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RADIOSPECTROMETRIC SIGNATURES OF THE UM SALIM GOLD MINE, EGYPT

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التباشير الإشعاعية الكلية والطيفية لمنجم ذهب أم سالم، الصحراء الشرقية، مصر

الخلاصة: يتمثل الغرض من هذا البحث في دراسة الملامح المميزة لمنجم ذهب أم سالم، والذي يقع في صحراء مصر الشرقية بإستخدام معطيات المسح الإشعاعي الطيفي الجيمي الجوي. ولتحقيق هذا الهدف تم تفسير الخريطة الإشعاعية الكلية(TC) وخرائط العناصر المشعة الثلاثة (البوتاسيوم واليورانيوم المكافئ والثوريوم المكافئ) وكذلك خرائط النسب الإشعاعية الطيفية الثنائية والثلاثية والخرائط المركبة زائفة الألوان. كما تم تحليل إحصائي للوجهات التركيبية على كل من معطيات الخريطة الإشعاعية الكلية المنسوبية بالإضافة إلي الفوالق المبينة على الخريطة الجيولوجية.

وكشفت الدراسة ارتباط موقع منجم الذهب بمستويات إشعاعية كلية وطيفية منخفضة للغاية على جميع الخرائط الأربع(TC, K, eU and eTh) وباتجاه شمال الشرق وتبين كذلك أن ملامح إشعاعية كلية وطيفية مميزة على خرائط النسب الثنائية مصاحبة لموقع منجم الذهب وبالأخص خريطتى اليورانيوم المكافئ والثوريوم المكافئ بالنسبة للبوتاسيوم (eU /K and eTh/K) ويمكن تمييز مناطق احتمال وجود تبادل للمحاليل البوتاسية الحارة على خريطة البوتاسيوم المركبة زائفة الألوان وأتضح كذلك تميز الخرائط المركبة زائفة الألوان والنسب الإشعاعية الثلاثية بوجود نطاقات التبادل بدرجات مختلفة والتي ترتبط بموقع منجم الذهب ومن الممكن استخدام هذه النطاقات كملامح استكشاف تشخيصي للأنواع المختلفة من رواسب المعادن غير المشعة مثل الفضة والذهب وتوضح هذه النطاقات وجود تغيرات في التركيزات النسبية للبوتاسيوم في البيئة الجيولوجية الأصلية كما أمكن تحديد أربعة وجهات تركيبية رئيسية باتجاهات شمال الشرق، شمال الغرب، شمال- جنوب وغرب شمال الغرب ويرتبط تقاطع كل من اتجاه شمال الشرق وشمال الغرب ارتباطا وثيقاً بموقع منجم الذهب بالمنطقة تحت الدراسة.

ABSTRACT: *The purpose of this research is to study the signatures of a gold mine (Um Salim), located in the Eastern Desert of Egypt, using aeroradiospectrometric data. To achieve this goal, interpretation of the total- count (TC) radiometric map, the three radioelement (K, eU & eTh) maps, the ternary radioelement composite image and the three radioelement composite images were carried out. Moreover, a two – dimensional trend analysis for the structural lineaments as traced from the geologic and total – count radiometric maps was conducted to define the relationship which might exist between location of the gold mine, lithologies and major structures of the area under consideration. The study revealed that the known gold mine is associated with very low aeroradiospectrometric levels on the four maps (TC, K, eU and eTh). They are all correlated with the same NE trend. There are other particular radiospectrometric ratio signatures for gold deposits on the (eU/eTh, eU/K and eTh/K) maps. Zones of potential hydrothermal potassic alterations can be discriminated on the potassium colour composite image. Ternary radioelement and composite images can discriminate also alteration zones in various degrees that correlate with the gold mine, but with no direct reference to gold occurrence location. These zones can be used as a diagnostic exploration guide for various types of non-radioactive mineral deposits (e. g., copper and gold). They involve changes in the relative concentrations of potassium in the original geologic environment. Four major tectonic trends were identified, that have the following directions: NE, NW, N-S and WNW, the most important of these trends is the NE direction which correlates well with the location of gold mine.*

INTRODUCTION

The Um-Salim gold mine lies in the Eastern Desert of Egypt (Fig. 1), and approximates 84 km^2 in surface area. This study applies high-resolution airborne radiospectrometric surveying as a powerful tool to aid both mineral exploration and lithological mapping. It presents the interpretation of these data which comprise one location of the gold mine in Egypt, to determine its radiospectrometric signatures. It could be possible through the use of these signatures to predict the occurrence of similar deposits elswhere in the region.

An airborne geophysical survey for a vast territory in the Eastern Desert of Egypt, including the area under study, was carried out by Aero-Service Division, Western Geophysical Company of America, USA, in 1984. It involved aeroradiospectrometric as well as aeromagnetic surveys. Both surveys were simultaneously conducted along parallel flight lines that were oriented in a NE-SW direction, at 1.0 km spacing. Meanwhile, the tie lines were flown perpendicularly in a NW-SE direction, at 10 km intervals. Total-intensity magnetic and multi-channel radiospectrometric measurements were made at 93 m intervals at a nominal sensor altitude of 120 m terrain clearance. A high-sensitivity 256-channel airborne gamma-ray spectrometer (50 l NaI “Tl” crystals) and a Varian V-85 proton precession magnetometer, mounted in a tail-stinger configuration, were the primary sensor elements in the Aero-Service CODAS/AGRS 3000F computer-based digital data acquisition system (Aero-Service, 1984).

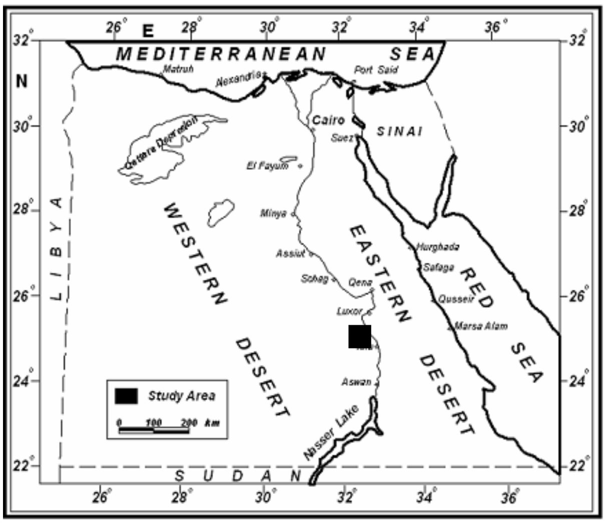


Fig. (1): Location map of the Um Salim gold mine, Eastern Desert, Egypt

Among 95 gold occurrences, known in the Eastern Desert of Egypt, since ancient time, the age of Pharaohs, mining has been carried out in the last century on about 15 deposits (e.g., Hume, 1937; Elramly et al., 1970; Sabet et al., 1976; Marten, 1986). Work on these deposits was intermittent and few deposits were operated into 1950s, but it is clear that all were on a small scale. The known reserves at most deposits are in the order of 10,000 t or less (Marten, 1986).

GEOLOGIC OVERVIEW

The country rocks hosting the gold-bearing veins in the studied locality are quite variable. They include complete to dismembered fragments of ophiolites (serpentinite-metagabbro-sheeted dyke complexes-pillow lava sequence) in a schistose pelitic matrix, together with an island-arc association made up of metamorphosed calc-alkaline volcanics and volcaniclastic sediments of comparable composition. This sequence is interpreted as an ensimatic telescoped ocean basin-island arc complex (e. g., Vail, 1983). It was subsequently thrusted over a sialic crust and the whole complex became variably deformed, regionally metamorphosed, transected by major steep shear belts and intruded by synorogenic, calc-alkaline granitoid plutons. Alteration of the ophiolitic complex to talc-carbonate is common and broad belts have been mylonitized into schistose rocks, previously interpreted as mudstones (Marten, 1986).

Mineralogically, the veins are mainly composed of quartz, together with minor amounts of sulphides, carbonates, micas, iron hydroxides and native gold. Generally, pyrite is the most predominant sulphide mineral in the veins, followed by arsenopyrite. Other subordinate sulphides including pyrrthotite, sphalerite, chalcopyrite and galena are usually identified, while marcasite and niccolite are very rarly detected (Sharara and Vennemann, 1999). Analytical investigations of different rocks in the Arabian–Nubian shield ANS (e.g. serpentinites, basalts, clastic sedimentary rocks) indicate exposed gold concentrations of 20–50 ppb in mafic rocks and clastic sediments, and concentrations close to 200 ppb in the serpentinites (Dietrich et al., 2001).

According to some modern classifications based on the works of Elshazly, 1964, Stern, 1979, Elshazly et al., 1980, Abdelmeguid, 1986 and Elgaby et al., 1988 and 1990. The rock units in the study area can be chronologically grouped into the following main rock sequences, starting from the oldest:

Shadli Metavolcanics

They are commonly found as flows, sills and thick sheet-like bodies, normally interbedded with the First Basement (or Geosynclinal) Sediments of Elshazly, 1977. The group originally includes a complex formation of surface and submarine volcanic effusions of basic up to acidic composition.

Serpentinites and Related Rocks

The serpentinites and related rocks are equivalent to the ultramafic magma associated with mafic volcanism of Hunting (1967), or as a member of ophiolite complexes (Church, 1983) or as a remnant crust abducted to continental crust (Gass, 1976), or a part of the Pan-African ophiolites of Elgaby et al. (1988). The massive serpentinites consist of antigorite, talc, chlorite, tremolite and carbonate mineral assemblages.

Older Granitoids

Older granitoids include the assemblage of felsic plutonic rocks of essentially intermediate composition, previously referred to as “Grey granites” by Hume (1935), or as “Synorogenic granites” by Sabet (1961, 1962 and 1972) or as “Older granites” by Elramly & Akaad (1960) and Akaad and Noweir (1980). Elramly and Akaad (1960) mentioned that these rocks are thought to have originated by granitization of older rocks, including both metasediments, usually of an amphibolitic nature, and epidioritic metagabbroid rocks. They are definitely younger than the Geosynclinal sediments and associated metavolcanics.

Quaternary & Wadi Sediments

Quaternary and Wadi sediments, consisting of detritus, sand, pebbles and rare boulders, are distributed allover the study area. They constitute the surficial cover of the main Wadis (dry valleys) and tributaries. They are generally formed by the weathering of local and adjacent rocks and their accumulation have been occurred during Quaternary time.

METHODS AND RESULTS

The following discussion describes some enhancement techniques and their results.

Gamma- ray Spectrometry

Airborne gamma-ray spectrometric data are used as an aid to geological (lithological and structural) mapping. Many times, there is a good correlation between patterns of the radiometric data and the unweathered rocks (Gunn et al., 1997). This technique is cost-effective and rapid for geochemical mapping of the radioactive elements: potassium, uranium and thorium. This section describes the results gained from the analysis of radiospectrometric data for the area under study. Study of these data was undertaken with the goal to recognize and understand the radiospectrometric signatures associated with host rocks carrying Au deposit.

Total- Count (TC) and the Three Gamma-Ray Spectrometric Maps

The four radiospectrometric maps (TC, K, eU and eTh, Figs. 3 to 6) show a great similarity with each other, concerning the general radiospectrometric features. These patterns mainly involve the general distribution, relief and gradient of anomalies as well as contours as seen on the four aeroradiospectrometric maps.

Generally, older granitoids manifest the highest radioelement concentration levels allover the exposed rock units in the study area. The surrounding rocks possess relatively lower levels and are associated mainly with serpentinites and metavolcanics. They show gradual gradients and low frequency anomalies on the T. C., K, eU and eTh maps. These four aerial radiospectrometric maps (Figs. 3 to 6) are characterized by gentle gradients, which run in various directions. It is worth mentioning that these gradients reflect the probable presence of contacts or fault that run in the same directions. Moreover, the Quaternary sediments show oval shaped anomalies, which take a NE direction on the eU map (Fig. 5). Um Salim gold mine is associated with low aeroradiospectrometric levels on all four aerial radiospectrometric maps and is correlated with the same NE trend direction (Figs. 3 to 6).

The Three Two-Element Ratio γ-Ray Spectrometric Maps

The eU/eTh ratio map (Fig. 7) shows that there are two groups of anomalies. The first group is composed of two anomalies which run in the NE direction and are associated with the contact between metavolcanics and serpentinites (northeast of the location of Um Salim gold mine). The second one is composed of three anomalies that are located at the end of a small Wadi and is oriented in a NE direction. These anomalies may be the locations of radioactive anomalies that need a ground check.

The eU/K and eTh/K ratio maps (Figs. 8 & 9) illustrate that they comprise two anomalies. The first (at the north) is directly correlated with the gold mine of Um Salim, but with some shift to the north. Whether due to original geographic location error on the geologic map or inaccuracy due to navigation error during airborne survey due to absence of GPS means or ….etc. The second anomaly, which is located to the southwest of the first one, may represent a new location of a Au deposits. This indicates that the ratio maps are the most reliable pathfinders to identify the locations of Au deposits. The two anomalies are correlated with the a NE trending fault.

Ternary or (Composite) Radioelement Images

A ternary radioelement map is a colour composite image generated by modulating the red (R), green (G) and blue (B) phosphors of the display device or yellow (Y), magenta (M) and cyan (C) dyes of a printer in proportion to the radioelement concentration values of the K, eTh, eU and T.C. grids. The use of red, green and blue for K, eTh and eU, respectively, is a standard for displaying gamma- ray spectrometric data. Blue is used to display the eU channel, since this is the noisiest channel and the human eye is least sensitive to variations in blue intensity. Areas of low radioactivity, and consequently low signal to noise ratios, can be masked by setting a threshold on the total- count grid. This reserves more colour space and ensures a better colour enhancement for the remaining data (IAEA, 2003). Figure (10) shows a ternary radioelement composite map from a high-resolution gamma- ray spectrometry survey, acquired over Um Salim gold mine area. Other types of composite colour images were used as follows:

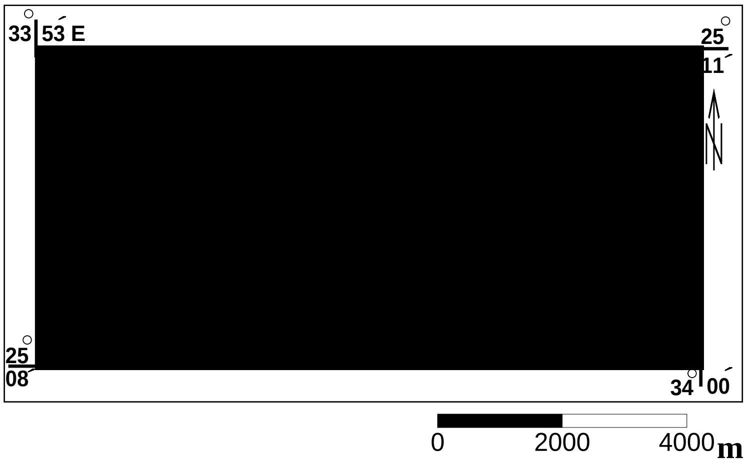
eU composite image (Fig. 12) = eU, eU/eTh and eU/ K

eTh composite image (Fig. 13) = eTh, eTh/eU and eTh/K

K composite image (Fig. 14) = K, K/eU and K/eTh

Ternary radioelement composite images

Potassium, thorium and uranium were assigned red, green and blue to create a composite RGB colour model. The resulting image (Fig. 10) comprises colours generated from the relative intensities of the three components and represents subtle variations in the ratios of the three bands. Normally, the thorium is assigned to green and uranium to blue, because the blue tends to reduce the poorest signal-to-noise ratio of uranium channel (Millingan and Gunn 1997). However, for this work, the composite image presented shows a better result.



Q *Quaternary & Wadi sediments*

go *Older Granitoids*

sp *Serpentinites*

mv *Metavolcanics*

m *Um Salim gold mine*

83 = Name of occurrence locality: Um Salim.

Hv = Ore class: Hydrothermal, vein type.

Msc = Geologic environment: Metamorphic, Schist.

M = Metallogenic age: Middle stage of the orogenic cycle.

Fault

LEGEND: Fig. (2): Metallogenic map of Um Salim gold mine area, Eastern Desert, Egypt. (Egyptian Geologic Survey and Mining Athority, 1978)

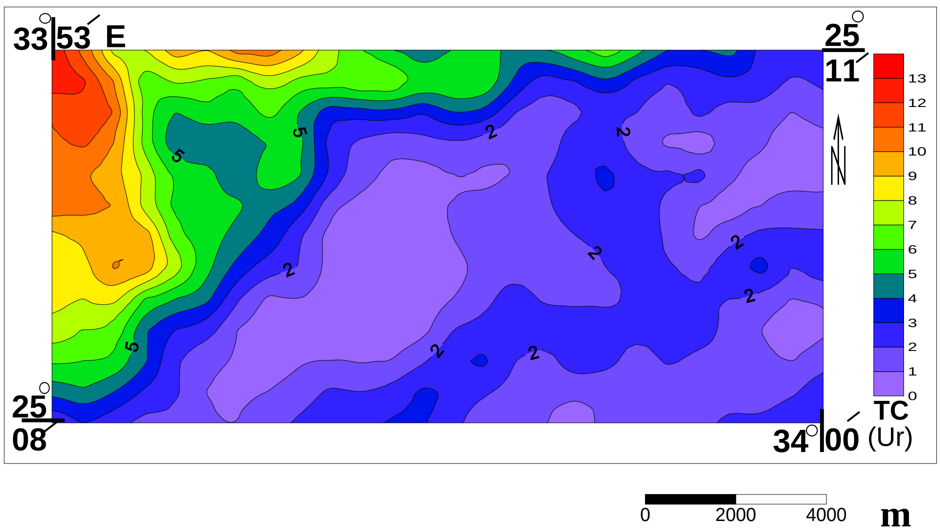


Fig. (3): Total-count airborne radioactivity contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984)

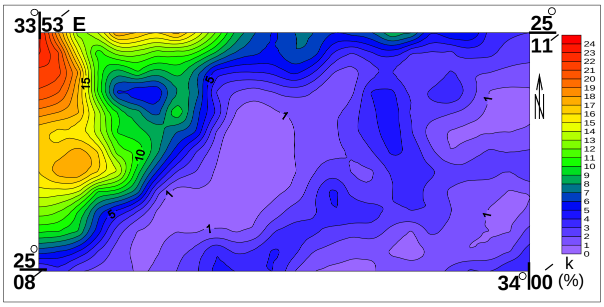


Fig. (4): Potassium airborne spectrometric contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984)/ Map values in units = One tenth of 1 % K.

0 2000 4000 m

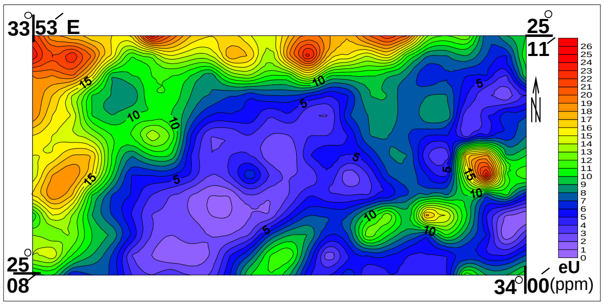


Fig. (5): Equivalent uranium airborne spectrometric contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984). Map values in units = One tenth of 1 ppm eU

0 2000 4000 m

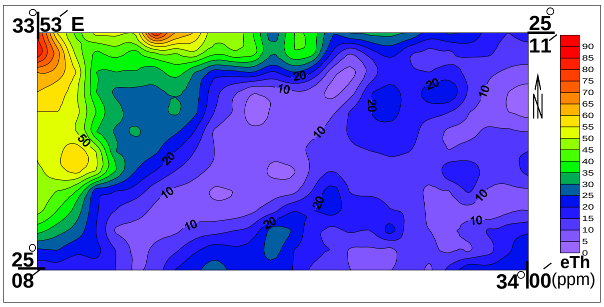


Fig. (6): Equivalent thorium airborne spectrometric contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984). Map values in units = One tenth of 1 ppm eTh

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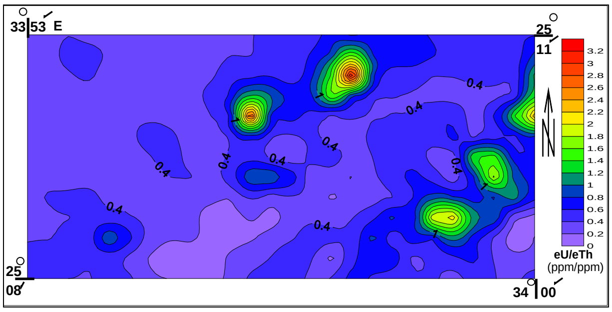

Fig. (7): Equivalent uranium/equivalent thorium ratio contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984). Map values in units = One hundredth of ppm eU/ppm eTh

0 2000 4000 m

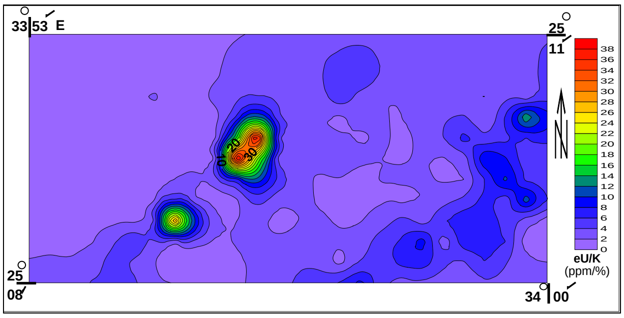

Fig. (8):Equivalent uranium/potassium ratio contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984). Map values in units = One hundredth of ppm eU/percent K

0 2000 4000 m

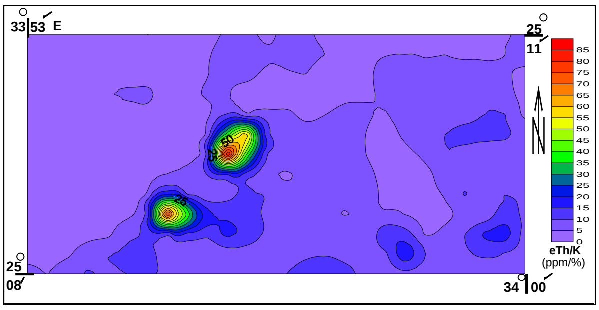

Fig. (9): Equivalent thorium/potassium ratio contour map, Um Salim gold mine area, Eastern Desert, Egypt (Aero-Service, 1984). Map values in units = One hundredth of ppm eTh/percent K

0 2000 4000 m

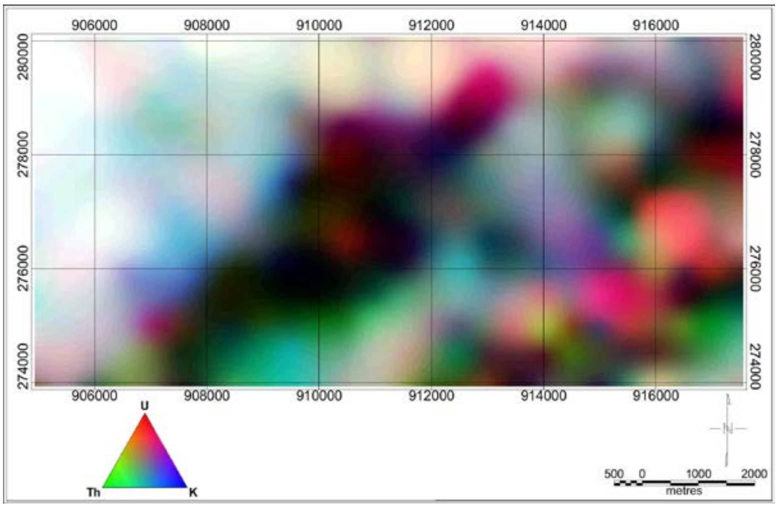

Fig. (10): Ternary radio-element composite image (RGB= eU, eTh & K) of Um Salim gold mine area, Eastern Desert, Egypt

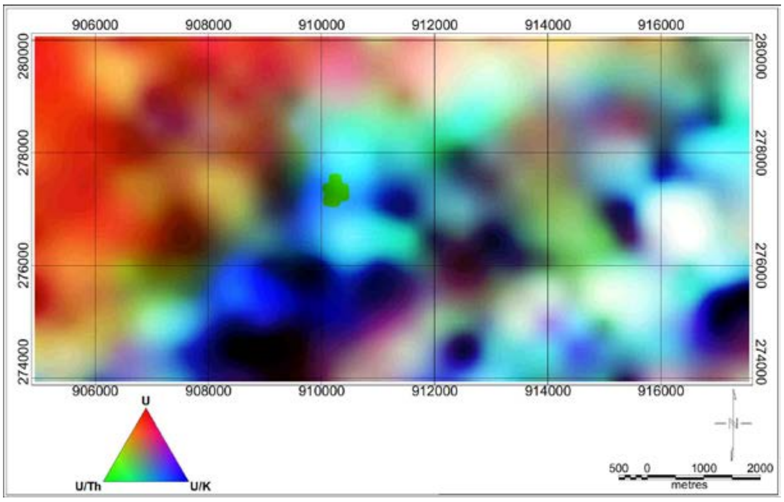

Fig. (11): eU composite image of Um Salim gold mine area, Eastern Desert, Egypt.

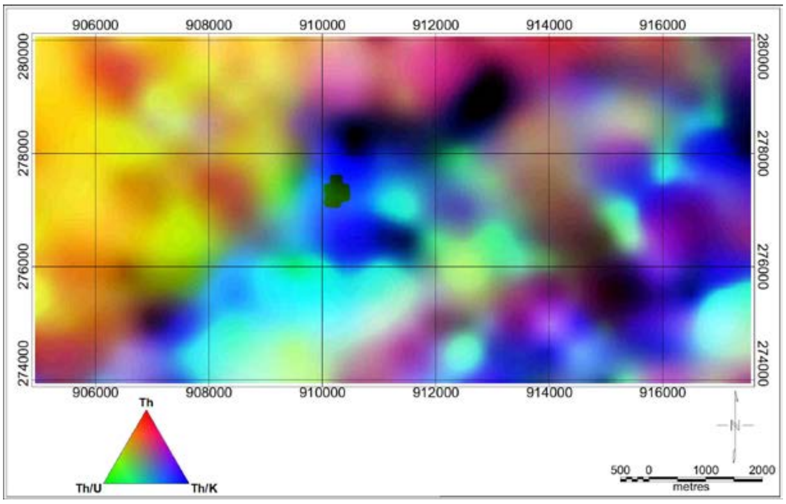

Fig. (12): eTh composite image of Um Salim gold mine area, Eastern Desert, Egypt.

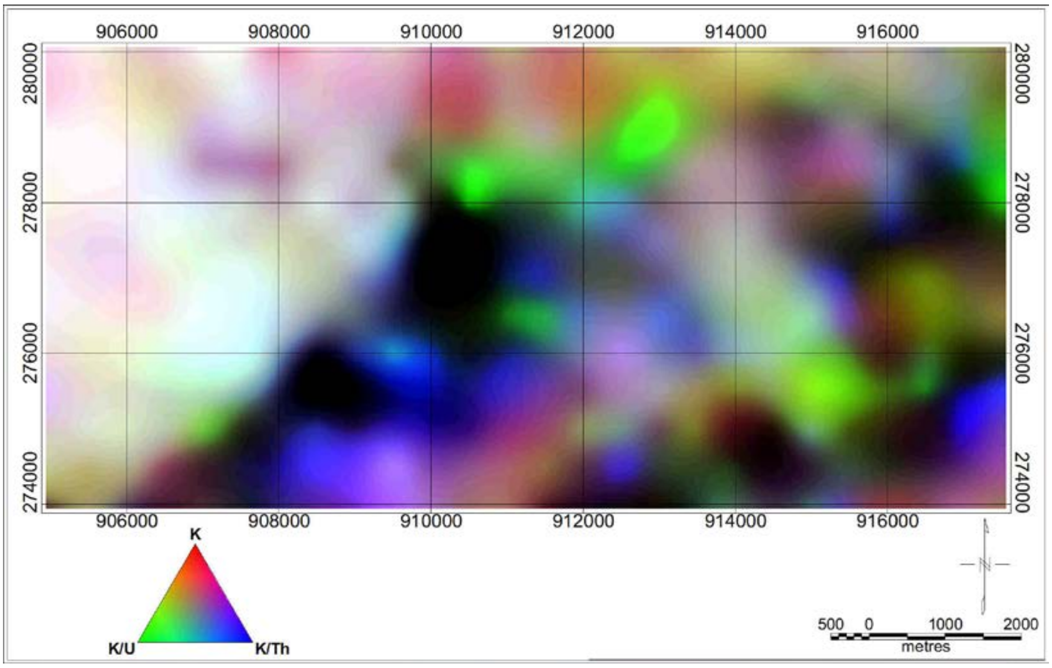

Fig. (13): Potassium composite image of Um Salim gold mine area, Eastern Desert, Egypt.

The composite image presents strong spatial correlations with the known geologic units. The metavolcanics and serpentinites appear darker than the surrounding units, indicating lower concentrations in K, eU, and eTh. The older granitoids - which are normally characterized by their relatively strong radiospectrometric responses - are clearly visible on the composite radioelement image and can be easily discriminated from the lower ones (areas in white colour). There are some anomalies with different colours, which show strong spatial correlations with the zones of anomalously high eU and eU/eTh. Um Salim gold mine shows low radioelement concentrations (black colour) on the radioelement composite image (Fig. 10).

eU composite image

The eU composite image (Fig. 11) combines eU (in red) with ratios eU /eTh (in green) and eU/K (in blue). This image emphasizes the relative distribution of uranium and highlight areas of uranium enrichment. Uranium enrichment, in specific circumstances, provides a sensitive pointer to many non-radioactive mineral deposits, e. g., gold and copper deposits (Duval, 1983). The eU composite image also reflects lithologic differences and could be useful in geologic mapping problems. The white colour, on Fig. 11, is a good pointer to areas where uranium has been preferentially enriched relative to thorium and potassium. These white coloured zones are mainly associated with the eU/eTh anomalies (Fig. 7). It is noticeable that the older granitoids is of relatively higher uranium content (red colour) than the other rocks.

eTh composite image

The eTh composite image (Fig.12) combines eTh (in red), with the ratios eTh/eU (in green) and eTh/K (in blue). The composite eTh image provides useful information regarding the identification of anomalous zones of thorium concentration. It provides a remarkable good colour discrimination between the older granitoids (yellow colour) and serpentinites. The latter is displayed as a zone dominated by blue colour, which sharply contrasts yellow coloured zone associated with older granitoids. This indicates an abrupt change in compositions of the rocks. Um Salim gold mine shows low concentrations (blue colour).

Potassium composite image

The potassium composite image (Fig. 13) combines K (in red) with the ratios K/eU (in blue) and K/eTh (in green). This image shows the overall spatial distribution of the relative potassium concentrations. It also highlights areas where hydrothermal alterations - associated with potassium enrichment (zones of potash alteration)- might have occurred. These alteration zones are frequently associated with the formation of various types of non-radioactive mineral deposits, e. g., copper and gold deposits (Duval, 1983). Um Salim gold mine can be distinguished on the potassium composite image as dark colour, varying from the blue to black colours. The older granitoids as well as Quaternary and Wadi sediments are characterized by bright colours (high values).

RELATIOSHIP BETWEEN UM SALIM GOLD DEPOSIT AND THE TRENDS OF INTERPRETED STRUCTURAL LINEAMENTS

The geophysical anomalies usually align themselves along definite axes forming trends. Therefore, the technique of trend analysis is to define statistically the major tectonic trends. A two – dimensional trend analysis for the interpreted structural lineaments, as traced from the geologic and total – count radiometric maps was carried out to define the relationship, which might exist between the location of the Um Salim gold mine and the major trends of these lineaments of the area under consideration.

The length and direction clockwise from north of all trends for geology and TC were measured. The length of trends within 100 range of azimuth was summed to give a percentage of the total length and number of all trends. The given results are drawn as rose diagram to show the distribution of different trends in the study area.

Four major structural trends were identified, and found to have four directions: NE, NW, N-S and WNW. Close examination and comparative inspection of the prominent peaks (Fig. 14 & 15) show clearly the pronounced development of a NE trend, associated with the structural lineaments as traced from the geological and TC radiometric maps (surface structures). This trend was traced as a main trend from the geological structures and the total-count radiometric map. Consequently, this trend plays an effective role in the structural framework as well as the radioactive occurrences in the area under study.

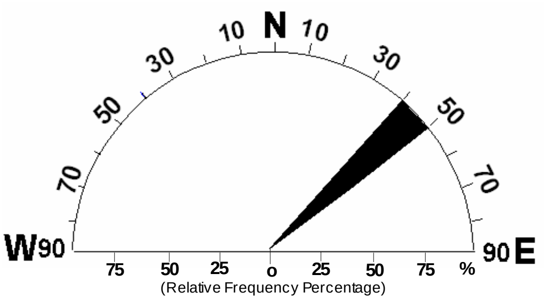

Fig. (14): Rose diagram of the gelogical structure (Fig. 2), Um Salim gold mine area, Eastern Desert, Egypt.

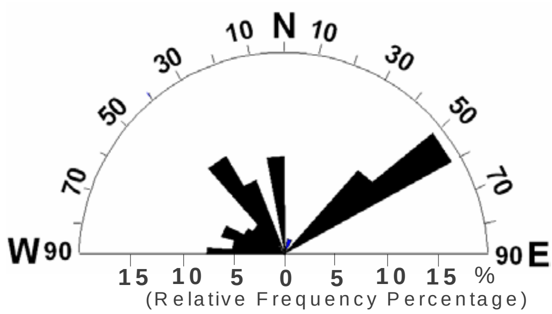

Fig. (15): Rose diagram of the T.C. radiometric lineaments (Fig. 3), Um Salim gold mine area, Eastern Desert, Egypt.

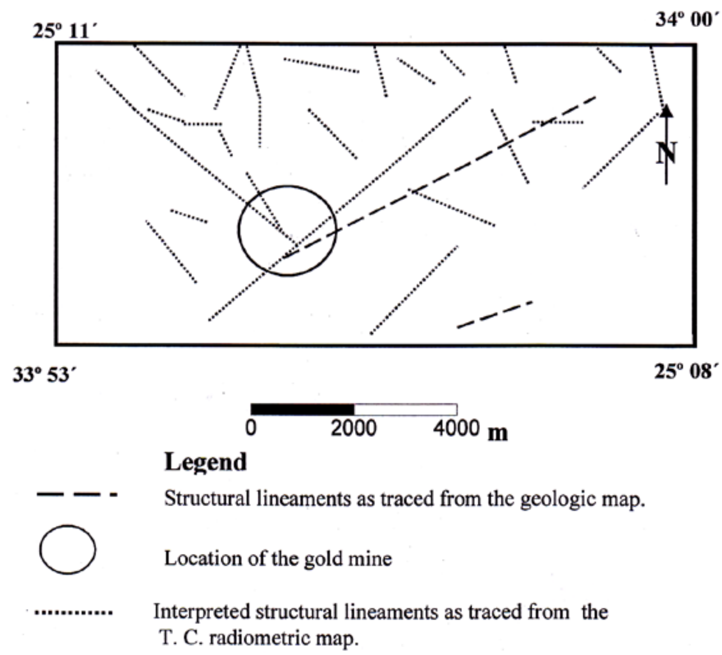

Fig. (16): Geologic and interpreted structural lineaments as inferred from TC radiometric data

CONCLUSIONS

It is found that the ratio maps are useful for determining the location of Um Salim gold mine. The two ratio maps (eU/K and eTh/K) illustrate that there are two anomalies; one of them (at the north) is directly correlated with gold mineralization of Um Salim mine, but with some shift to the northeast. Whether due to original geographic location error on the geologic map or inaccuracy due to navigation error during airborne survey due to absence of GPS means ..….etc. Moreover, the second anomaly, which is located to the southwest of the first one, may be a new location of a similar gold occurrence. Therefore, the eU/K and eTh/K ratios are useful for determining the location of Um Salim gold mine.

The Ternary radioelement and the ratio maps offer much in terms of lithologic discrimination based on colour differences. The observed three radioelement zones show a fairly close spatial correlation with the geologically mapped lithologies. The eU colour composite image was useful in defining zones of preferential uranium enrichment. These may provide good prospects for uranium exploration. The eTh colour composite image was useful in defining thorium enriched zones. These zones (eU/K and eTh/K) can be used as diagnostic exploration guide for various types of non-radioactive mineral deposits (e. g., copper and gold), which involve changes in the relative concentrations of potassium in the original geologic environment. Four major tectonic trends were identified, and found to have the following directions: NE, NW, N-S and WNW. The new disclosed anomaly at the SW of the main one having similar appearance on both eU/K and eTh/K composite maps, is highly recommended for further ground geophysical, geological and analysis of collected samples to prove or disprove the occurrence of gold.

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