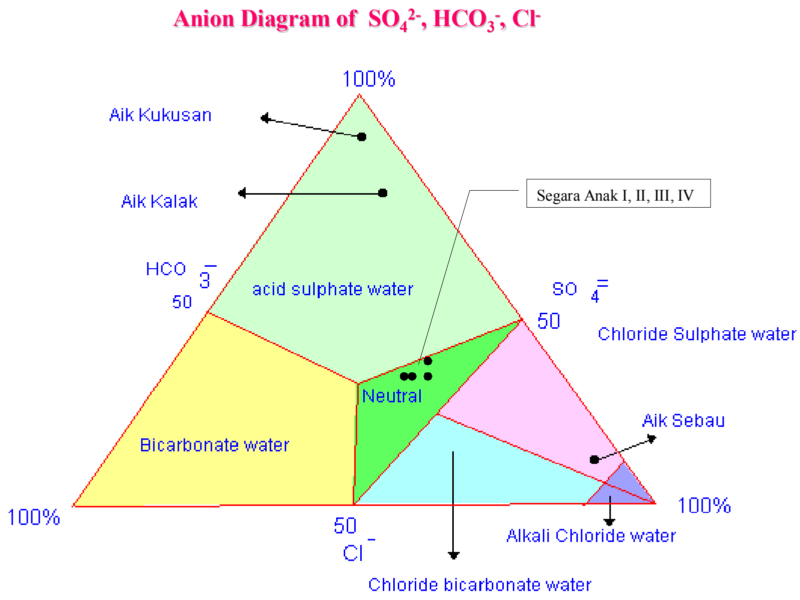

Figure 3: Anion diagram showing hot spring types in the survey area

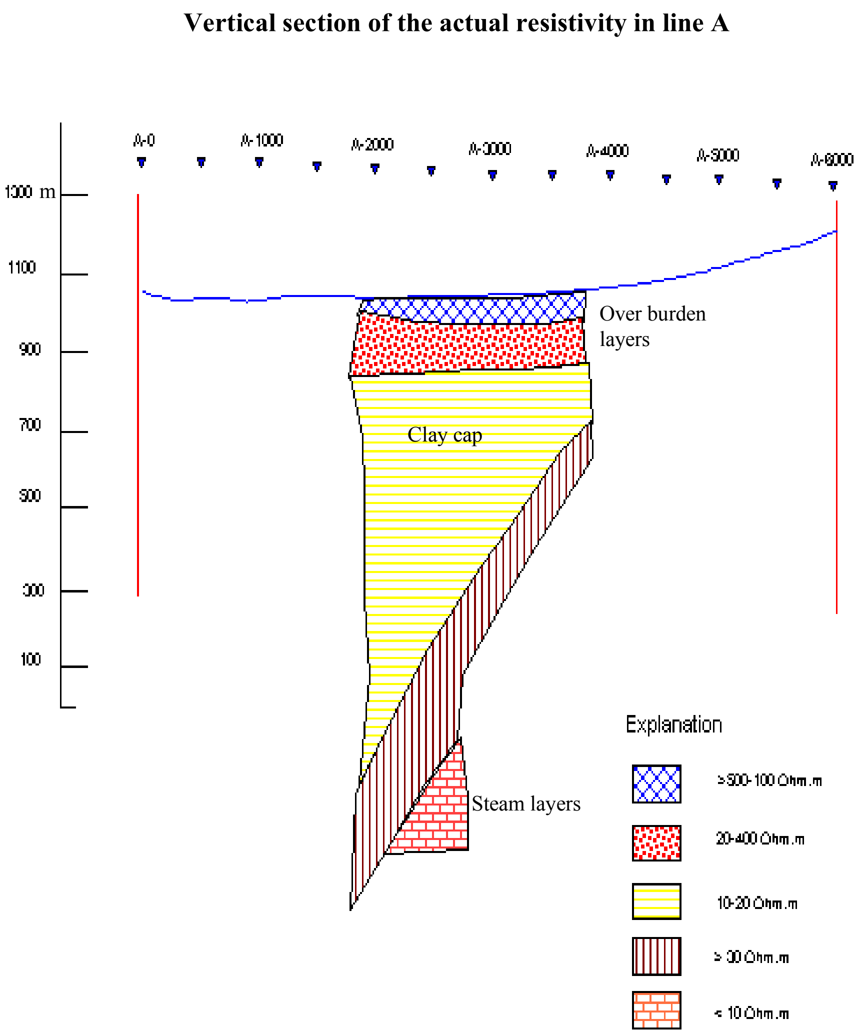

Figure 4. Vertical section of the actual resistivity on line A between points A 2000 and A 4000

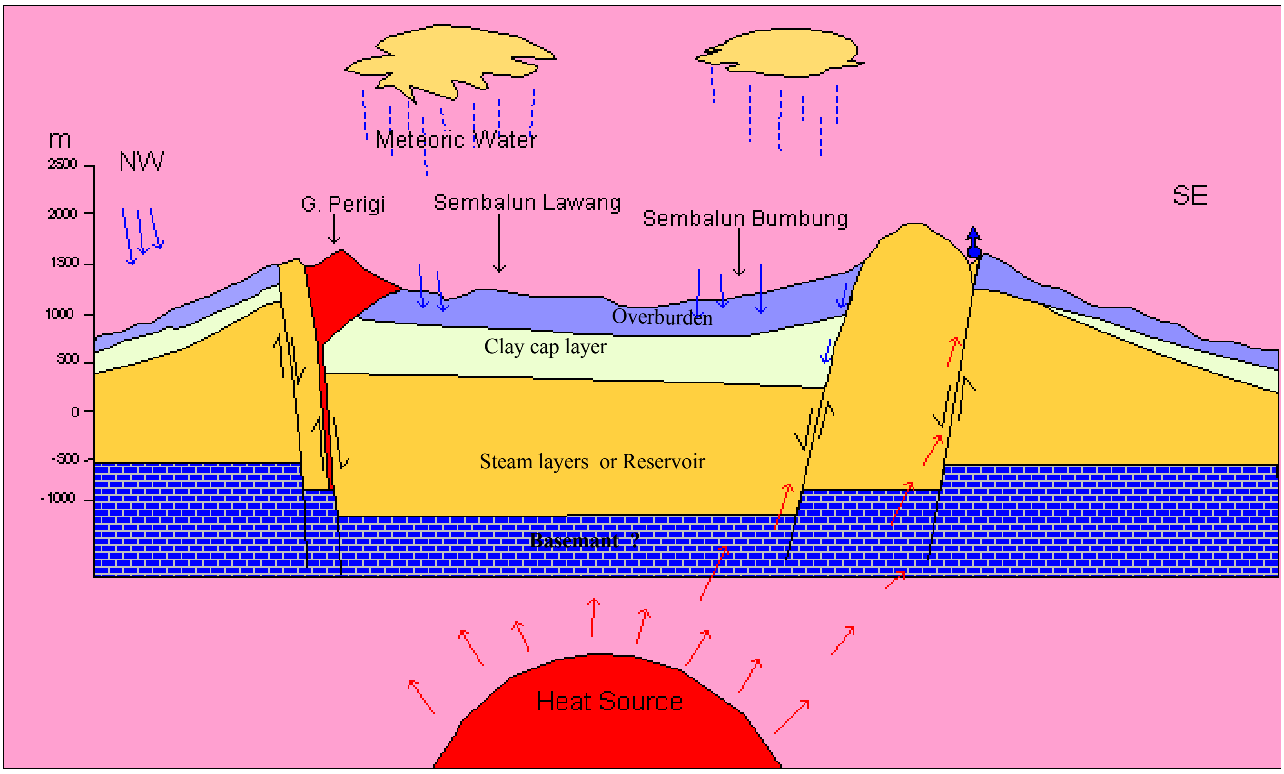

Figure 5: Schematic model of the Sembalun Bumbung area