

# Carbon Dioxide (CO<sub>2</sub>) Survey at Makaroyen Village in Kotamobagu Geothermal Field, North Sulawesi, Indonesia

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## ABSTRACT

Kotamobagu geothermal field is one of the prospects of geothermal development in North Sulawesi, Indonesia. We conducted soil air gas survey in Kotamobagu, mainly within Makaroyen village, on the foot of Ambang Mountain. Concentrations of CO<sub>2</sub> were measured for 20 sampling points in the area of 1.0 km EW and 1.0 km NW with elevation around 1000 m above sea level. High concentrations of CO<sub>2</sub>, 1% to 3.8%, were mainly measured in the center, northeast and east of the study area whereas lower concentrations to the south and to the west. High concentration of CO<sub>2</sub> above 1.0% was detected in the center, northeast and east of the area Makaroyen village. The presence of flow path of high temperature fluid and heat source is expected below the areas with high concentrations of CO<sub>2</sub>.

## 1. INTRODUCTION

Kotamobagu geothermal field lies on the southern slope of Ambang Volcano in North Sulawesi Province, Indonesia, 200 km to the southwest of Manado city, capital of the province. The field has been proved to be one of the geothermal prospects in Indonesia (Hochstein and Sudarman, 2008). PT. Pertamina Geothermal Energy (PT.PGE) has conducted reconnaissance and feasibility studies in Kotamobagu and concluded that the field has high potential for power generation. PT. PGE also conducted a research on environmental impact upon development and issued a document related to the environmental impact, which is one of the requirements by Indonesian government for starting geothermal development project in Kotamobagu.

In geothermal exploration, geochemical methods such as soil air gas surveys have been recognized as an excellent tool to find the locations of subsurface heat source and of faults or fractures that act as pathway for geothermal fluid (Koga, 1984). For example Carbon dioxide (CO<sub>2</sub>), Carbon dioxide (CO<sub>2</sub>) is one of the main volcanic gases. The high concentration of CO<sub>2</sub> in soil air may be attained of magma degassing at depth, and that rises through fractures and faults to the surface.

In this study, we have carried out soil air gas surveys including CO<sub>2</sub>. The area for soil air gas survey mainly lies within Makaroyen village and the area is covered by mainly house of local people and paddy field and wild grassing with elevation around 1000 m above sea level. The area survey is choosing at Makaroyen village because in this area had crossed of fault by direction northeast to southwest. In this area of 1.0 km EW and 1.0 km NW, we measured gas CO<sub>2</sub> concentrations of soil air.

## 2. GEOLOGY

### 2.1 Geological Section

Survey area locates in the Eastern Kotamobagu city mainly lies at Makaroyen village on the slope of Ambang Mountain (Fig. 1). The lithology consist of the Tertiary and the Quaternary rocks. Tertiary sedimentary rocks consist of shale and sandstone with intercalation of limestone and chert, and are overlain by Tertiary and Quaternary volcanic rocks. The Tertiary volcanic rocks are products of Old volcano consisting of breccia, tuff and andesitic lava, dacite and rhyolite. Ambang Volcano and Lake Deposits of Quaternary overlain the Tertiary volcanic rocks in Liberia village. Ambang volcanic unit consists of tuff, agglomerate, lahar, lava, and sulfur deposit within a crater of Ambang volcano. Southern side of Ambang Volcano, Lake Deposits unit consist of grey clay stone, plant remnants and lignite. The survey area partly locates within tuff pumice. Geological map is shown in Fig.2 with cross section and lithologies.

### 2.2 Geological Structure

Fault in Kotamobagu had directions northwest to southwest, northeast to southwest and west to east. Fracture with direction west to east which is crossing the sedimentary rocks controls the appearance of Pusian and Bakan hot springs (PT.PGE, 2005). Fracture with direction northwest to southeast controls the appearance of Lobong hot spring. Fumaroles appearances are controlled by fracture, with direction northeast to southwest (PT.PGE, 2005).

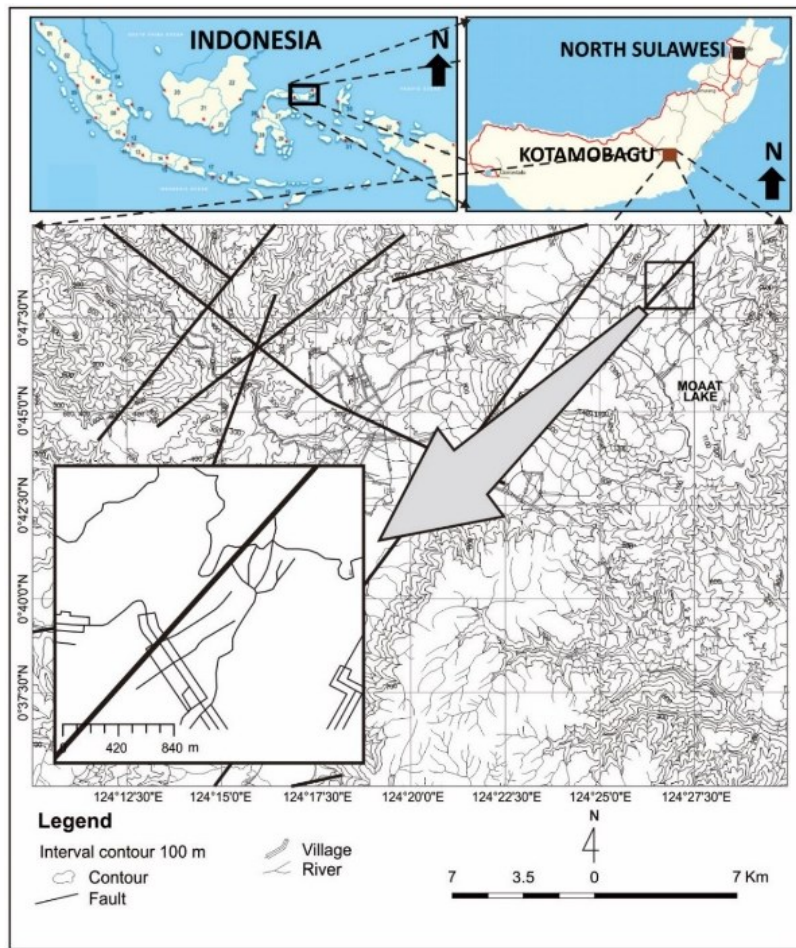


Figure 1: Located of survey

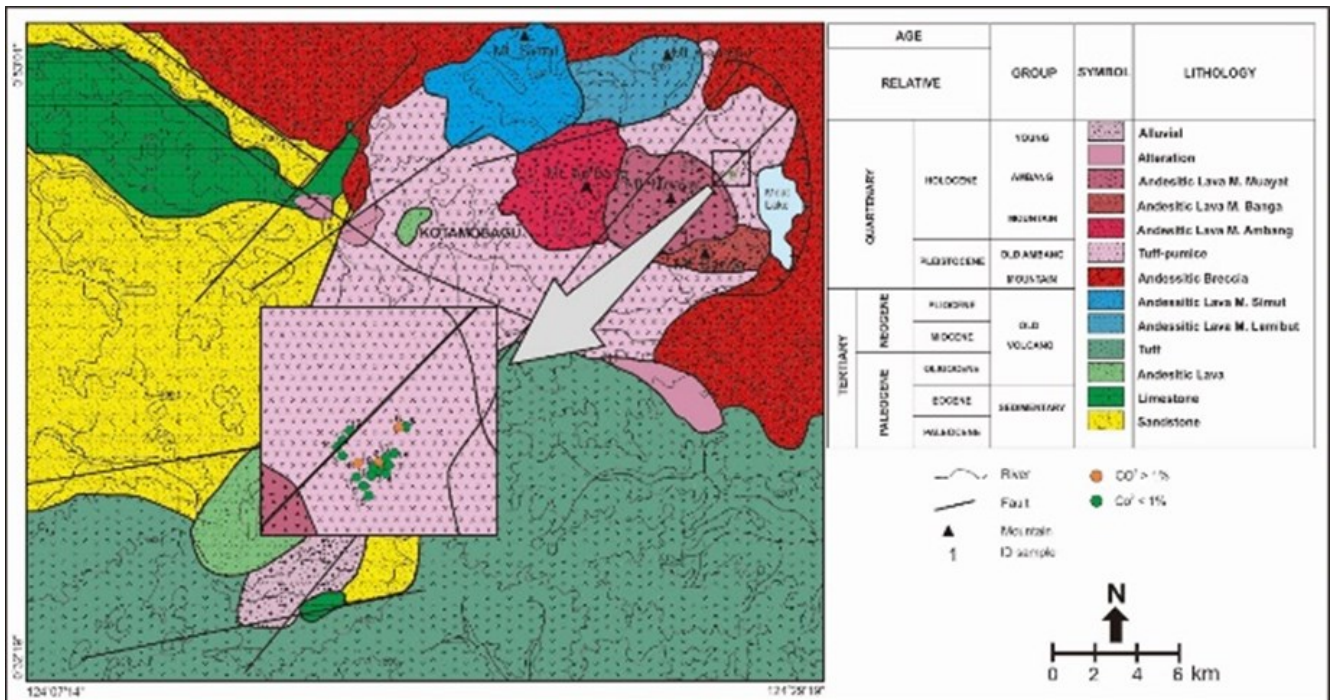


Figure 2: Geological map

### 3. MEASUREMENT METHODS

Survey area locates in the Eastern Kotamobagu city mainly lies at Makaroyen village on the slope of Ambang Mountain (Fig. 1). The lithology consist Soil air gas was measured at 20 points, mainly in Makaroyen village (Fig.1). The measurements were made at intervals from 50 to 200 m. Concentration of CO<sub>2</sub> was measured at each point where the hole of 60 cm depth and 5 cm diameter was made by hammering steel pipe into the ground. Immediately after pulling out the pipe, soil air in the hole was taken with the plastic syringe and 100 ml of air was sent through a gas detector tube (Komyo-Kitagawa instruments Co Ltd.) that was set between the syringe and a tube for taking the air. A gas detector tube for concentration range 0.05-2.6% was first. However, a tube for 0.5-10% was used where CO<sub>2</sub> concentration is higher than 2.6%.

### 4. RESULTS AND DISCUSSION

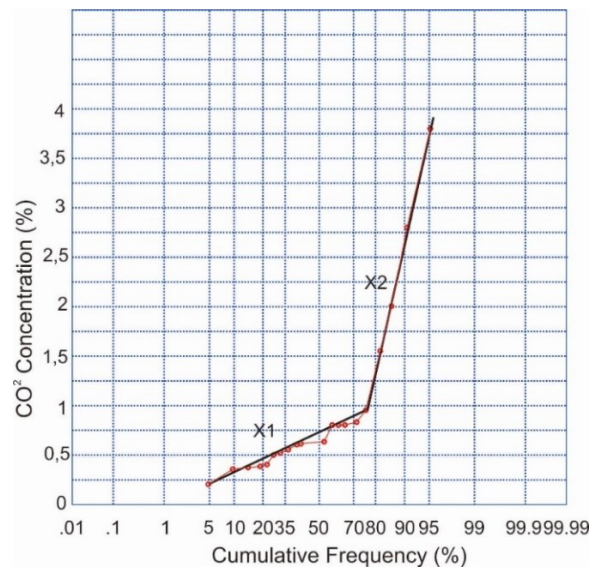
Results of CO<sub>2</sub> survey are summarized in Table 1 and Figures 2 and 4.

**Table 1: CO<sub>2</sub> concentrations (%)**

ID Sample	North Coordinate			East Coordinate				CO <sub>2</sub> (%)	
1	0	48	9.4	0.803	124	26	56.3	124.449	2.80
2	0	48	9.4	0.803	124	26	56.3	124.449	3.80
3	0	48	10.9	0.803	124	26	55.4	124.449	0.37
4	0	48	8.2	0.802	124	26	55.3	124.449	0.8
5	0	48	7.2	0.802	124	26	57.7	124.449	0.4
6	0	48	22.4	0.806	124	27	4.2	124.451	2
7	0	48	22.1	0.806	124	27	1.9	124.451	0.60
8	0	48	18	0.805	124	26	44	124.446	1.55
9	0	48	10.5	0.803	124	26	48.8	124.447	0.8
10	0	48	3.2	0.801	124	26	50.6	124.447	0.38
11	0	48	6.4	0.802	124	26	53	124.448	0.95
12	0	48	6	0.802	124	26	48.3	124.447	0.83
13	0	48	21	0.806	124	26	46.2	124.446	0.35
14	0	48	12.9	0.804	124	26	43.9	124.446	0.80
15	0	48	15.7	0.804	124	26	42.1	124.445	0.63
16	0	48	0.1	0.800	124	26	52.2	124.448	0.52
17	0	48	12.4	0.803	124	26	57.7	124.449	0.61
18	0	48	9.9	0.803	124	26	58.6	124.450	0.50
19	0	48	13.7	0.804	124	27	0.40	124.450	0.20
20	0	48	9	0.803	124	26	53.6	124.448	0.55

The CO<sub>2</sub> data are plotted for cumulative frequency and concentrations in Figure 3. As shown in the figure, the data can be divided into two groups and are approximated by three straight lines in the two ranges below 1% and above 1%. This suggests that two populations of CO<sub>2</sub> present in the field. Figure 2 and 4 shows concentration distribution of CO<sub>2</sub>. The concentrations of CO<sub>2</sub> range from 0.2% to 3.8%. Figure 2 and 4 shows CO<sub>2</sub> concentration distribution with circles of different colour that represents two concentration groups. High concentrations of CO<sub>2</sub> with range from 1% to 3.8% were measured mainly in the center, east and northeast of the area (samples 1, 2, 6 and 8) and relatively low concentration in the northwest and the south (samples 3, 4, 5, 7, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20).

Concentrations of CO<sub>2</sub> shown in Fig. 3 as below:



**Figure 3: CO<sub>2</sub> concentrations (%)**

Concentrations of CO<sub>2</sub>, were measured for 20 sampling points in the area of 1.0 km EW and 1.0 km NW. High concentrations of CO<sub>2</sub>, 1% to 3.8%, were mainly measured in the centre, northeast and east of the study area. Concentrations of CO<sub>2</sub>, below of 1%, were measured in the south and northwest of study area.

High concentration of CO<sub>2</sub> above 1.0% was detected in the centre, northeast and east of the area Makaroyen village. The presence of flow path of high temperature fluid and heat source is expected below the areas with high concentrations of CO<sub>2</sub>.

## 5. CONCLUSION

Soil air gas survey was conducted at 20 points at Makaroyen village in the Kotamobagu geothermal field, North Sulawesi Indonesia. High concentrations CO<sub>2</sub> were detected in the centre, northeast and east of the survey area. This implies the presence of high temperature heat source or a flow path of high temperature fluid below this area.

## 6. ACKNOWLEDGMENTS

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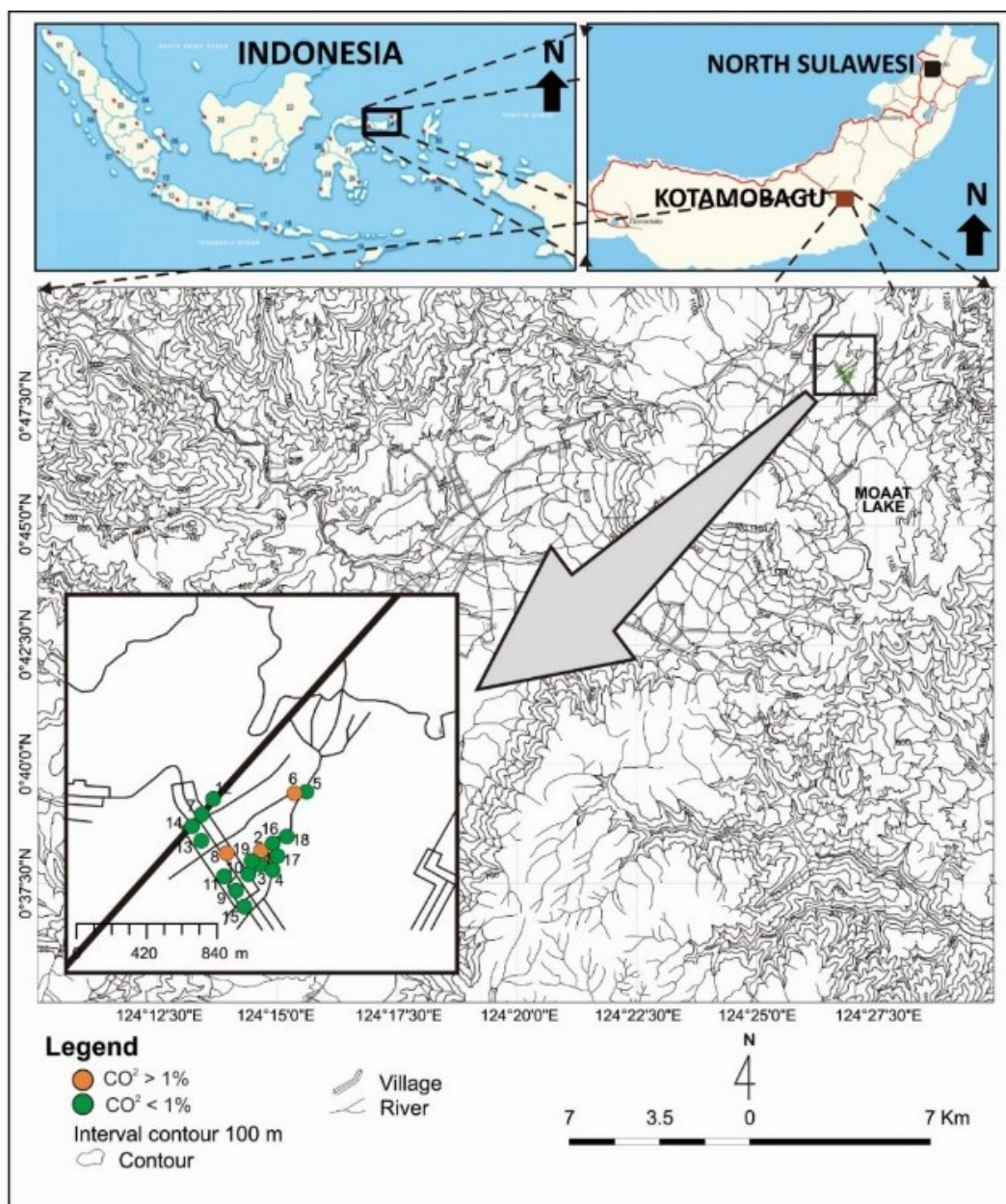


Figure 4: Sampling point of soil air gas in Kotamobagu.