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UTILIZATION OF HORIZONTAL–LOOP ELECTROMAGNETIC METHOD TO CONFIRM THE EXISTENCE OF AN OLD BERYL MINE WITH FOCUSING ON THE RADIOACTIVITY IN SIKEIT AREA, SOUTHEASTERN DESERT, EGYPT

R.A. Elterb
Nuclear Material Authority, P.O. Box 530, Maadi, Cairo, Egypt.

استخدام الحلقة الأفقية الكهرومغناطيسية للتأكد من وجود مناجم البريل القديمة مع التركيز على النشاط الإشعاعى فى منطقة سكيت ، جنوب شرق الصحراء الشرقية ، مصر

الخلاصة: لقد تعرضت منطقة نجرس – سكيت لأعمال منجمية وتعدينية كثيفة بواسطة قدماء المصريين، حيث يرتبط معدن البريل بصخور الميكا على طول تماسها مع صخور النيس الفلسى – المروى. يوجد البريل وما يرتبط به من الزمرد فى صخور الميكا وتداخلات المرو التى تقطعها. تقع منطقة الدراسة فى منطقة محدودة بوادى سكيت ، حيث تقع بين خطى طول 34^o 47` 46`` و $34^o$ 47` 51`` شرقا ، وخطى عرض 24^o 37` 52`` و $24^o$ 37` 55`` شمالاً وتغطى المنطقة بصخور الشيست والنيس وبعض الصخور الجرانيتية.

تتناول الدراسة الحالية استكشاف وفحص أحد المناجم القديمة الأثرية فى منطقة سكيت، وذلك باستخدام طريقة الحلقة الأفقية الكهرومغناطيسية، والتى تعتبر من أهم الطرق والوسائل الجيوفيزيقية فى الكشف عن الأجسام والمناجم التحتسطحية جيدة التوصيل ويتناول البحث كذلك دراسة النشاط الإشعاعى لمختلف الصخور حول المناجم الأثرية القديمة لتحديد المستوى الإشعاعى لها، هذا بالإضافة إلى تحديد مستوى الاشعاع البيئى.

يبين تفسير المعطيات وجود جسم مطمور يرجح أن يكون مرتبطا بمنجم قديم عند عمق يتراوح من ٣ الى ٤,٥ متر، بزاوية ميل تجاه الشرق يبلغ مقدارها ٢٠ درجة ، وبعرض يتجاوز ١٠ أمتار، وخاصية توصيلية كهربية تصل إلى ٢٧ مهو / متر. بالإضافة إلى ذلك سجلت إشعاعية المنطقة مستوى عاديا، حيث تراوحت القياسات من ١,٤ إلى ١١,٤ يو آر. وعليه فإن الأحوال البيئية تظل فى المستوى الآمن (متوسط ٠,٧٧ مللى سيفرت / عام)، وذلك فيما عدا بعض المواضع المتناثرة والتى تزيد قيمتها عن ١ مللى سيفرت / عام والتى تمثل المستوى الآمن الأعلى.

ABSTRACT: *Nugrus-Sikeit area was extensively mined by the ancient Egyptians, where, beryllium (Be) mineralization is associated with the mica rock along its contact with the quartzofeldspathic gneiss. Beryl and associated emerald occur in the mica rock and the quartz stringers that traverse them. The study area was considered as a limited area located in Wadi Sikeit, bounded by Long. 34o 47` 46`` & $34^o$ 47` 51``E and Lat. 24^o 37` 52`` & 24o 37` 55``N. It is covered by schist, gneiss and some granitic rocks.*

The present study deals with the exploration of one of the ancient old mines in the Sikeit area using the Horizontal-Loop Electromagnetic (HLEM) method, as one of the important geophysical tools to explore the subsurface conductive bodies and mines. In addition, the radioactivity of the different rocks around the old mines was studied to determine the radiometric level and the natural radiation environment of the surveyed area. The interpretation of the data shows an important bored body related to an old mine at a depth ranging from 3 to 4.5m with a dipping angle of about 20^o to the east, and a width of more than 10m. Its conductivity reaches about 27 mho/m. In addition, the radioactivity of the rocks is in the normal level (1.4-11.4 Ur), hence, the environmental conditions remain in the safe side (the mean 0.77 mSv/y) except some scattered spots of more than 1 mSv/y.

I- INTRODUCTION

Wadi Sikeit occurs as a tributary of W. Nugrus which is a tributary of W. El Gemal, South Eastern Desert. Wadi Sikeit hosts a multitude of economical, archeological and environmental resources. Economic resources such as beryl deposits and base metals are present. Archeological resources such as Sikeit Temple, Madinat Sikeit and the remnants of the old beryl mines are also present. Harrell, (2006) shows that, the same old mines were reopened repeatedly, but there is no exploitation at present. The present study in Wadi Sikeit old beryl mines deals with a limited area bounded by Long. 34^o 47` 46`` & $34^o$ 47` 51`` E and Lat. 24^o 37` 52`` & $24^o$ 37` 55`` N (fig.1).

The Horizontal-Loop Electro-magnetic method was used as one of the important geophysical tools which can be used to explore the subsurface conductive bodies such as old mines of Sikeit area. In addition, the radio-activity of the different rocks around the old mines was studied to determine the radioactivity and environmental level of the studied area.

II- GEOLOGY

The lithological composition of Sikeit area comprises a sequence of dismembered ophiolites, tectonic mélange association and arc assemblage. These older rocks are intensively deformed and intruded by intracratonic association, as shown in the area map (fig.1). They are represented by gabbros and the associated hornbledite together with younger granites, in addition to the gneiss and schist rocks.

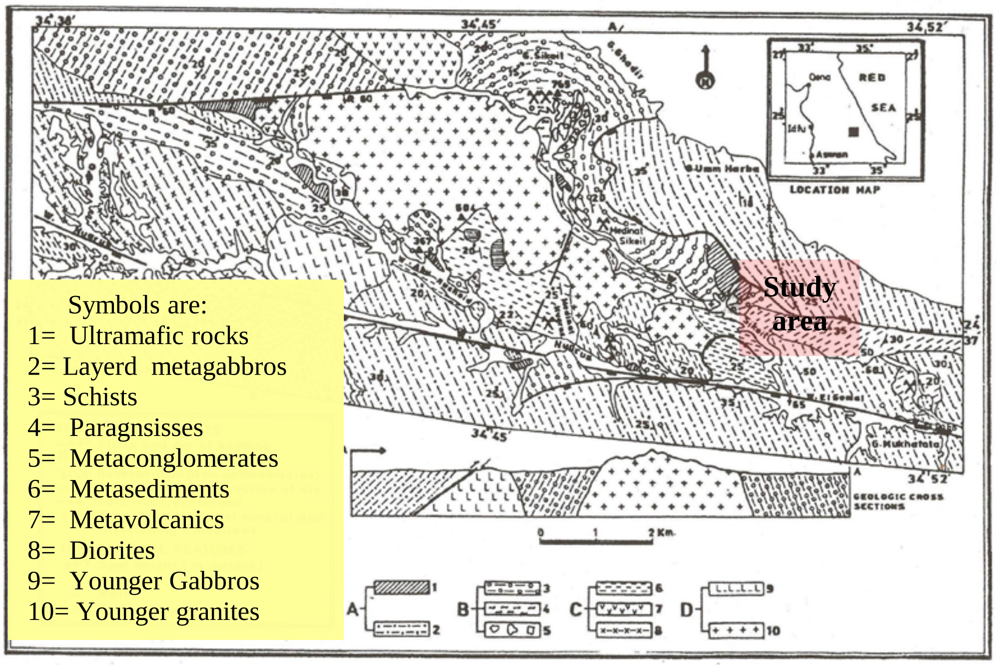

Fig. (1): Geological map of Nugrus-Sikeit area, Southeastern Desert, Egypt. (After Assaf et. al., 2000).

The structures exhibited by the rocks of Sikeit area indicate that these rocks are involved in super imposed folding events and at least three fold generations can be recognized (*Assaf et al., 2000*).

III- HORIZONTAL-LOOP ELECTRO-MAGNETIC (HLEM) METHOD

1- General:

Electromagnetic methods of prospecting are based on the measurement of the magnetic field associated with an alternating currents induced in the subsurface conductors by primary magnetic fields. In most methods, the primary ore inducting field is artificially produced by passing an alternating current (AC) through a coil or loop. The basic principle is most easily illustrated by reference to the two-coil system shown in (fig. 2).

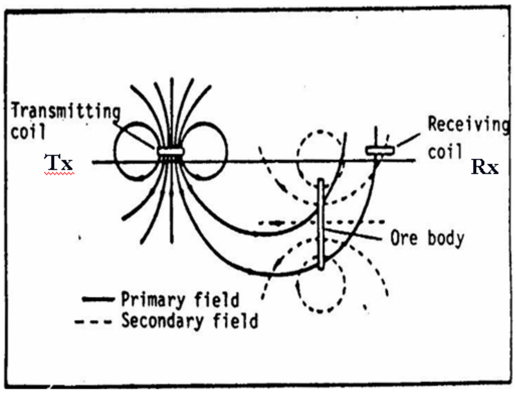

Fig.(2): Principle of the HLEM method.

AC usually with a frequency ranging between few hundreds and few thousands hertz, is passed through the transmitting coil. Eddy currents are thus induced in the conducting ore body with a transmitter (Tx), which generates a primary electromagnetic field. The strength of the induced current and consequently that of the secondary electromagnetic field depend on the conductivity, shape and size of the target body. The in-phase and out-of-phase components of the resulting secondary electromagnetic field are detected by the receiver coil (Rx).

2- Instrumentation and Field Procedures:

The whole system used in the present work is composed of two essential units, a transmitter and a receiver model (Max-Min I-8). This system is qualified to conduct provide a Horizontal-Loop Electromagnetic survey. It is capable of sending primary currents from the transmitter with different frequencies (i.e. selected frequencies are 110, 220, 440, 880, 1760 & 3520 HZ) and receives the accompanied secondary currents of each frequency. This helps investigating the conductor at difference depth levels where low frequencies investigate deeper conductors.

During the present work, the two coils (transmitter and receiver) were separated by a fixed distance which was 25m (fig. 3). The survey was conducted along two selected profiles of 80m apart (fig. 4) to investigate the conducting zones, especially those related to the conductive bodies of the old mine and faults in Sikeit old mine.

Fig. (3): Photo showing the (MaxMin I-8) instrument and the survey method.

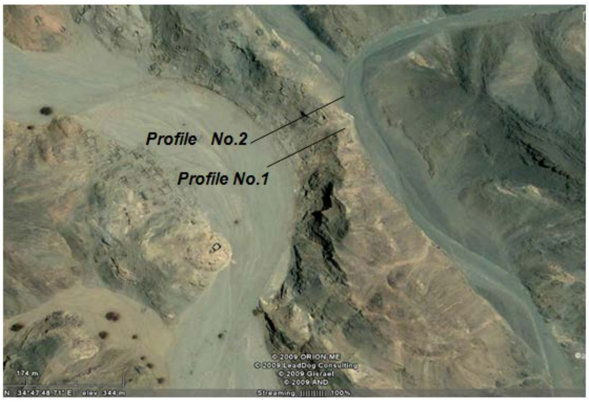

Fig. (4): Snapshot from Google Earth showing the location of HLEM profiles in Sikeit old mine area, Southeastern Desert, Egypt.

3- Data Reduction and Presentation:

Where the ground is slopping, a correction of the data must be applied. This correction is made by using the tilt angle, in-phase and out- of phase data in the correction tables and equations prepared by Apex Parametrics Limited, to obtain the corrected in-phase and out –of-phase data. Each of these data (in-phase or out-of-phase) was plotted in two dimensional plot, where the distance along profile is represented along the X-axis and the percentage of the in-phase and out-of-phase is represented along the Y-axis together.

4- Data Analysis:

The qualitative analysis is an attempt to get a preliminary idea about the location of the conductive zone, depending on the form and shape of the negative and positive peaks of the in-phase and out-of-phase components. Whereas the geometry of the body, the depth to its upper edge and the product of the conductivity can be deduced by using type curves for the interpretation of Horizontal-Loop Ketola and Puranen, 1967 and Standard curves of Nair, et al. 1974. The thickness or width of the conductive body could also be calculated from the relation between the two zero points of the in-phase & out-of-phase components and the distance between the two coils. Moreover, the dip angle could be calculated from the shape and value of the two positive peaks of in-phase & out-of-phase components using the same standard curves. As frequency and coil spacing are known, the conductivity – thickness product can be obtained. The product has proved to be a useful measure of the economic value of the ore body.

5- Interpretation and Results:

Both the HLEM profiles (Fig. 4) have E-W direction which is nearly perpendicular to the direction of the expected old mine and structures. The corrected results were represented in profile form. Examination of these profiles has led to the following observations:

A- Profile no. 1:

The length of this profile was 70m (fig. 5) with a station separation 5m represented. Six frequencies were used with 25m as coils separation. The interpretation of the HLEM data on this profile detected a conductive body at depth of about 3 m (Fig.6). which may be old mine or tunnel? Its dipping is about 20^o due east and 10m width as well as conductivity reaches up to 22.7 mho/m. It is worth noting that, the positive values of the out-of-phase component of the low frequencies (110 & 220 Hz) and high frequencies (1760 & 3520 Hz) reflect that, the conductive zone is not deeply extended and not exposed at the surface.

B- Profile no. 2:

This profile has a length of 110m and station separation of 5m (fig.7). The distance between the two coils was 25m. The conductive zone was detected between measuring points 40 and 60m, at a depth of 4.3m. It is dipping to the east with an angle 20^o, its width reaches about 15m and the conductivity is about 27 mho/m (fig.8). These interpreted values may be prove that this conductive zone represents the old mine and it is the extension of the conductive zone in profile no.1. A weak anomaly could also be delineated at the measuring point 90m which may be due to a basic dyke.

IV- RADIOMETRIC AND ENVIRONMENTAL MONITORING

The studied area was surveyed using calibrated ground spectrometer, GS 512 to show the radiometric level of the different rocks. The total counts radiometric map (fig.9) shows that the granitic rocks and wadi sediments give relatively high values (i.e. more than 8Ur). The intermediate values (i.e. 5-8 Ur) are related to the schist rocks. However, the low total radiometric values are related to the basic rocks (gabbro and metagabbro rocks) represent the lowest values which are less than 5 Ur.

The radiation exposure rate (E) has been calculated from the apparent concentrations of K (%), eU (ppm), and eTh (ppm) using the expression of (IAEA, 1991) as follows:

Exposure rate (µR/h) = 1.505 K (%) + 0.653 eU (ppm) + 0.287 eTh(ppm)

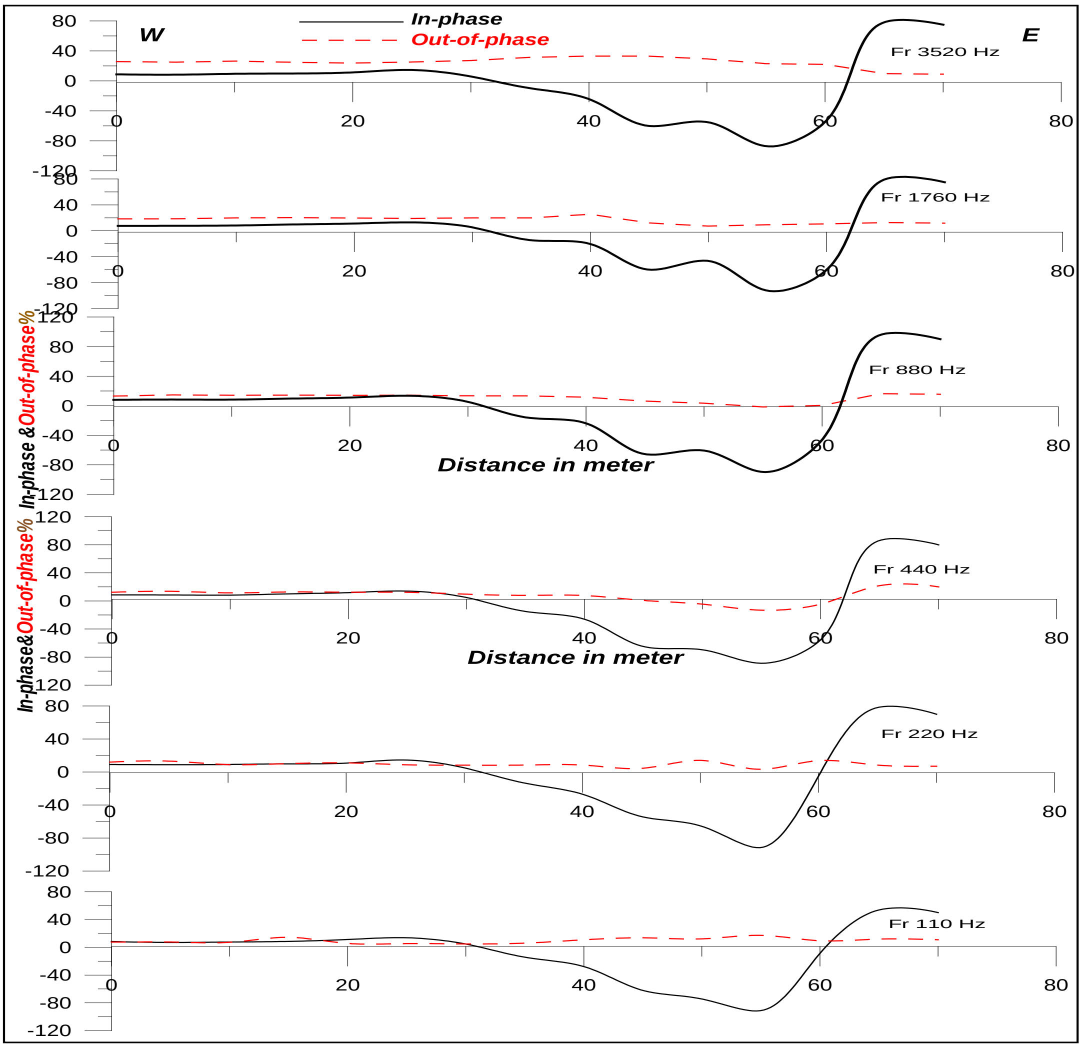

Fig. (5): HLEM profile No.1, beryl old mine in Sikeit area, Southeastern Desert, Egypt.

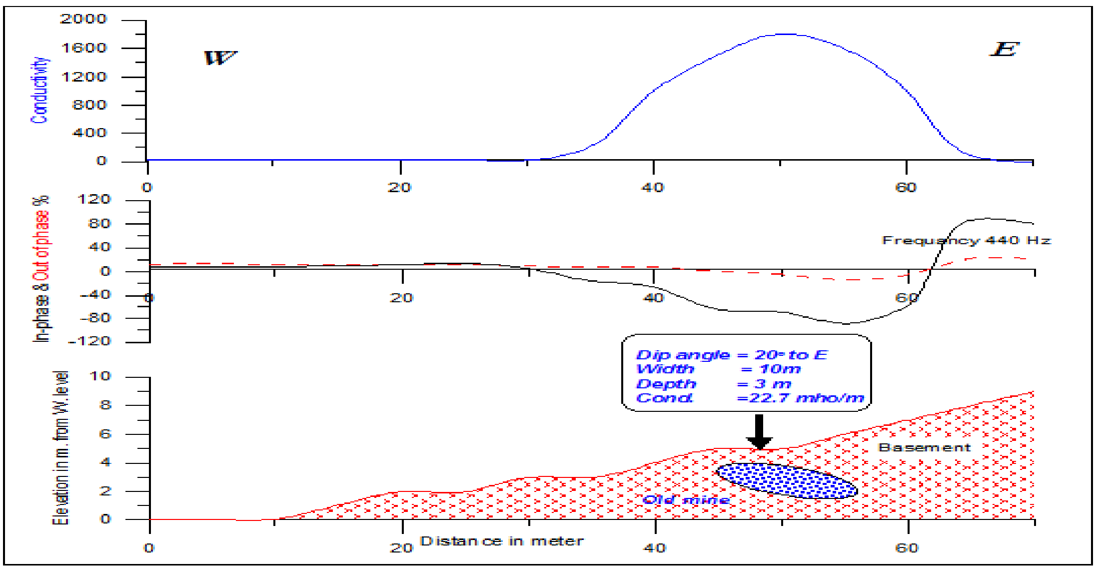

Fig. (6): Interpretation of HLEM profile no.1, beryl old mine in Sikeit area, Southeastern Desert, Egypt.

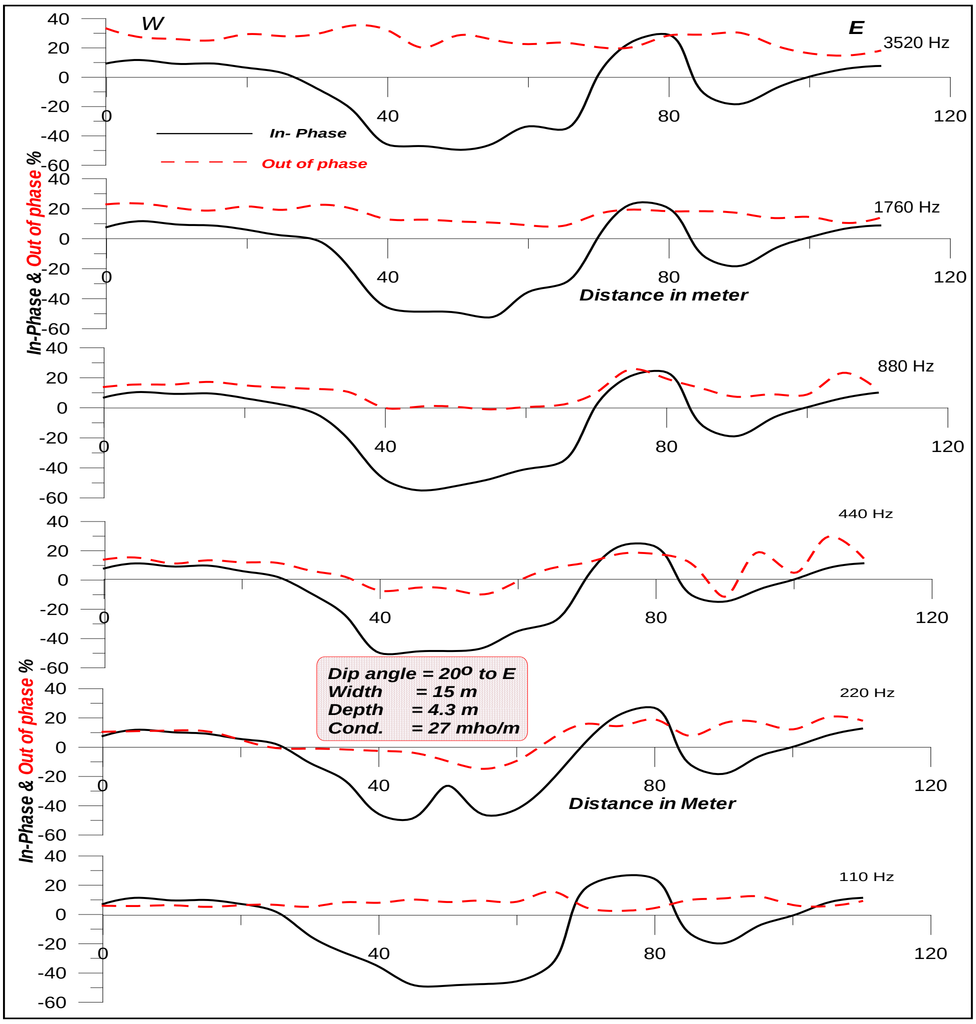

Fig. (7): HLEM profile no.2, beryl old mine in Sikeit area., Southeastern Desert, Egypt.

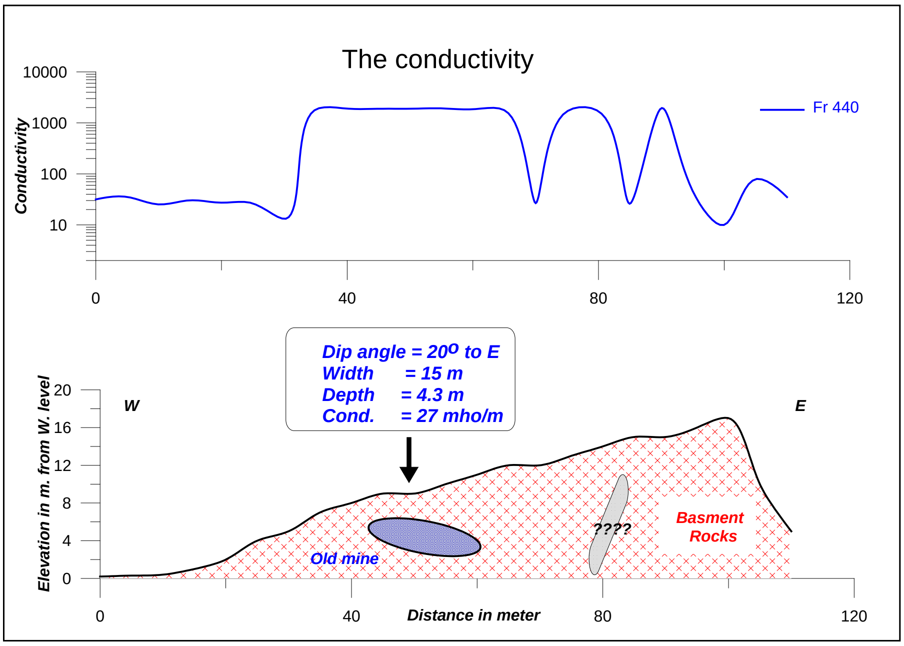

Fig. (8): Interpretation of HLEM profile no. 2, beryl old mine in Sikeit area., Southeastern Desert, Egypt.

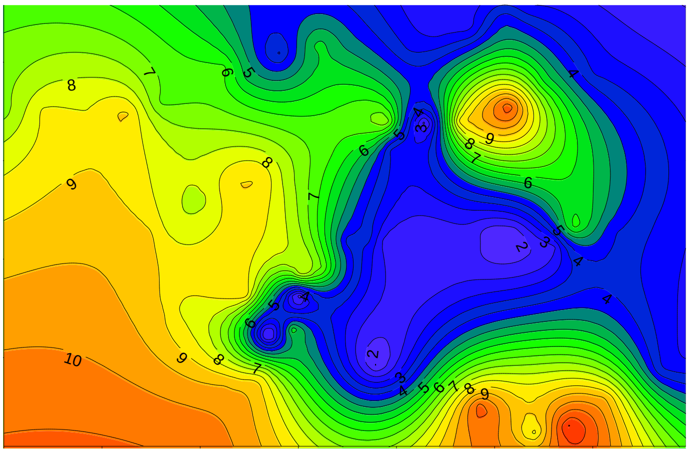

Fig. (9): Filled colour contour map of total-count (T.C. Ur) radiometric data on beryl old mine in Sikeit area, Eastern Desert, Egypt.

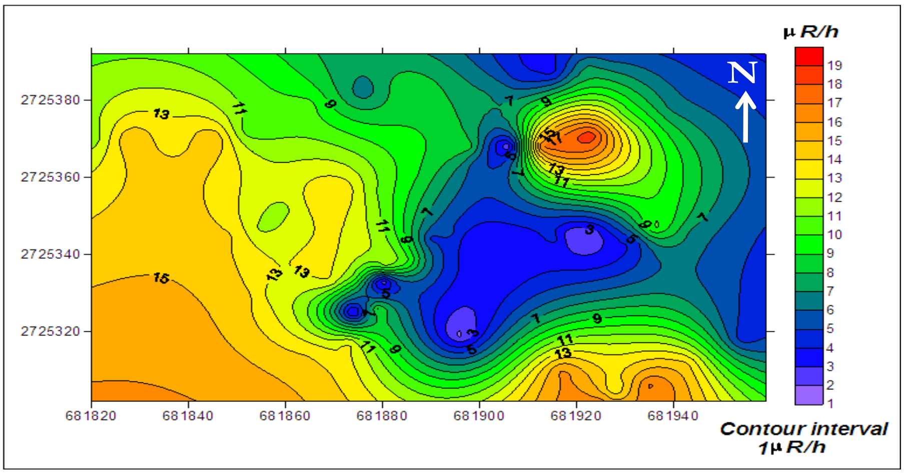

Fig. (10): Filled colour contour map of the radiation exposure rate (µR/h) values on beryl old mine in Sikeit area, Eastern Desert, Egypt.

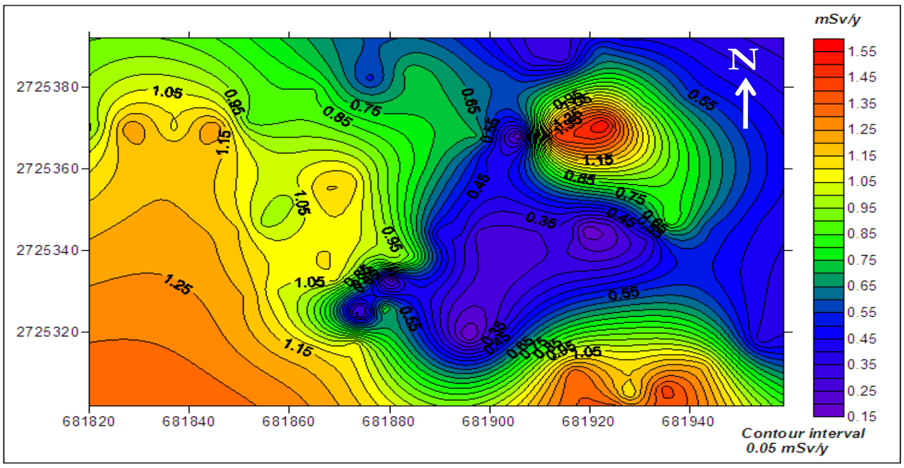

Fig. (11): Filled colour contour map of the radiation dose rate (mSv/y) values on beryl old mine in Sikeit area, Eastern Desert, Egypt.

The exposure rate can be converted to the equivalent dose rate using the following relation (Grasty et al., 1991):

Dose rate (mSv/y) = 0.0833*E (μR/h).

The international Commission of Radiological Protection (ICRP) has recommended that no individual should receive more than 5000 millirems/years (50 mSv/y) from all natural and artificial radiation sources in human environment (IAEA, 1979). Currently, the recommended dose rate should not exceed one millisievert per year (IAEA, 2000).

The radiation exposure rate map (Fig.10) of the study area shows that this rate5 varies in intensity from 1.7 μR/h to 18.8 μR/h, with a computed arithmetic mean reaching 9.2 μR/h. The equivalent radiation dose rate map of the study area (Fig. 11) shows the intensity ranging from 0.14 mSv/y to 1.6 mSv/y, with a computed arithmetic mean of 0.77 mSv/y. This shows the same features as the radiation exposure rate map (Fig. 10).

V- CONCLUSION

The interpretation of the two HLEM profiles indicates that, there is an important bored old mines in the study area, where the parameters of one of these mines could be calculated. The interpreted depth of this mine ranges from 3 to 4.5m from the ground surface. This mine is dipping to the east direction with an angle of about 20^o and has a width ranges from 10 to 15m. The conductance of this zone ranges from 22 to 27mho/m, which reflects that this old mine may contain some traces of minerals.

The total radioactivity of the rocks in the study area ranges from 1.4 to 11.6 Ur, the average of the environmental dose rate was recorded as 0.77 mSv/y, which proves that the area remains in the safe side except some spots which have values more than 1 mSv/y. More geophysical studies are highly recommended in this area and surroundings.

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REFERENCES

APEX: Scintrex Parametric Limited Co, Canada.

Assaf H.S., Ibrahim M.E., Zalata A.A., Metwally A.A. and Saleh G.M., (2000): Polyphase folding **in** Nugrus-Sikeit area south eastern desert, Egypt. JKAU: Earth Sci., vol. 12,pp. 1-16.

Google Earth (2009): Satellite Images.

Grasty, R.L., Holman, P.B. and Blanchard, Y.B., (1991): Transportable calibration pads for ground and airborne gamma-ray spectrometers, Ottawa, Canada. Geological Survey of Canada, Paper 90-23, 24 p.

Harrell, J.A. (2006): Archaeological geology of Wadi Sikeit, PalArch' s Jurnal of Archaeology of Egypt/Egyptology 4, 1.

International Atomic Energy Agency (IAEA) (1979): gamma- ray surveys in uranium exploration. IAEA, Vienna, Austria, Technical Report Series No. 186, 90 p.

International Atomic Energy Agency (IAEA) (1991): Airborne gamma-ray spectrometer surveying. IAEA, Vienna, Austria, Technical Report Series No. 323, 97 p.

International Atomic Energy Agency (IAEA) (2000): 5th international conference on high level of natural radiation, Munich, (Waste solutions, Vol.42 No3, Vienna, Austria,p7).

Ketola, M and Puranen, M, (1967): Type curves for the interpretation of Slingram (Horizontal Loop) anomalies over tabular bodies. Report of investigations No.1, Geologinen Tutkimuslaitos, Geological Survey of Finland.

Nair, M.R. Biswas and Mazumdar, K. (1974): Standard curves for the interpretation of Horizontal Loop EM anomalies. Geological Surv. of India. Miscellaneous Publication No. 25.