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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 106 m2, and 1.56 x 104 m2. 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 8º-11º south latitude and 123º -126º 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 to138 counts per minutes and 1.4×10^{-5} µCi - 6.20×10^{-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 1 (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 U_3O_8, standard classification characteristics for ore deposit quality (ore grade deposit) were low if $< 0.15\%$ U_3O_8, middle: 0.15% up to 0.50% U_3O_8, and high if $> 0.50\%$ U_3O_8 [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

formula on equation (10), 8) plot contour and three dimensional curves of radiation power (Fig. 8 and Fig. 9), 9) interpret and conclusion. 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:

$$d = F\left(X_{\frac{1}{2}}\right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

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):
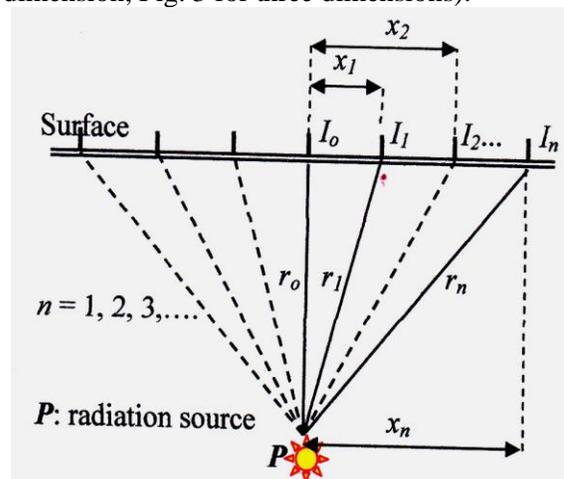
Figure 1. Geometry model calculates radiation power on elevation or altitude correction
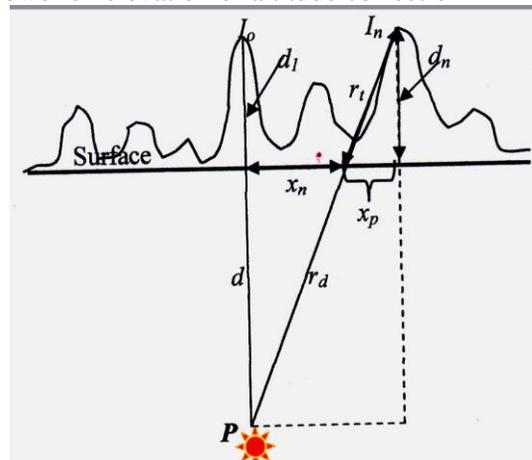
Fig. 2 Geometry model calculates power on topography correction.

$$P = I_o(4\pi r_o^2 e^{\mu r_o}) \ldots\ldots\ldots\ldots (2)$$

$$P = I_n(4\pi r_n^2 e^{\mu r_n} = I_n[4\pi(r_o^2 + x_n^2)]e^{\mu r_n} \ldots$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(3)$$

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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.

$$P = I_o(4\pi r^2 e^{\mu r}) \quad\text{.................}(4)$$

where: $d = r = r_o + d_1$, d_1 and d_n is measured with altimeter, $r_n = r_t + r_d$

$$P = I_n(4\pi r_n^2 e^{\mu r_n}) \rightarrow$$
$$(r_d + r_t)^2 = \left[(x_n + x_p)^2 + (r_o + d_n)^2\right]$$

$$P = I_n[4\pi(x_n + x_p)^2 + (r_o + d_n)^2]e^{\mu r_n})$$
$$\text{..},,,(5)$$
$$P = I_o(4\pi r_o^2 e^{\mu r_o} \quad\text{.........................}(6)$$
$$P = I_n(4\pi r_n^2 e^{\mu r_n} = 4\pi I_n(r_o^2 + x_n^2)e^{\mu r_n} \quad\text{......}$$
$$\text{..}(7)$$
$$P = I_{do}(4\pi r_{do}^2 e^{\mu r_{do}}) = 4\pi I_{do}(r_o^2 + y_n^2)e^{\mu r_{do}}$$
$$\text{..}(8)$$
$$P = I_{dn}(4\pi r_{dn}^2 e^{\mu r_{dn}}) = 4\pi I_{dn}(r_o^2 + D_n^2)e^{\mu r_{dn}} = 4\pi I_{dn}[r_o^2 + (y_n^2 + x_n^2)e^{\mu r_{dn}}]$$
$$\text{..}(9)$$

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

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:

$$\begin{pmatrix} P_1 \\ P_2 \\ . \\ P_n \end{pmatrix} = \begin{pmatrix} G_{11} & G_{21} & .... & G_{m1} \\ G_{12} & G_{22} & .... & G_{m2} \\ .... & ..... & ...... & \\ G_{1n} & G_{2n} & & G_{mn} \end{pmatrix}^{-1} \begin{pmatrix} C_1 \\ .... \\ .... \\ C_n \end{pmatrix} \quad\text{...........}(10)$$

Where: *G* was a variable defined by:

$$(G) = \frac{1}{4\pi r_{mn}^2 e^{\mu r_{mn}}} \quad\text{.....................} (11)$$

Where: μ is absorption coefficient of matter or medium. In this case was taken the average of absorption coefficient of medium was 0.5 (approach).
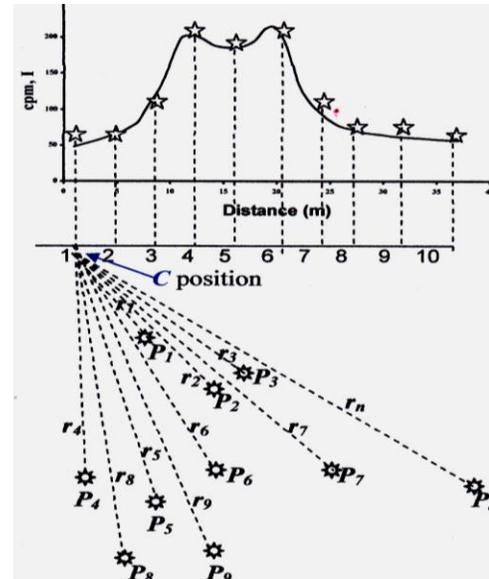
Fig. 3 Geometry model in three dimensions calculate radiation power based on profile curve.
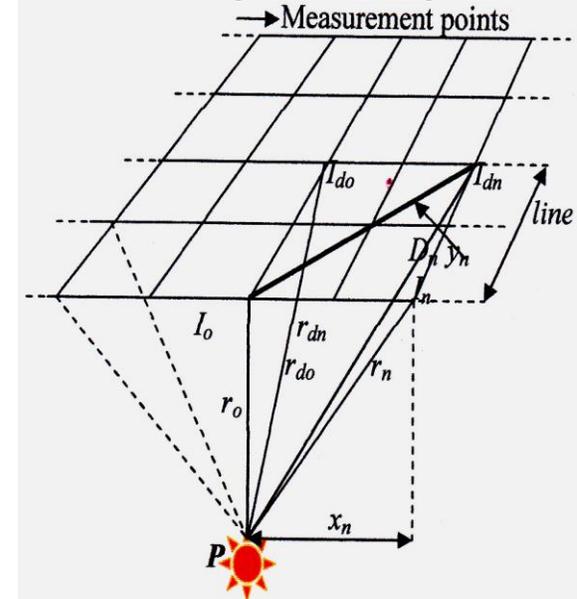
Fig. 4 Geometry model calculates radiation power on elevated correction.

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 Kupang 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
31	36	29	48	34	24	31
32	41	25	46	41	33	42
33	19	18	37	38	38	47
34	34	32	37	28	17	10
35	21	26	37	29	24	13
36	15	33	43	25	17	19
37	17	23	39	17	28	15
38	19	28	26	21	15	21

Where: $(L_1, L_2, L_3 \ldots \ldots L_6$ were measurement lines, cpm was count per minute).

Table 2. Radiation intensities (C keV/m^{2}s) 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 keV/s) for 60 points according to equation (10) on three layers and MATLAB program

First Layer			
P	1	2	3	4
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			
P	1	2	3	4
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			
P	1	2	3	4
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
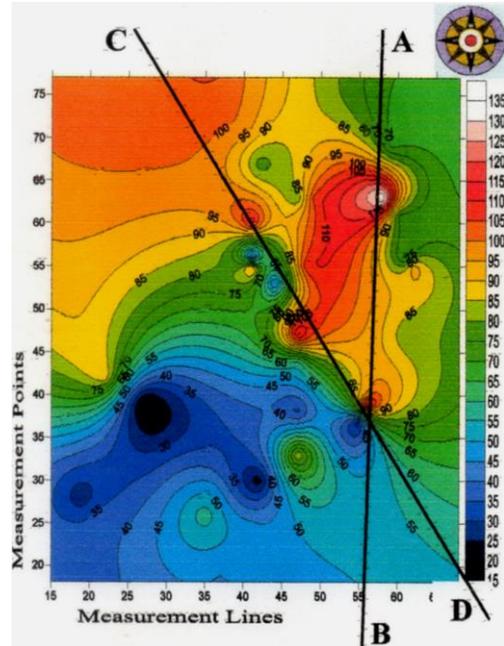
Figure 5. Contour map of radiation counts of radioisotope in mineral deposit

where: AB and CD were line which show two contour slices in different direction.
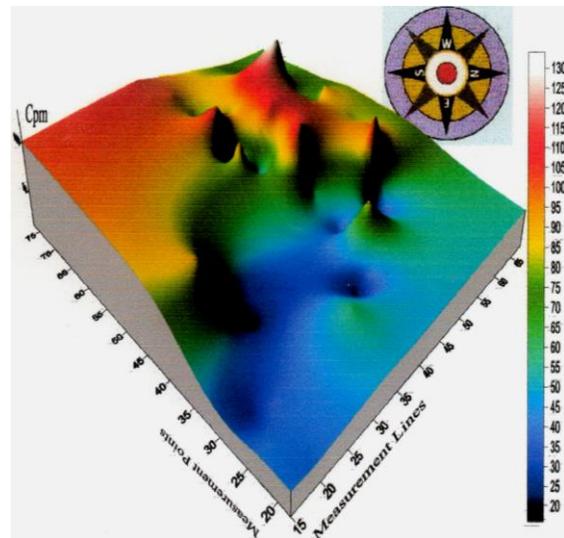
Figure 6. Three dimensions curve of radiation counts of radioisotope in mineral deposit.
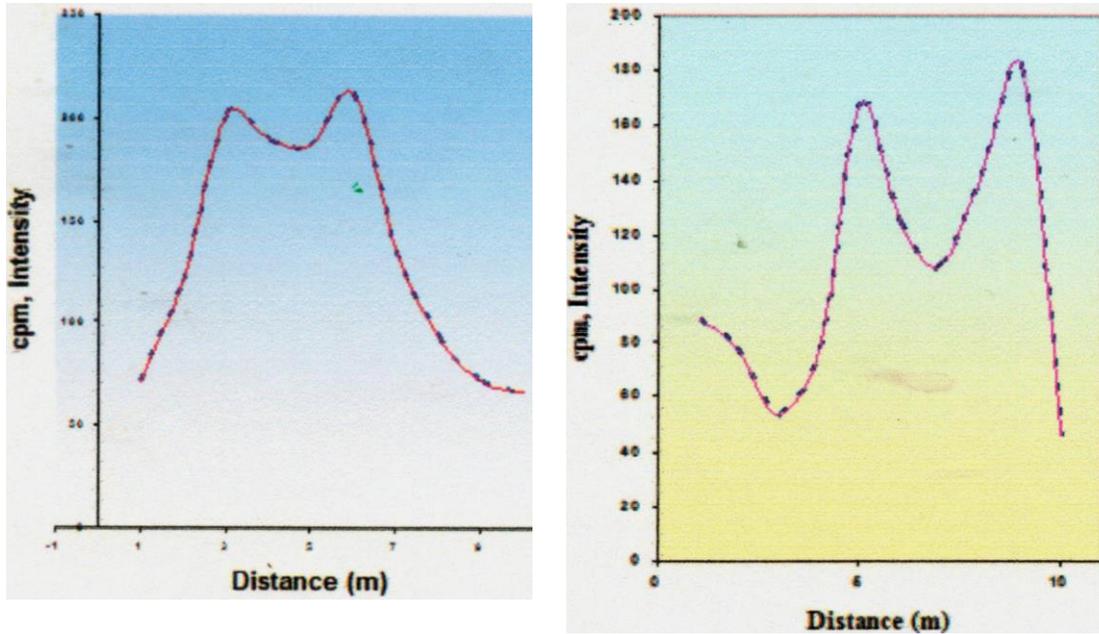
Fig. 7 Profile curves of radiation counts of radioisotope in mineral deposit based on AB and CD contour slice.
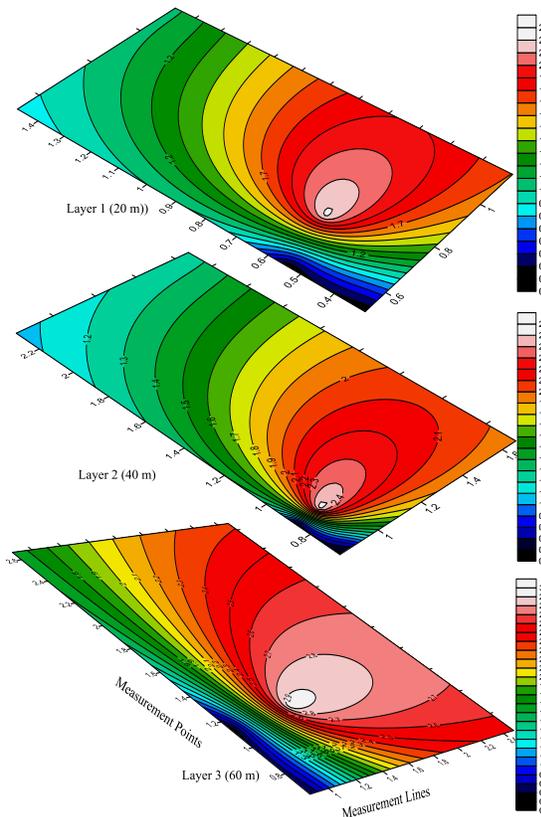
Figure 8. Contours of radiation power for estimating of accumulation center of radioisotope in mineral deposit.

Fig. 9 Three dimensions curve of radiation power for estimating of accumulation center of radioisotope in mineral deposit.

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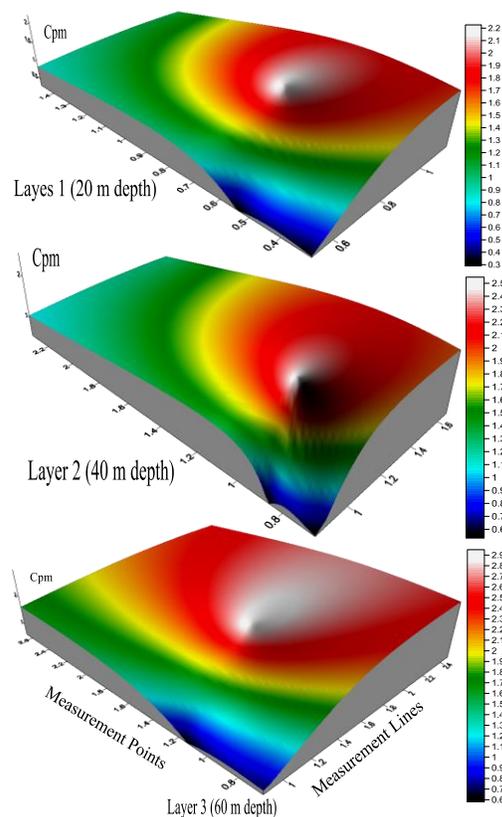
For estimating of accumulation center of radioisotope in mineral deposit has been plotted contour and three dimensions curve of radiation power and shown on Fig. 8 and Fig.9.

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 $\times 10^6$ 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 ranges 20 m up to 60 m which detected. Accumulation of radioisotope in mineral deposit initially follows of basic rocks layer dominated by tertiary sediment rocks from Permian to Jurassic which forms of Timor Island. The new accumulation of radioisotope in the mineral deposit was formed by tectonic processing that cause faulting, folding, and dynamic motion of rocks. The content of radioisotope detected in mineral deposit was very small, if it observed on surface, except there was a large accumulation on the layer in more depth. The prospecting of radioisotope content in mineral deposit for exploration was necessary espoused by others data like as drilling data, gamma logging, magnetic, and seismic data which can give information of layer thickness, the depth of rocks mineralization, and the total form of content accumulation of rocks mineralization.

Conclusion

The distribution of radioisotope content in mineral deposit based on contour map, three dimensional curves of field data of radiation counts, and contour map, three dimensional curves of radiation power of radioisotope estimated on area 4.5 $\times 10^6$ m^2 (1,500 m x 3,000 m) and accumulation center of radioisotope content in mineral deposit estimated 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

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