RADIATION MEASUREMENT OF RADIOISOTOPE IN MINERAL DEPOSIT AT SUBDISTRICT OF MIDDLE KUPANG WEST TIMOR ISLAND INDONESIA

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Abstract

The general objective of this work was investigation of radioisotope distribution and accumulation center in mineral deposit at sub-district of Middle Kupang West Timor Island Indonesia. The purposes of research were: to map of radioisotope distribution in the mineral deposit, to estimate area of radioisotope accumulation center in the mineral deposit, to establish range of nuclear radiation counts in the center region of radioisotope content in mineral deposit. The general methods used in this research were observation, survey, mapping, analysis, and interpretation. Procedures detail of research consists of: observe and identify the potential region and plot gridding, calibrate equipment necessary, measure background count in around of survey location and nuclear radiation in the survey location, plot of three dimensions curve and contour after corrected by background count. Based on geology information or geology data (drilling data) three depth levels determined (about 20 m, 40 m and 60 m), Radiation powers were calculated for estimation of accumulation center of radioisotope in deposit mineral, and contour and three dimensions curves of radiation power of radioisotope in deposit mineral were plotted. Results: Based on three dimensional curves and contour map (radiation counts and radiation powers on three levels) of radioisotope in mineral deposit respectively was distributed on area 3.00 x 10^6 m^2, and 1.56 x 10^4 m^2. The interval of radiation counts of radioisotope in mineral deposit was 10 counts per minute-137 counts per minute.

Keywords: Radiation, measurement, radioisotope, mineral, deposit

Introduction

The position of Timor Island was approximately located on 8°-11° south latitude and 123° -126° east longitude in East Nusa Tenggara Indonesia. The region of Timor Island was rich with any kinds of mining mineral like as natural gas, petroleum, geothermal, iron, coal, and tin/ lead (A group minerals), aluminum, gold, silver, nickel, copper, manganese, and radioisotope (B group minerals), limestone, sulfur, barite, gypsum, marble, granite, and dolomite (C group minerals).

Pre survey gives result that radiation counts and specific activities range of radioisotope in deposit mineral at sub-district of middle Kupang respectively was 32 counts per minute up to 138 counts per minutes and 1.4 x 10^5 μCi - 6.20 x10^4 μCi [1]. Radioisotope content in mineral deposit at these regions was estimated since formed of Timor Island. The forming of Timor Island was resulted of uplift caused by collision between Banda Arc and Continental Australian Shelf on processing of tectonic [2]. Audley-Charles et a l (1972)[3], Gageonnet et al (1958) [4], and Grunau (1953, 1957) [5,6] suggest that rocks association and structure in the Timor Island were originally uplift a part of Continental Australian Shelf deformation, and others masses enclosed up to cover of all rocks in Timor Island [2]. From this case can be proposed that radioisotope in mineral deposit in Timor Island was directly involved with earth material that came from continental Australian Shelf.

Radioisotope was an energy source on Electric Generator of Nuclear Power. It reasons that energy source prom petroleum was more decrease on future time. These planning has been begun on 1997 which to be developed in Indonesia located at Jepara Middle Java.
The main problem investigated in the research was accumulation center and distribution of radioisotope in mineral deposit. The specification of problems inspected were: distribution of radioisotope in mineral deposit in west Timor Island, estimation of accumulation center of radioisotope in deposit mineral, and counts range of nuclear radiation at the center region of radioisotope.

The general purpose of research was to investigation distribution and accumulation center of radioisotope in mineral deposit at Middle Kupang West Timor Island as a basic consideration for exploration and environment mapping. The specific purpose of research consists of: map distribution of radioisotope in mineral deposit, estimate area of accumulation center of radioisotope in mineral deposit, and establish range of nuclear radiation at the center region of radioisotope in mineral deposit.

There were two steps on radiometric survey that was observation step and field survey step. On observation step was done identification of regions that potentially content of radioisotope, and then to identify several locations which were estimated the most potential for survey location [7–9]. Fields survey of nuclear radiation started on local survey appropriate to survey location which have been chosen, and then expanded for regional mapping.

Field survey (nuclear radiation) was started on local survey appropriate with location potential which have been chosen, and then expanded for regional mapping. Local survey was proposed to accurately identify distribution anomaly of radioisotope in mineral deposit. The region area for local survey was only several kilometers square [7,10]. Radiometric survey on local state can be done on foot with using Geiger Muller portable detector. Radiation counts in units counter per minute. This equipment can detect total counts (alpha, beta, and gamma radiation) from radioisotope sources. Gamma radiation was an electromagnetic wave in order that it was easy to be measured. Radioisotope radiation can be detected on 100 feet distance (approximately was 30 meters) above source surface with using airborne survey [10].

Measurement of radiation count can be done based on measure point on each line (grid) which have been planned to obtain the best mapping on survey location. Actually, measurement of radiation count on radiometric survey can be done randomly [10]. Radiometric local survey can be expanded for regional mapping, and can be continuous expanded for more area of region that adjusts with the area of potential region. Target reconstruction of rock mineral can be predicted based on profile of content anomaly of radioisotope in mineral deposit, in generally appropriate with magnetic anomaly profile of rock [11,12]. For dry region and relatively homogeneous rock structure, content anomaly profile of radioisotope in mineral deposit, in generally appropriate with temperature anomaly profile which produced by decay of radioisotope.

If content of radioisotope in mineral deposit was Uranium mineral with composition U₃O₈, standard classification characteristics for ore deposit quality (ore grade deposit) were low if < 0.15% U₃O₈, middle: 0.15% up to 0.50% U₃O₈, and high if > 0.50% U₃O₈ [13].

Material and Methods

Material Studied

The main instruments (Laboratory of nuclear Physics Faculty of Sciences and Technology Nusa Cendana University) used in this research consist of Portable Geiger Muller Counter, GPS, Computer with Surfer 11 and MATLAB software, and others add equipment.

Methods

The methods were used in the research comprises of observation/surveying, mapping, analysis, and interpretation. Detail procedures of research as follow: 1) prepare and calibrate Geiger Muller counter with using Cs-137 standard on energy 662 keV. The Geiger Muller Counter calibrated on count about 1050 counts per minute, 2) observe for determining measurement points and measurement lines (gridding), 3) measure background counts around field survey to correct of field data, 4) measure count of radioisotope in mineral deposit, 5) contour and three dimensional curves of radioisotope content in mineral deposit plot (Fig. 5 and Fig. 6), 6) plot profile curve based on contour slice for geometry modeling to calculate radiation power (Fig. 7), 7) calculate radiation power of radioisotope content in mineral deposit with using MATLAB program and matrix.
distribution and accumulation of radioisotope in mineral deposit was estimated with plotting profile curve and contour of modeling. The target modeling of radioisotope content was cleared with to paint profile of contour slice on several directions. Target modeling was done with earlier or previous to estimate the depth of radioisotope content based on geology information. The average depth of radioisotope content in mineral deposit estimated 20 m (previously geology information). Furthermore, to calculate radiation power (P keV/s) may be in mutual accord with profile of field data. In this case used MATLAB program and source point model. The calculation of radiation power was taken three layers of rock mineral with depth respectively 20 m, 40 m, and 60 m. The distance of measurement points in the research location was 85 m and distance of measurement lines was 400 m. The distance of measurement points in the center region of deposit was 10 m and the distance of measurement lines was 40 m. The area of research location was 6.3 x 10^6 m^2 (2,000 m x 3,150 m) and the area of center region of mineral deposit was estimated 6.0 x 10^4 m^2.

**Statistical Calculation**

Estimation of distribution and accumulation of radioisotope in deposit mineral was based on plotting of contour and three dimensions curves from calculation result of radiation power of radioisotope radiation. Radiation powers of radioisotope were calculated with previously estimating the depth of radioisotope content in mineral deposit based on geology information (drilling data). The average depth of radioisotope content in mineral deposit was estimated 20 m (previously geology information). Furthermore, to calculate radiation power (P keV/s) used MATLAB program and taken three layers of mineral deposit with depth respectively 20 m, 40 m, and 60 m. The construction of ore deposit anomaly of radioisotope was estimated with using the principal that nuclear radiation of radioisotope source emitted to all directions. Furthermore, the construction form consists of a small ball. Accumulation of radioisotope in mineral deposit was shown by the unions of all small balls. For calculating of radiation power of radioisotope in mineral deposit was began with plotting profile curve from contour slice of radiation counts (Fig. 4). The depth of ore deposit of radioisotope can be determined by using equation:

\[ d = F \left( \frac{X_{1/2}}{2} \right) \] ..............................(1)

Where: \( d \) is the depth of ore deposit, \( X_{1/2} \) is half value of \( X \) maximum anomaly profile of ore deposit, \( F \) are geometry factors. \( F = 1.990 \) for ball, and \( F = 1.000 \) for infinite [11].

Radiation power calculated with using several geometry mathematic models (Fig. 1 for one dimension, Fig. 3 for three dimensions):

\[ P = I_o \left( 4\pi r_o^2 e^{\mu r_o} \right) \] .................................(2)

\[ P = I_n \left( 4\pi r_n^2 e^{\mu r_n} \right) = I_n \left[ 4\pi (r_n^2 + x_n^2) \right] e^{\mu r_n} \] .................................(3)

![Figure 1. Geometry model calculates radiation power on elevation or altitude correction](image1)

![Figure 2. Geometry model calculates power on topography correction](image2)
Where: \( r = \sqrt{r_o^2 + x_1^2} \) and \( r_n = \sqrt{r_o^2 + x_n^2} \)

If region with topography was not flat, topography correction use geometry model on Fig. 2.

\[
P = I_o (4\pi r^2 e^{\mu r})
\]

where: \( d = r = r_o + d_i \), \( d_i \) and \( d_o \) is measured with altimeter, \( r_n = r + r_d \)

\[
P = I_n (4\pi r_n^2 e^{\mu r_n})
\]

\[
(r_d + r_i)^2 = \left[(x_n + x_p)^2 + (r_o + d_n)^2\right]
\]

\[
P = I_n [4\pi (x_n + x_p)^2 + (r_o + d_n)^2] e^{\mu r_n}
\]

\[
P = I_o (4\pi r_o^2 e^{\mu r_o})
\]

\[
P = I_n (4\pi r_n^2 e^{\mu r_n}) = 4\pi I_n (r_o^2 + x_n^2) e^{\mu r_n}
\]

\[
P = I_{do} (4\pi r_{do}^2 e^{\mu r_{do}}) = 4\pi I_{do} (r_o^2 + y_n^2) e^{\mu r_{do}}
\]

\[
P = I_{dn} (4\pi r_{dn}^2 e^{\mu r_{dn}}) = 4\pi I_{dn} (r_o^2 + D_n^2) e^{\mu r_{dn}} = 4\pi I_{dn} [(r_o^2 + D_n^2) e^{\mu r_{dn}}]
\]

Where: \( r_{do}^2 = r_o^2 + y_n^2 \), \( r_{dn}^2 = r_o^2 + D_n^2 \), \( D_n^2 = y_n^2 + x_n^2 \), \( r_{do}^2 = r_o^2 + x_n^2 \), \( r_{dn}^2 = r_o^2 + D_n^2 \), \( r_n^2 = d^2 + x_n^2 \)

For determining of radiation power decided several points (for example 10 points) on the profile of field data with certain counts (Fig. 4). \( P \) was calculated by using matrix MATLAB program, \( P \) can be calculated by matrix formula:

\[
\begin{bmatrix}
P_1 \\
P_2 \\
. \\
P_n
\end{bmatrix} =
\begin{bmatrix}
G_{11} & G_{21} & \ldots & G_{m1} \\
G_{12} & G_{22} & \ldots & G_{m2} \\
. & . & \ldots & . \\
G_{1n} & G_{2n} & \ldots & G_{mn}
\end{bmatrix}^{-1}
\begin{bmatrix}
C_1 \\
. \\
. \\
C_n
\end{bmatrix}
\]

………..(10)

Where: \( G \) was a variable defined by:

\[
(G) = \frac{1}{4\pi r_{mn}^2} e^{\mu r_{mn}}
\]

………..(11)

Where: \( \mu \) is absorption coefficient of matter or medium. In this case was taken the average of absorption coefficient of medium was 0.5 (approach).

**Results and Discussion**

Table 1 shows measurement results of nuclear radiation counts of radioisotope in mineral deposit at sub-district of middle Kupang West Timor Island, which appropriated with total area of survey location. Based on data in Table 1, contour and three dimensions curve of radiation counts were plotted like as shown on Fig. 5 and Fig. 6. Fig. 7 show profile curve of radiation counts of radioisotope in mineral deposit with plotting from AB and CD contour.
slices on Fig. 5. From that profile curve was determined radiation intensities which appropriated with radiation counts of radioisotope in mineral deposit and included in Table 2 and Table 3 shows calculation results of radiation power for 60 points according to equation (10) on three layers and use MATLAB program.

Table 1. Measurement results of radiation counts in the region of radioisotope source at Sub-district of Middle Kupa West Timor Island.

| No | L1 | L2 | L3 | L4 | L5 | L6 |
|----|----|----|----|----|----|----|
| 1  | 55 | 37 | 26 | 23 | 26 | 28 |
| 2  | 47 | 38 | 33 | 15 | 19 | 36 |
| 3  | 27 | 39 | 15 | 31 | 53 | 47 |
| 4  | 42 | 30 | 21 | 16 | 42 | 39 |
| 5  | 41 | 56 | 34 | 27 | 41 | 18 |
| 6  | 47 | 44 | 59 | 48 | 53 | 21 |
| 7  | 44 | 53 | 42 | 42 | 51 | 33 |
| 8  | 62 | 55 | 93 | 25 | 47 | 48 |
| 9  | 60 | 61 | 74 | 29 | 65 | 23 |
| 10 | 61 | 56 | 68 | 35 | 48 | 32 |
| 11 | 59 | 69 | 69 | 49 | 41 | 45 |
| 12 | 47 | 63 | 81 | 48 | 42 | 47 |
| 13 | 56 | 40 | 95 | 46 | 38 | 51 |
| 14 | 61 | 47 | 81 | 59 | 61 | 48 |
| 15 | 41 | 60 | 114 | 71 | 67 | 52 |
| 16 | 40 | 71 | 98 | 52 | 63 | 59 |
| 17 | 68 | 49 | 78 | 66 | 57 | 64 |
| 18 | 49 | 63 | 107 | 45 | 67 | 66 |
| 19 | 41 | 55 | 98 | 49 | 45 | 61 |
| 20 | 41 | 67 | 77 | 82 | 41 | 63 |
| 21 | 22 | 42 | 89 | 55 | 44 | 47 |
| 22 | 53 | 75 | 79 | 68 | 36 | 50 |
| 23 | 48 | 55 | 109 | 52 | 49 | 69 |
| 24 | 47 | 47 | 117 | 53 | 47 | 57 |
| 25 | 58 | 63 | 137 | 46 | 42 | 48 |
| 26 | 37 | 77 | 105 | 43 | 55 | 43 |
| 27 | 56 | 39 | 126 | 45 | 27 | 65 |
| 28 | 47 | 33 | 86 | 33 | 18 | 49 |
| 29 | 35 | 26 | 58 | 38 | 58 | 40 |
| 30 | 37 | 19 | 45 | 32 | 37 | 55 |

Table 2. Radiation intensities (C keV/m²s) were determined from the profile curves which appropriated with radiation counts of radioisotope in mineral deposit on three layers (20 m, 40 m, 60 m).

| Layer 20 m | C | 1 | 2 | 3 | 4 |
|------------|---|---|---|---|---|
| 1          | 37 | 77 | 46 | 107 |
| 2          | 55 | 99 | 43 | 94 |
| 3          | 69 | 83 | 78 | 98 |
| 4          | 27 | 41 | 148 | 49 |
| 5          | 69 | 58 | 99 | 48 |

| Layer 40 m | C | 1 | 2 | 3 | 4 |
|------------|---|---|---|---|---|
| 1          | 158 | 105 | 84 | 171 |
| 2          | 55 | 109 | 65 | 182 |
| 3          | 218 | 115 | 123 | 165 |
| 4          | 167 | 81 | 189 | 85 |
| 5          | 112 | 63 | 213 | 56 |

| Layer 60 m | C | 1 | 2 | 3 | 4 |
|------------|---|---|---|---|---|
| 1          | 57 | 145 | 51 | 57 |
| 2          | 49 | 205 | 56 | 61 |
| 3          | 112 | 155 | 58 | 82 |
| 4          | 83 | 121 | 24 | 72 |
| 5          | 167 | 79 | 43 | 56 |
Table 3. Calculation results of radiation power \( (P \text{ keV/s}) \) for 60 points according to equation (10) on three layers and MATLAB program

|       | First Layer |       |       |       |
|-------|-------------|-------|-------|-------|
|       | P1          | P2    | P3    | P4    |
| 1     | 0.52        | 0.52  | 0.72  | 1.15  |
| 2     | 0.31        | 0.54  | 0.58  | 1.48  |
| 3     | 0.31        | 0.28  | 2.23  | 1.07  |
| 4     | 0.26        | 0.87  | 0.84  | 0.78  |
| 5     | 1.33        | 0.46  | 1.58  | 0.57  |

|       | Second Layer|       |       |       |
|-------|-------------|-------|-------|-------|
|       | P1          | P2    | P3    | P4    |
| 1     | 0.88        | 0.83  | 0.94  | 1.67  |
| 2     | 0.67        | 0.86  | 0.87  | 2.34  |
| 3     | 0.68        | 0.51  | 2.56  | 1.23  |
| 4     | 0.29        | 1.14  | 0.96  | 0.93  |
| 5     | 2.24        | 0.76  | 2.36  | 0.94  |

|       | Third Layer |       |       |       |
|-------|-------------|-------|-------|-------|
|       | P1          | P2    | P3    | P4    |
| 1     | 0.91        | 0.87  | 1.35  | 2.49  |
| 2     | 0.65        | 1.14  | 1.19  | 2.67  |
| 3     | 0.76        | 0.58  | 2.96  | 2.38  |
| 4     | 0.34        | 1.68  | 1.52  | 1.28  |
| 5     | 2.55        | 0.66  | 2.87  | 1.24  |
Fig. 7 Profile curves of radiation counts of radioisotope in mineral deposit based on AB and CD contour slice.

Figure 8. Contours of radiation power for estimating of accumulation center of radioisotope in mineral deposit.

Fig. 9 Three dimensions curve of radiation power for estimating of accumulation center of radioisotope in mineral deposit.
For estimating of accumulation center of radioisotope in mineral deposit has been plotted contour and three dimensions curve of radiation power and shown on Fig. 8 and Fig.9.

Distribution and accumulation center of radioisotope content in mineral deposit was estimated from this profile curve and contour of radiation power. Based on Figure 8 and Figure 9 can be proposed that content distribution of radioisotope in mineral deposit estimated about 4.5 x10^6 m^2 (1,500 m x 3,000 m) and accumulation center of radioisotope content in mineral deposit estimated to be distributed on area 6 x 10^4 m^2 (200 m x 300 m) with depth range 20 m - 60 m. The range of radiation counts in the center region of radioisotope content in mineral deposit 10 counts per minute up to 137 counts per minute.

**Acknowledgements**

This research was supported and funded by Department of Mining Territory of Tana Toraja Government South Sulawesi Indonesia. Special thanks to all colleagues in English Training Centre in US, that have helped to our in technical writing of this manuscript.

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