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RADON AND THORON MAPPING TO DELINEATE THE LOCAL-FAULT IN THE WAY RATAI GEOTHERMAL FIELD LAMPUNG INDONESIA Nandi Haerudin<sup>1</sup>, Karyanto<sup>1</sup> and Yudi Kuntoro<sup>2</sup> <sup>1</sup>Department of Geophysical Engineering, Faculty of Engineering, University of Lampung, Indonesia <sup>2</sup>Research and Development Center for Oil and Gas "LEMIGAS", Indonesia E-Mail: [nandi.haerudin@eng.unila.ac.id](mailto:nandi.haerudin@eng.unila.ac.id) ABSTRACT The Survey in the area of geothermal Way Ratai Lampung has been conducted to measure the concentration of Radon and Thoron. The Radon detector RAD 7 used to get field data. The measurement points are 70 stations. These were taken with 200 m - 400 m spacing stations which cover an area of 10 km<sup>2</sup>. Study area covered four hot spring geothermal manifestations namely Bambu Kuning, Padok, Margodadi and Way Asin. The aim of this study is to determine the local fault based on the profile of Radon concentration. The observation data were taken in 15 minutes for each station measurement to obtain the value of the Radon concentration accurately. After the Radon concentration values are obtained, it made a contour map. The peaks of contour were connected by a line to get the delineation of the local fault. The result showed three lineament anomalies through geothermal manifestations that indicating as the local fault, namely F1, F2, and F3. The first delineation fault (F1) connected Bambu Kuning and Margodadi hot springs in the northwest to southeast direction. The second (F2) connected Padok and Way Asin hot springs in the southwest to northeast directions. The third (F3) passed Margodadi hot spring in the same direction with F2. Based on the Radon to Thoron ratio, F1 and F2 were suggested as the fault that extends to depth.

Both are suggested as the conduit of geothermal fluid. Keywords: radon measurement, delineation, high permeability, fault. INTRODUCTION Indonesia is the country with the largest geothermal reserves in the world. This country has approximately 29.163 GW or 40% of the world's geothermal reserves. **7 More than 200 geothermal systems with significant active surface manifestations occur throughout Indonesia** [1]. The geothermal system in Indonesia is generally a volcanic hydrothermal system in the area of high elevation or high terrain occurs with Quaternary volcanism [2,3]. The Pesawaran volcano is located in the southern part of Sumatera Island, Indonesia. Its area is cut by Sesar Menanga. The direction of Sesar Menanga is parallel with the major structure of Sumatra, i.e. Semangko Fault, trending northwest-southeast. (Figure-1), Way Ratai geothermal field located in the southern part of The Pesawaran volcano and is an undeveloped geothermal prospect. The study area is located in Padang Cermin SubDistrict of Pesawaran District, Lampung Province, Indonesia. It is approximately 40 km southwest of Bandar Lampung, the city of Lampung Province. The Way Ratai geothermal field is identified by five manifestations in the form of hot springs. Table-1 showed characteristics of manifestation. Temperature geothermal reservoir estimated 275o C - 350o C. Based on geological observations, in this area was found a few outcrops of rock that have undergone a change. Most hot springs produce precipitated silica sinter. Deployment of broad manifestation is identified by the discovery of stone and vegetation suffered liquefaction degeneration [4]. A research in the geothermal Way Ratai has conducted to map the sources of hot water by using MiseA-La-Masse [5]. This study, carried out measurements at two local craters namely Magrodadi A and Margodadi B which has a lower elevation. From the results obtained that hot water from the crater Margodadi A is not connected to the crater Margodadi B underneath. This is corroborated by the results of imaging subsurface geothermal area Way Ratai with two-dimensional resistivity method [6]. Then a study about temperature slope vertically and horizontally was conducted in 2013 [7]. Figure-1. Regional geological map of Gunung Pesawaran Ratai Based on the result, horizontal temperature mapping, the high temperature about 61o C spread

throughout on the center of the study area, generally adjacent to the geothermal manifestations. Based on the map of vertical temperature slope, it could be concluded that temperature is getting bigger proportional to the depth. This is an initial indication that the vertical temperature slope is positive and predicted as geothermal prospect area. Tabel-1. Characteristic of Manifestation in Way Ratai. The geothermal manifestations were controlled by structures that were formed in the high permeability zone i.e. fault or fracture. The fracture serves as a channel of geothermal fluid migrating from its source in the reservoir up to the surface which appears to be manifestations of geothermal. Sometimes the fault is buried under an overburden layer. 1 In the study area, no local fault that control of geothermal manifestations is described in the Geology regional map. The faults could be buried by an overburden layer. A detailed description of the fault (local and regional fault) is very important in the geothermal exploration for the success of drilling. Based on this problem, the aim of this study is to determine the high permeability zone and local fault that controls the appearance of the manifestation in the Way Ratai geothermal by analysis of concentration Radon in soil gas. No study in the Way Ratai geothermal was reported in an international and track-able journal. It is also to be a consideration to write this paper. METHOD We used Radon Survey in this study. Radon Survey in geothermal area is a Geochemistry tool [8]. The Elements Radon has three isotopes that often occur in nature, i.e. 222-Rn (radon), 220-Rn (Thoron) and 219-Rn (Action). Radon 5 has a half-life time of 3825 days, Thoron has a half-life of 54.5 seconds, and action has a half-life of 4 seconds. This survey measured only 11 Radon and Thoron. The Radon and Thoron concentration was measured with Alpha detector RAD 7 from Durridge. First, 12 the probe is inserted into the soil to a minimum depth of 70 cm, to avoid the influence of the atmospheric effect such as humidity, temperature, and wind. Soil

gas under the surface was sucked to the detector electrically, **2** replacing the air in the detection cell. Before reaching the detector, soil gas is filtered and passed into the desiccant tube so that water vapor and other particles do not come inside. The Radon concentration was measured by an alpha scintillation Radon counter when the soil gas trough a scintillation chamber and calculated it in 15 minutes. The Radon and Thoron concentrations are classified into three categories, namely low, high, and anomaly based on the statistical approach using the geometric mean and standard deviation parameters [9]. Geometric mean ( $\bar{r}$ ) reads at the 50th percentile, and standard deviation ( $\sigma$ ) described **1** the distribution of data. Low values of Radon concentration regard as a background value, while the Radon anomaly value is used to delineate the fault lineament. The contour maps of concentration Radon, Thoron, and 'Radon to Thoron ratio', were created using Kriging interpolation to determine the location of anomalies. They are usually characterized by peaks of closed contours. These peaks are connected by a line to get the local fault trends. The Radon concentration and the ratio Radon to Thoron is compared and analyzed.

## RESULT AND DISCUSSION

**2** A total of 70 measurement points was taken with spacious 200 m - 400 m which covers an area of 10 km<sup>2</sup>. Station measurement covered for four geothermal manifestations namely Bambu Kuning, Padok, Margodadi and Way Asin hot spring (Figure-2). No station **1** carried out in the Kali Tiga hot spring. The nearest station is about 150 m distance. Anomalous of radon concentrations ( $<12\ 803\ \text{Bq/m}^3$ ) was founded around manifestation Bambu Kuning, Padok, Margodadi and Asin Way. There are the anomalous areas which are distant of manifestation in the northwest and southwest of the study area. Figure-2. Contour map of Radon concentration and distribution of station measurement in the Way Ratai geothermal field. Soil gas classification data listed in the Table 2. **2** The results of Radon (Rn) concentration values are from 267 Bq/m<sup>3</sup> to 25700 Bq/m<sup>3</sup> and Thoron (Tn) values are from 100 Bq/m<sup>3</sup> to 59000 Bq/m<sup>3</sup>. Low concentration values are less than 6378 Bq/m<sup>3</sup> for Radon and less than 14685 Bq/m<sup>3</sup> for Thoron. This value **1** is considered as the value of the background. The anomalous values are more than 12806 Bq/m<sup>3</sup> for Radon and more than 30211 Bq/m<sup>3</sup>

for Thoron. The Thoron maximum value is greater than the Radon maximum value. This showed that the top layer is a rock <sup>1</sup> that has a high porosity and permeability in the form alluvium and Tuff. This value is greater than a Radon <sup>4</sup> survey in the nearest geothermal area i.e. Rajabasa. The results of Radon measurements in the Rajabasa geothermal area are from 311 Bq/m<sup>3</sup> until 17750 Bq/m<sup>3</sup>, while Thoron are from 0 Bq/m<sup>3</sup> until 8133 Bq/m<sup>3</sup> [10]. To characterize <sup>2</sup> the study area, the spatial distribution of soil gas data was interpreted using contour maps. The observation data are presented on contour maps with Kriging method provided by Surfer 10. In the contour map of Radon concentrations, there are three lines that connected Radon anomaly. The first (F1) is trending from northwest to southeast through Bambu Kuning and Margodadi hot spring, the second (F2) is trending from southwest - northeast connect three manifestations that are Kali Tiga, Padok and Way Asin hot spring, and the third is trending from southwest - northeast through Margodadi hot spring (Figure-3). The local fault F1 is parallel to the Sesar Menanga regional fault. Table-2. Soil gas classification for observation data. The values of Radon anomaly indicated high permeability zone where Radon quickly migrates <sup>1</sup> to the surface before decaying into daughter products and it can be calculated by the device of the detector [11,12,13]. The existence of fault supporting gas transportation because it increases the permeability of rock and to be the geothermal fluid channels that migrating to the surface. A velocity of geothermal fluid migrating from the reservoir to surface also depends on other factors, including the level of cracking and porosity of the rock. The level of rock's cracking is the more dominant factor to be a geothermal fluid channel. The peak value of <sup>2</sup> the concentration of radon shows the area of geothermal conduits. As we discussed in the introduction, geothermal Way Ratai Regions have not the outcrop at the surface that indicate the presence of a fault. Delineation of high radon anomaly <sup>1</sup> in this area proves

that the Radon method can detect the buried fault under overburden layer as reported [14]. Figure-3. Delineation of local fault based on Radon concentration map. Thoron contour map illustrated in Figure-4. Thoron has a short half-life of 54.5 s, so that the concentration decreases rapidly when it migrate to the surface. The measurable Thoron values come from the shallow layer. A zone with high Thoron values ( $> 14\ 685\ \text{Bq/m}^3$ ) describes the shallow layer with high porosity. This area is thought to be the area in the form of a thick sedimentary Tuff. This zone is located in the southwestern part of the study area. In other side, Radon has a half-life of 3.825 days and can be transported in a fracture for a considerable distance. Figure-4. Delineation of high Thoron concentration. To detect the presence of faults or fracture system that connecting surface to the depth, is used by the anomaly of Radon to Thoron ratio. The Radon from the depth contains less Thoron and has high value of 'Radon to Thoron ratio'. The Radon concentration map compared with the Radon to Thoron ratio map as shown in Figure 5. The values of anomalous Radon and Radon ratio to Thoron used to determine the local fault that penetrates to the depths. There are two lineaments that determined on this map, namely f1 and f2. Line f1 is similar to F1 and f2 is similar to F2. It's located in a zone bounded by Bambu

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4807 Kuning, Padok, Margodadi and Way Asin hot spring. No line is similar to F3. So, it is interpreted as a shallow fault. Figure-6 showed fault lineaments located on a geological map. The lineament F1 is parallel with Menanga regional fault (sesar Menanga), but F2 is perpendicular to it. The lineament F1 is suspected as the main fault that controlled the geothermal system of Way Ratai. To strengthen these results, it needs to calculate the length and direction of topographic lineament using the Ross diagram. To researchers who want to continue this study, we list data of measurements of Radon and Thoron in the

Way Ratai **geothermal field in** Table-3. CONCLUSIONS The Radon concentration map shown three lineament anomalies that indicating as the local fault. The first (F1) is trending from northwest to southeast trough Bambu Kuning and Margodadi hot spring, the second (F2) is trending from southwest - northeast connect three manifestations that are Kali Tiga, Padok and Way Asin hot spring, and the third (F3) is trending from southwest - northeast through Margodadi hot spring. **2** **Based on the** contour map **of Radon and Thoron** concentration ratio, the fault which is being main channel fluid from reservoir migrated to surface **located in a** zone bounded by Bambu Kuning, Padok, Margodadi and Way Asin hot spring. Table-2(a). Results of measurements of radon and thoron in the geothermal area Way Ratai.

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4808 Table-2(b). Results of measurements **of radon and thoron in the geothermal area** Way Ratai (continued).

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4809 Figure-5. Contour Map of Radon concentration and Radon to Thoron Ratio (F1 = f1; F2 = f2). Figure-6. The local fault (blue dash line) that control manifestations **1** **of Way**

**Ratai geothermal field.** REFERENCES [1] Phuong N. K., Harijoko A., Itoi R., and Unoki Y.

2012. **2** **Journal of Volcanology and Geothermal Research.** 229–230: 23–33. [2] Sudarman

S., Suroto, Pudyastuti K., Aspiyo S. 2000. Geothermal development progress in Indonesia: country update 1995–2000. Proceedings of the WGC 2000, Japan. pp. 455–460. [3]

Hochstein M.P., Sudarman S. **9** **2008. History of geothermal exploration in Indonesia from 1970 to 2000.** Geothermics. 37: 220–266. [4] Suharno, Amukti R., Hidayatika A., and Putroi



M. K. 2015. Geothermal Prospect of Padang Cermin Pesawaran Lampung Province, Indonesia. <sup>10</sup> *Proceedings World Geothermal Congress 2015, Melbourne, Australia*. 19-25 April. [5] Karyanto. 2002. Mapping Deployment Hot Springs in Region Geothermal Way Ratai, Lampung with MiseA-La-Masse Method, *Jurnal Sains dan Teknologi, FMIPA Unila*, 8(2): 81-86. [6] Karyanto. 2003. Subsurface Imaging Regional The Geothermal Way Ratai Lampung by 2 Dimensional Resistivity Method, *Jurnal Sains dan Teknologi, FMIPA Unila*, 9(3): 20-26. [7] Karyanto and Haerudin N. 2013. A Qualitative Interpretation of Surface Temperature on Geothermal Way Ratai Lampung. Seminar Nasional SATEK V 19 – 20 November, Bandar Lampung. [8] J. E. Gingrich. 1984. <sup>2</sup> *Journal of Geochemical Exploration*. 21: 19-39. [9] R.W. Klusman. 1993. <sup>13</sup> *Gas and Related Methods for Natural Resource Exploration*, England. John Wiley & Son Ltd. pp. 483. [10] Haerudin, N., Wahyudi and Suryanto, W. 2013. Radon and Thoron Analysis of Soil Gas Survey Case Study of Rajabasa Geothermal Field. AIP Proceeding conference, USA. 1554: 218-221. [11] <sup>6</sup> Ioannides K., Papachristodoulou C., Stamoulis K., Karamanis D., Pavlides S., Hatzipetros A., and Karakala E. 2003. *Applied Radiation and Isotopes*. 59 (2-3): 205–213. [12] Swakon J., Kozak K., Paszkowski M., Gradzin'ski R., Loskiewicz J., Mazur J., Janik M., Bogacz J., Horwacik T., and Olko P. 2004. *Journal of Environmental Radioactivity*. 78(2): 137 – 149. [13] Jönsson G. 1995. *Radiation Measurements*. 25(1-4): 537-546. [14] <sup>14</sup> Fu C. C., Walia Y. F., and Chen C. H. 2005. *Geochemical Journal*. 39: 427-439.

## Sources

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