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GEOPHYSICAL STUDIES USING GAMMA-RAY SPECTROMETRIC AND SELF-POTENIAL TECHNIQUES OF MAKHRAG EL-EBEL AREA, SOUTH GABAL MONQUL, NORTH EASTERN DESERT, EGYPT

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دراسات جيوفيزيائية بإستخدام تقنيات المسح الإشعاعى الطيفى والجهد الذاتى لمنطقة مخرج الإبل، جنوب جبل منقول، شمال الصحراء الشرقية، مصر

الخلاصة: تم تطبيق المسح الإشعاعى الأرضى والمسح بطريقة الجهد الذاتى وذلك لتحديد وتتبع نطاقات الشاذات الإشعاعية أفقيا ورأسيا بمنطقة مخرج الإبل, شمال الصحراء الشرقية، مصر. والمنطقة مغطاة بصخور القاعدة والتى تعود فى العمر إلى عصر ماقبل الكامبرى المتأخر. هذه الصخور ممثلة بالصخور البركانية وصخور الجرانيتات الحديثة و المخترقة بسدود و قواطع القاعده وعروق من الكوارتز المتمعدنة بالنحاس والأحدث فى العمر و يمكن تلخيص هذه النتائج فى الأتى:-

تم معالجة وتحليل نتائج المسح الإشعاعى و التى بينت أن منطقة مخرج الإبل عالية نسبياً من الناحية الإشعاعية حيث يتراوح بها النشاط الإشعاعي الكلي من ٣,٢٥ إلي ٦٧,٣ وحدة قياس إشعاعى ومن ٠,٨٣ إلي ٦,٣ % للبوتاسيوم ومن ١,٧٢ إلي ٥٢,٨ جزء في المليون لمكافىء اليورانيوم و من ٢,٠٤ إلي ٦٤,٢ جزء في المليون لمكافيء الثوريوم وقد شيدت خريطة اليورانيوم المعتمدة علي خلط صور الألوان المختاره للعناصر الإشعاعية الثلاثة (البوتاسيوم واليورانيوم والثوريوم) لتحديد نطاقات شاذات اليورانيوم العالية.

كما أمكن معالجة المعطيات الإشعاعية الطيفية الأرضية كيفاً وكماً عن طريق تطبيق بعض التقتنيات الإحصائية المناسبة، والتى منها "تحليل المعامل" التى استخدمت فى اختزال المتغيرات الإشعاعية السبعة (العدد الكلى، والبوتاسيوم، والثوريوم المكافئ، واليورانيوم المكافئ ونسبها الثلاث إلى بعضها البعض) إلى ثلاثة مقادير معاملية (ف١ ، ف٢ ، ف٣)

القيم السالبة القوية للجهد الذاتى والتى تتراوح من (-٤٤,٢ إلى -١٤٧,٢ مللى فولت) والتى تم تسجيلها على سدود وقواطع القاعدة وعروق الكوارتز المخترقة لصخور الجرانيتات الحديثة فى وسط الجزء الجنوبى من منطقة الدراسة أظهرت خريطة الجهد الذاتى ترابط شديد بينها وبين خريطة مكافىء اليورانيوم، حيث كانت أعلى قيم لمحتوى اليورانيوم مرتبطة بوجود سدود وقواطع القاعدة وعروق الكوارتز المخترقة لصخور الجرانيتات الحديثة والتى أيضاً سجلت أعلى قيم سالبة للجهد الذاتى وهذا يعكس أن وجود اليورانيوم مرتبط بتمعدنات النحاس والتى أدت لتسجيل أعلى قيم سالبة للجهد الذاتى.

ABSTRACT: *Gamma-ray spectrometric and self-potential (SP) surveys were carried out to determine the radioactive anomalous zones and to follow their extensions at Makhrag El-Ebel area, south Gabal Monqul, Northeastern Desert. The study area and its surroundings is built up of igneous and metamorphic rocks of late Precambrian age. The basement rocks of Makhrag El Ebel area are part of the Pan African belt. They comprise Dokhan volcanics which are distinguished into basic and acidic volcanic, younger granite, dolerite dykes, quartz and barite veins. These rocks are traversed by dry wadies.*

The ground gamma-ray spectrometric data have been analyzed qualitatively and quantitatively by applying specific interpretation techniques. These data revealed that, the study area shows relatively wide range of concentrations, oscillating from 3.25 to 67.3 Ur, 1.72 to 52.8 ppm, 2.04 to 64.2 ppm and from 0.83 to 6.3 %, for the total count (T.C.), equivalent uranium (eU), equivalent thorium (eTh) and potassium (K), respectively. The uranium composite image showed that, the highly radioactive parts are mainly associated with the younger granite rocks. Also, the interpreted radiometric lithologic unit map reflects a distinct content of radioelements for each of the interpreted radiometric lithologic (IRL) units, and probably, common features that could be found in the lithologic composition for each unit.

The SP data of the surveyed area exhibit moderate to very high anomalies, with amplitudes vary from -147.2 to +123.2 mV. The very high anomalies (relatively high negative amplitudes -44.2 to -147.2) are associated with strong surface mineralization or shallow ore bodies, these anomalies zones associated with younger granite which has fracture fillings with copper (Cu) and barite mineralization and a basic dyke which is located in the centeral southern part of the selected area as confirmed from the field observations. The moderate anomalies (relatively moderate negative amplitudes -8.4 to -44 mV), which located in the northern part of mapped area, can be related to ground water and wadi sediments, as confirmed from the field observations. The parameters of the source causative bodies, such as the locations, depth, polarization angle and electric dipole momentum were estimated for six SP anomaly lines (profiles), representing six anomalies. A fair agreement was found among the radiometric and SP anomalies at some places of the study area. This may indicate that the surface radiometric mineralization continued to deeper depths at these parts.

1. INTRODUCTION

Makhrag El-Ebel area is situated in the northern part of the Eastern Desert of Egypt. It lies between latitude 27°48'54.25"N and 27°49'28.20"N and between longitude 33° 3'31.73"E and 33° 4'8.90"E, located at about about 40 Km to the southwest of Ras Gharib city (Fig. 1).

The result of previous geological and geochemical studies had identified high copper grades in South Monqul (Makhrag El-Ebel area) associated with the alteration zone with 0.1 to 0.5% of copper with potassic alteration, meanwhile the outer zone (0.3 to 0.6 % Cu) was found to be in contact with the phyllitic–argillic alteration. The border zone is characterized by an abundance of quartz veins and veinlets that are mostly auriferous and were the sites of old mining working. A considerable part of the copper mineralization (0.4 to 1 % Cu) is also linked with the phyllitic–argillic alteration (Botros et al., 1997).

Copper provinces were extensively investigated using different geochemical and geophysical techniques, while uranium poses a particular problem regarding the subsurface geophysical exploration. So, the objectives of the present study are to identify the concentrations of the radioactive elements uranium (U), thorium (Th) and potassium (K), using the ground gamma-ray spectrometry method and to delineate any possible spatial relation with the observed Cu mineralization in the area, and to follow the exposed surface Cu-U mineralization at deeper depths and obtain information about the probable lateral and vertical extensions through the application of the self-potential electrical method.

2. GEOLOGIC SETTING

The basement rocks of Makhrag El Ebel area are part of the Pan African belt. They comprise Dokhan volcanics which distinguished into (basic and acidic volcanic), younger granite, dolerite dykes, quartz and barite veins and wadi sediments (Fig. 1).

a) Dokhan Volcanics

The Dokhan volcanics lies on the western and northern parts of the study area (Fig. 1). These volcanics constitute a thick sequence of stratified lava flows of basalt, andesite, dacite, rhyodacite and rhyolite together with subordinate sheets of ignimbrite and a few intercalations of pyroclastics. The volcanics grade into reddish to deep purple color of imperial porphyry composed of andesite and dacite fragments (Abdel Wahed et al., 2010).

b) Younger granites (Biotite granite)

They are the dominant rock unit in the study area represented around wadi Makhrag El Ebel which lies in the central and southern parts of the study area (Fig. 1). It is low to moderate relief, reddish grey, massive, medium to coarse-grained, Jointed, fractured and enclose xenoliths of tonalite and metavolcanics with different sizes. Porphyritic varieties are also observed. It composed mainly of K-feldspar, plagioclase, quartz and biotite (Abdel Wahed et al., 2010).

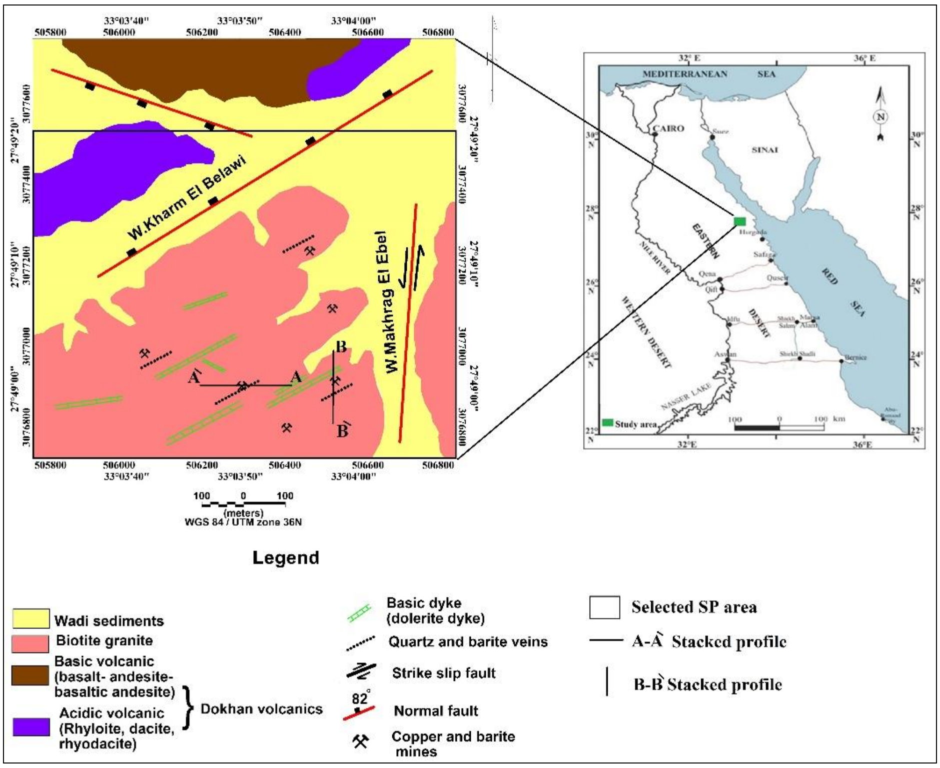

Fig. (1): Location and Geologic Map of Makhrag El-Ebel area, North Eastern Desert, Egypt, modified after Abdel Wahed et al., 2010.

c) Dykes

The various rock units of the study area are dissected by numerous dykes and veins. Dykes can be distinguished into dolerite types. Dolerite dykes are fine- to medium-grained, dark greenish grey in color, composed essentially of plagioclase, olivine and pyroxene with some opaque minerals (Abdel Wahed et al., 2010).

d) Quartz and barite veins

Quartz veins crosscut younger granite (YG) and were recorded especially in the mineralized zones in wadi Makhrag El Ebel area. The quartz veins are milky white in color varying in thickness from 10 to 50 cm (Abdel Gawad et al., 2015).

Barite veins crosscut the YG in the mineralized zone, rhyodacite rhyolite and dacite porphyry and range from 15 cm to 2 m in thickness (Abdel Gawad et al., 2015).

e) Wadi sediments

Composed of rock fragment of acidic volcanics (rhyolite, dacite and rhyodacite), basic volcanics (basalt, andesite and basaltic andesite), biotite granite, dolorite, quartz, barite, copper minerals and alluvium sands. They vary in size range from few millimeters to coarse grain gravels. They are angular to subangular, subrounded to rounded fragments (Abdel Gawad et al., 2008).

3. GROUND GEOPHYSICAL SURVEYS

3.1. Gamma-Ray Spectrometric Survey

Gamma-ray surveying is widely used for geological and geochemical mapping as well as exploration of radioactive minerals. Also, gamma-ray survey is conducted for environmental studies to the evaluation of the radon risk (Moxham, 1965; Charbonneau et al., 1976; Durrance, 1986; Grasty et al., 1991 and IAEA, 2003).

Hence, systematic ground gamma-ray measurements for the total gamma-ray activity (TC) and the three individual radioactive elements (K, eU and eTh) were taken along nearly North-South profiles, on a grid pattern of 20 m station separation and 40 m line spacing, for Makhrag El Ebel area. Gamma-ray measurements were carried out, using a portable hand-held radiation spectrometer, model GS (512), with internal data storage and PC data retrieval.

3.2. Self-Potential Survey

The self-potential (SP) method is based upon measuring the natural potential developed in the earth by electro-chemical actions between the minerals and subsurface fluids or by electro-kinetic processes, involving the flow of ionic fluids.

The method was first used for mineral exploration, it has found increasing use for geothermal, engineering and environmental applications (Corwin and Hoover, 1979). As the method offers relatively rapid field data acquisition, it is often cost-effective for reconnaissance or initial investigation of an area, prior to more intensive studies, using other geophysical and geochemical techniques (Telford et al., 1990; and Parasnis, 1997).

The SP survey in the studied area was conducted along 26 profiles trending NS with profile spacing 40 m, 20 m station separation and 650 m length to each one in the same grid of gamma-ray spectrometric survey, one station was selected as a base station and all potentials were referenced to that point. The base station located at a calm SP potential point as possible and one of the two electrodes put in this station. At the base station, the instrument was adjusted to zero value by connecting it to the non- polarizing electrodes staying at the same station. All the base stations were reduced to the zero value of the general base station (base station for the whole area). The other electrode (rolling electrode) was moving on the grid stations.

4. DISCUSSION AND INTERPRETATION

4.1. Interpretation of the Gamma-Ray Spectrometric Data

4.1.1 Qualitative Interpretation

a) Total-count and radioelements maps

The Qualitative interpretation of ground gamma-ray survey data depends mainly upon the excellent correlation between the general pattern of the recorded measurements and the surface distribution of the various types of rock units recorded in the geologic map (Fig. 1).

The investigation of the texture of the radiospectrometric contour lines and their signatures could be an aid in interpretation of the surface geology (lithology and structure) of the surveyed area.

Close investigation of the various radiospectrometric maps (TC, eU, eTh and K) shows that there is a great similarity between these four maps (Figs. 2, 3, 4 and 5), as concerning the relief of general features, the gradient of contours, the distribution of anomalies, and the trend of radiometric surficial structures, etc. The four maps were thoroughly investigated, especially where the agreement is best, to establish the general radiometric characteristic features and levels for the different rock types in the study area. The careful inspection of the total-count and the three-radioelement maps (eU, eTh and K) could show- at a glance-that the distribution of the high radioelement concentrations is highly controlled by younger granite and their tributaries dissecting the study area which are exposed generally on the northwestern and southern parts of the study area.

Generally, the total-count, eU and eTh maps of the surveyed area display relatively wide range of radioactivity ranging from 3.25 to 67.3 Ur, 1.36 to 52.8 ppm and 2.04 to 64.2 ppm respectively. The correlation of these radiometric maps with the geologic map of the area (Fig. 1), illustrates different radioactivity levels within and between the different rock types exposed in the study area. Generally, the three maps can be divided into three distincit zones with overlap radioactivity levels. The first zone is characterized by a low radioactivity values, which is recorded over a small area in the northern part of the study area associated with dacite and basaltic andesite (Figs. 2, 3 and 4). The second zone represents intermediate radioactivity level, which is represented mainly by the wadi deposits (Figs. 2, 3 and 4). The third and highest radioactivity zone is associated with younger granite rocks (Figs. 2, 3 and 4). On the other hand, the potassium map shows values ranging from about 0.83 to 6.3 % all over the exposed rock units in the study area. The average abundance values recorded on the total count gamma radiation (TC in Ur), and the absolute concentration of the three radioelements (eU in ppm, eTh in ppm and K in %) reach 5.67, 2.7, 6.83 and 2.5 respectively.

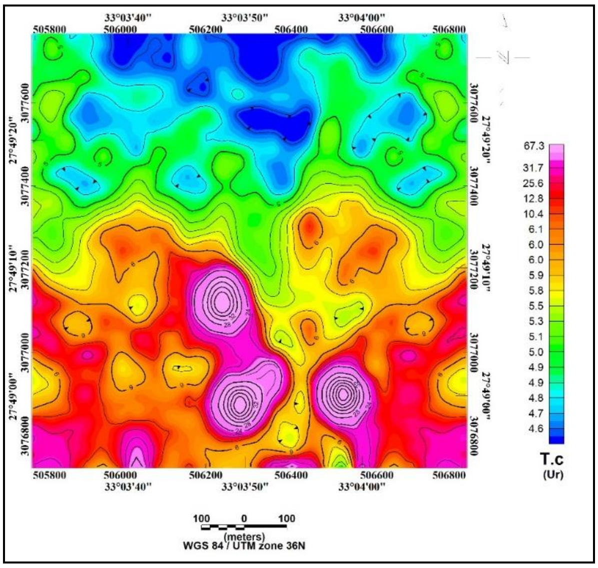

Fig. (2): Total count filled colored contour map (in Ur), Makhrag El-Ebel area, Northeastern Desert, Egypt.

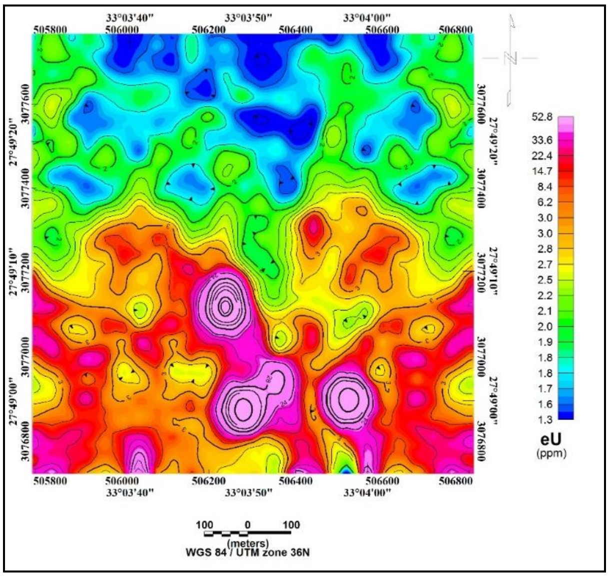

Fig. (3) : Equivalent uranium filled colored contour map (in ppm), Makhrag El-Ebel area, Northeastern Desert, Egypt.

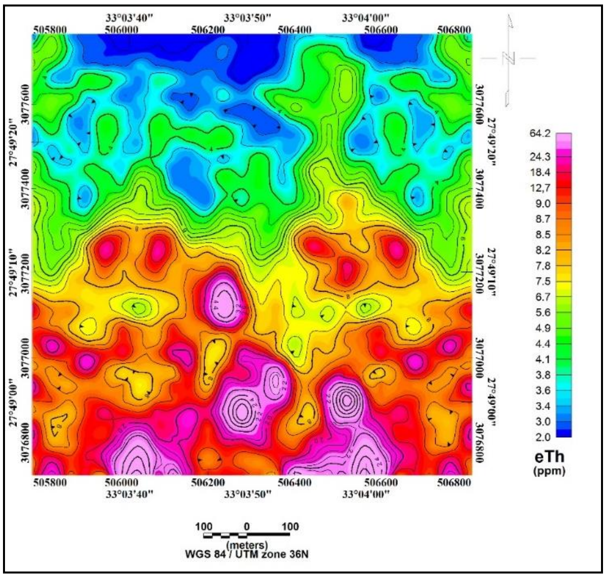

Fig. (4): Equivalent thorium filled colored contour map (in ppm), Makhrag El-Ebel area, Northeastern Desert, Egypt.

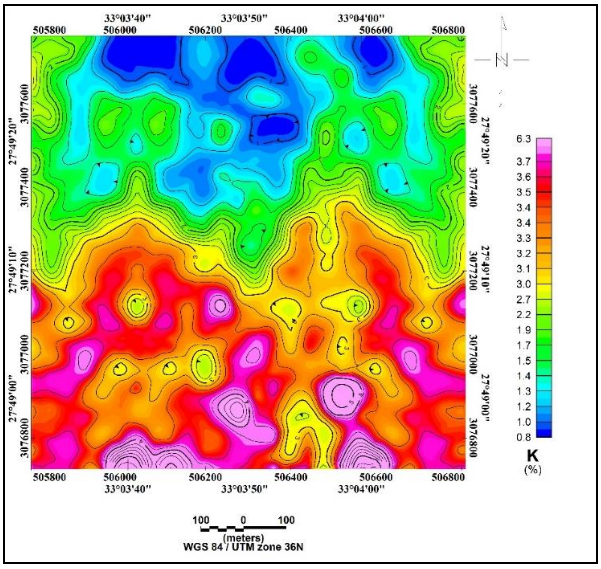

Fig. (5): Potassium filled colored contour map (in %), Makhrag El-Ebel area, Northeastern Desert, Egypt.

b) False-color uranium composite image

The relative concentration of uranium with respect to both potassium and thorium is an important diagnostic factor in the recognition of probable zones of enriched uranium concentration, which could provide good prospects for further uranium exploration (IAEA, 2003). Therefore, the uranium composite image (Fig. 6) provides useful information regarding the identification of anomalous zones of enriched uranium concentration. The uranium composite image combines eU (in red) with two ratios eU/eTh (in green) and eU/K (in blue). As illustrated from the image, the uranium anomalous zones are displayed as bright white color areas, coinciding with the younger granite rocks located in the southern part of the study area. On the other hand, the dark color areas are distributed in the Northern part of the study area coinciding with the dacite, basaltic andesite and wadi sediments.

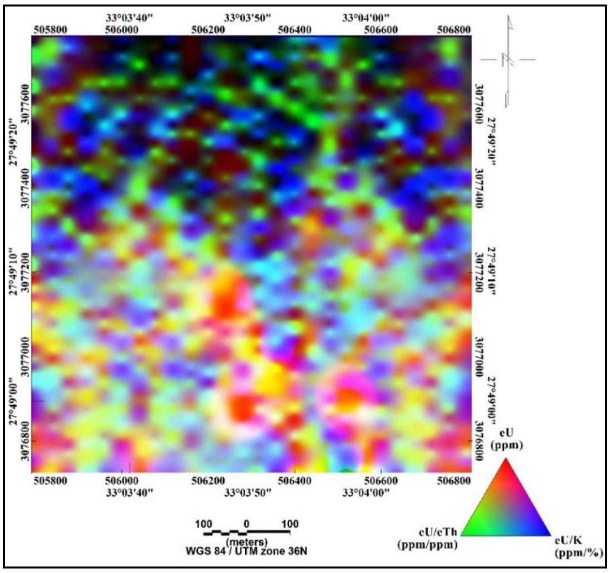

Fig. (6): False – Color uranium composite image, Makhrag El-Ebel area, Northeastern Desert, Egypt.

4.1.2 Quantitative Interpretation of the Gamma-Ray Spectrometric Data

a) Factor Analysis technique

Factor analysis is a multivariate statistical technique, which attempts to create a minimum number of new fundamental quantities (factors), which are linear combinations of the original ones, such that the new variables contain the same amount of information, as do the originals. In such a way, it becomes possible to describe a set of variables in terms of a smaller number of indices or factors, that elucidate the relationship between the original variables and the variation in the data set (Manly, 1986).

In the present study, the available geophysical data (TC (Ur), eU (ppm), eTh (ppm) K (%), eTh/K, eU/K and eU/eTh) are linearly combined, giving rise to new fundamental quantities (factors), which can be named and simply interpreted on the light of sound geologic reasoning without significant loss of information.

The correlation matrix of the seven radiospectrometric variables table (1) shows that, there is a high positive correlation between the T.C and the three variables (eU (ppm), eTh (ppm) and K (%)) of about 44%, 70% and 80%, respectively. The eU/K ratio is correlated positively with TC and eTh, while others are correlated negatively. A weak positivity correlation of eTh/K is shown with the TC and eTh, meanwhile it shows strong positive correlation with the eU/K. The negative correlation distinguishes between eU/eTh and eU, K, eTh and eU/eTh, while it is correlated positively strongly with the eTh and eU/K.

Table (2) shows the three principle factors (F1, F2 and F3) extracted from the previous table (1), after their rotation by using the varimax method. It can be concluded from this table (2) that, factor one (F1) has an appreciably high positive loading with the four variables T.C, eU, eTh and K as 90%, 85 %, 95 % and 65 %, respectively (Table 2). F1 exhibits weak positively loading with the eU/eTh and eU/K, eTh/K as the negative values attaining 12%, 20 %, and 0.6 % respectively, Therefore, F1 can be identified as the factor of integrated radioactivity or the factor of uranium exploration (Mostafa et al, 1990). The second factor (F2) is highly loaded with the eU/eTh and K as 95 % and 60 %, respectively, and is negatively loaded with the T.C and eTh/ K as 0.7 % and 7 %, respectively. F2 is also, weakly loaded factor with the eU, eTh and eU/K by 42 %, 0.8 % and 13%, respectively. The third factor (F3) is a negatively loaded factor with the K only by - 35%, and is positively loaded with the eU, eTh, eU/K, eTh/K and eU/eTh by 23%, 18%, 96%, 66% and 19%, respectively. It is weakly loaded factor with the T.C by 0.7%.

Clustering of these three factors (F1, F2 and F3) together in a ternary composite map (Fig. 10) is expected to give a better information for interpretation. It could be utilized in the geochemical mapping of major rock units. This map was found to be comparable to a great extent with the geological map (Fig. 1), and identifies the area of high radioactivity in the study area. When it is well examined together with the three factor scores maps (Figs. 7, 8 and 9) as well as the geologic map (Fig. 1) it will be highly effective in separating detailed units as those inferred from the geological map. The result of matching these maps collectivelly will establish an interpreted radiometric lithologic unit (IRLU) map as an end product of this process (Fig. 11).

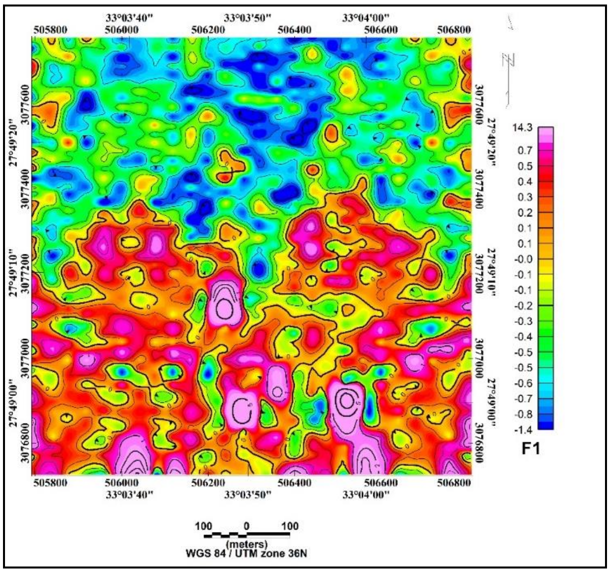

Fig. (7): Filled Colored contour map of the first factor (F_1) map, Makhrag El-Ebel area, Northeastern Desert, Egypt.

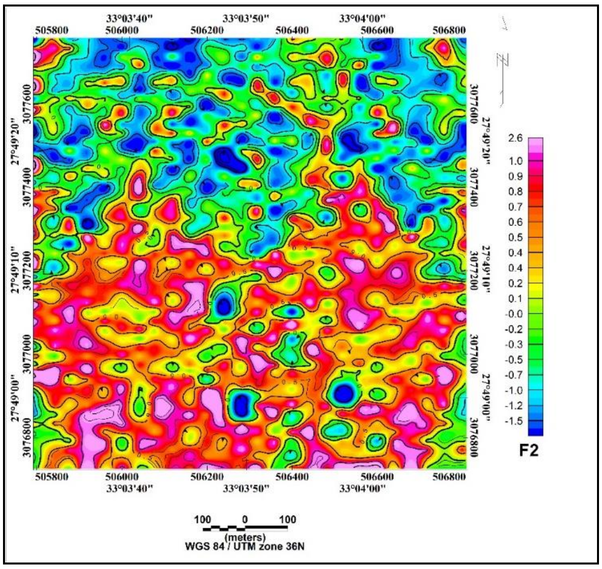

Fig. (8): Filled Colored contour map of the second factor (F_2) map, Makhrag El-Ebel area, Northeastern Desert, Egypt.

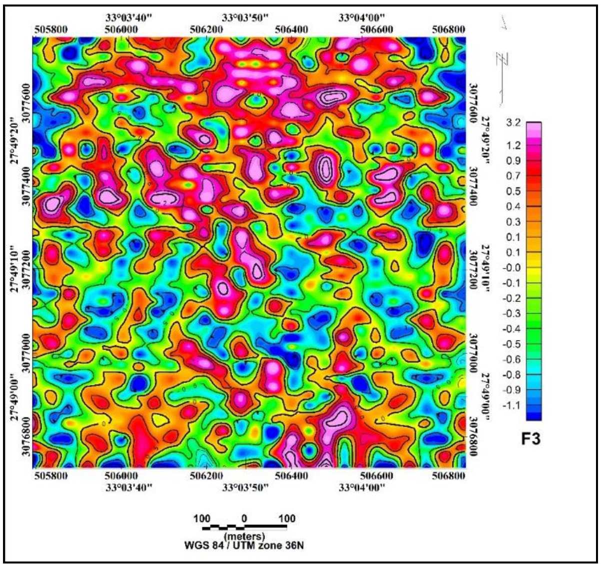

Fig. (9): Filled Colored contour map of the third factor (F_3) map, Makhrag El-Ebel area, Northeastern Desert, Egypt.

The Interpreted Radiometric Lithologic Unit (IRLU) map

The interpreted radiometric lithologic unit map (Fig.11) reflects a distinct content of radioelements for each of the IRL units, and probably, common features that could be found in the lithologic composition for each unit. Consequently, the identity and contacts of some mapped rock exposures or units were ascertained through the work, while others were modified, subdivided or partially corrected on the basis of their radioelements (geochemical content).

b) Statistical treatment of the ground spectrometric data

Using the Geosoft package (Geosoft, 2010), the gamma-ray spectrometric data within every rock unit have been extracted in the XYZ format and evaluated with simple statistical applications. Calculations of the arithmetic mean ($\overline{x}$), standard deviation (S) and coefficient of variability (C.V.) have been carried out on the eU, eTh, K, eU/eTh and eU/K for each of the whole data of the study area. Also, the statistical analysis of the data includes minimum and maximum values, as shown in Table (3).

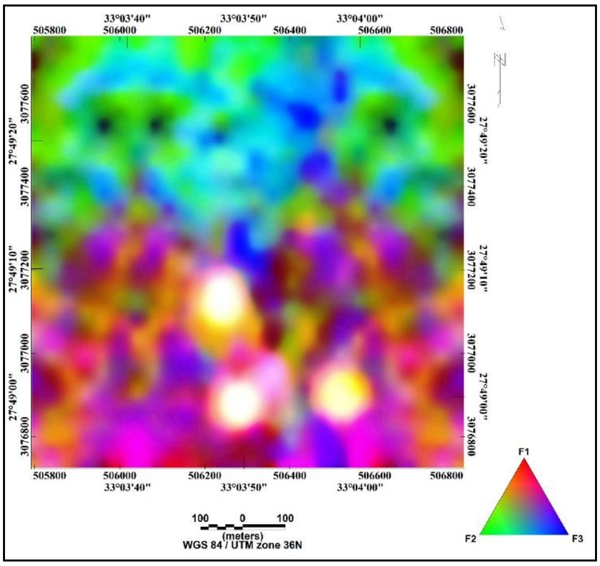

Fig. (10): Composite image of F1, F2 and F3 factor scores, Makhrag El-Ebel area, Northeastern Desert, Egypt.

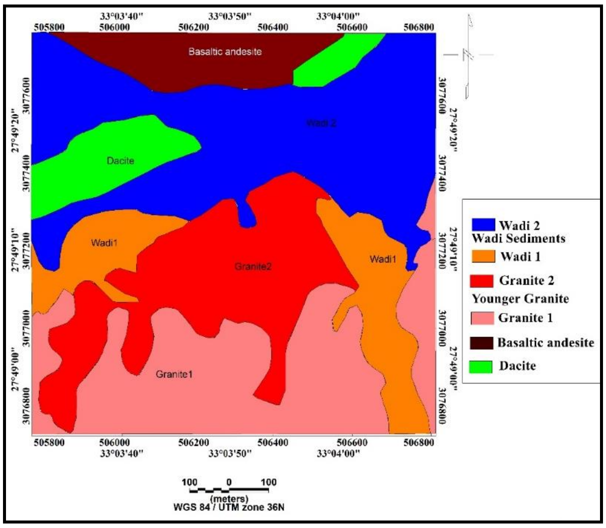

Fig. (11): Interpreted radiometric lithologic unit (IRLU) map, Makhrag El-Ebel area, Northeastern Desert, Egypt.

Table (1): Correlation coefficient between the seven data variables, Makhrag El-Ebel area, Northeastern Desert, Egypt.

Variables	T.C (Ur)	K %	eU (ppm)	eTh (ppm)	eUeTh	eUK	eThK
T.C (Ur)							
K (%)	0.443						
eU (ppm)	0.700	0.741					
eTh (ppm)	0.805	0.628	0.917				
eUeTh	0.114	0.564	0.542	0.211			
eUK	0.251	-0.127-	0.453	0.386	0.325		
eThK	0.113	-0.577	-0.084	0.126	-0.535	0.547	0

Table (2): Varimax factor loadings matrix for the seven radiospectrometric variables, Makhrag El-Ebel area, Northeastern Desert, Egypt.

Variables	Rotated factors		
	F1	F2	F3
T.C (Ur)	0.903	-0.077	0.074
K (%)	0.658	0.602	-0.358
eU (ppm)	0.854	0.427	0.236
eTh (ppm)	0.959	0.082	0.183
eU/eTh	0.126	0.955	0.194
eU/K	0.207	0.131	0.961
eTh/K	0.06	-0.706	0.669

Table (3): Results of the statistical treatment of the different radiospectrometric variables for the whole area, Makhrag El-Ebel area, Northeastern Desert, Egypt.

Variables	T.C.	K	eU	eTh	eU/eTh	eU/K	eTh/K
Min	3.25	0.83	1.72	2.04	0.14	0.42	1.50
Max	67.3	6.30	52.80	64.20	0.97	4.34	5.90
$\bar{X}$	10.67	2.55	8.70	9.23	0.48	1.13	2.70
S	7.30	1.02	4.15	4.80	0.10	0.35	0.46
C.V (%)	68.42	39.92	47.70	52.00	20.89	30.94	17.01

4.2. Interpretation of SP data

4.2.1. Qualitative Interpretation of Self-Potential Data

The SP anomaly is generally negative and centered over the ore body, since that it is commonly the part of high sulphide mineral concentrations. The investigation of uranium minerals on the surface and exploratory mining works at Makhrag El-Ebel area, revealed the presence of uranium minerals associated with some copper, pyrite, etc. (Botros et al., 1997).

The SP map was also compared with the radiometric and geologic data, in order to find out whether there is a relation between the mineralization and radioactivity in the study area, as well as to follow the extensions of the near-surface mineralization at deeper levels.

The constructed SP color map of the surveyed area (Fig. 12) exhibits a wide range of negative amplitudes which varies from -147.2 to +123.2 mV. The anomaly zones are clustered into two zones: the first one with high negative amplitudes (from about -44.2 to -147.2 mV) can be related to strong surface mineralizations or shallow ore bodies, and are associated with younger granite containing fracture fillings Cu- and barite mineralization and basic dyke. It is located in the central southern part of the selected area and is associated with near-surface radiometric anomalies, which reach 67.3 Ur, 52.8 ppm, 64.2 ppm and 6.3 %, for the total count (Tc), equivalent uranium (eU), equivalent thorium (eTh) and potassium (K), respectively (Figs. 2, 3, 4 and 5).The second zone with scattered moderate negative SP amplitudes (-8.4 to -44 mV) are all located in the northern part of mapped area, and can be related to ground water, as confirmed from the field observations and are related to wadi sediments in the northern part. The relatively weak negative SP values could be related to clay or poorly conductive materials within the drainage lines, while the positive SP values which ranges from (0 to 123.2) are mainly associated with the resistant un-mineralized younger granite rocks and wadi sediment located in the central and South western portions of the studied area.

4.2.2. Quantitative interpretation of Self-Potential Data

The quantitative interpretation of SP data depends usually on transformation of the SP anomaly to a physical model of simple geometric shape and determine the model parameters (shape, depth, polarization angle and electric dipole momentum) using several graphical methods. The methods include, for example, use of characteristic points, distances, and curves.

In the present study, six SP anomaly lines (profiles), representing six anomalies, were selected for the quantitative interpretations. Two of those profiles have NE-SW direction, and other two profiles were conducted in the N-S direction and the last two have E-W direction (Fig. 12). The parameters of the source anomaly were evaluated using method of the characteristic curves.

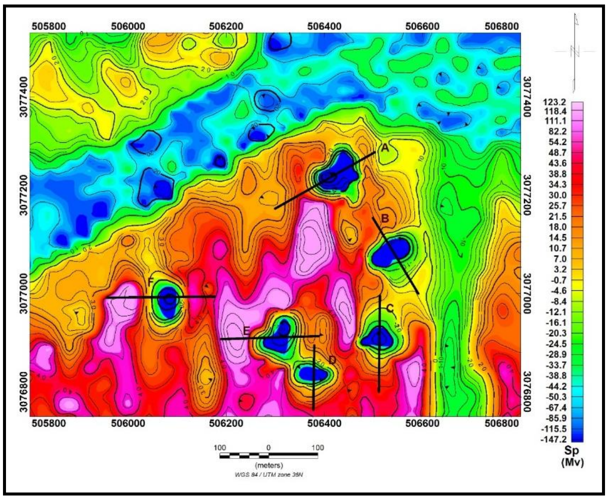

Fig. (12): Self-potential Filled-Colored contour map, Makhrag El-Ebel area, Northeastern Desert, Egypt.

The parameters of the source anomaly were evaluated using method of the characteristic curves of Ram Babu and Atchuta (1988), where the field profile can be interpreted in a very short time with ease and accuracy (Figs 13, 14 and 15).

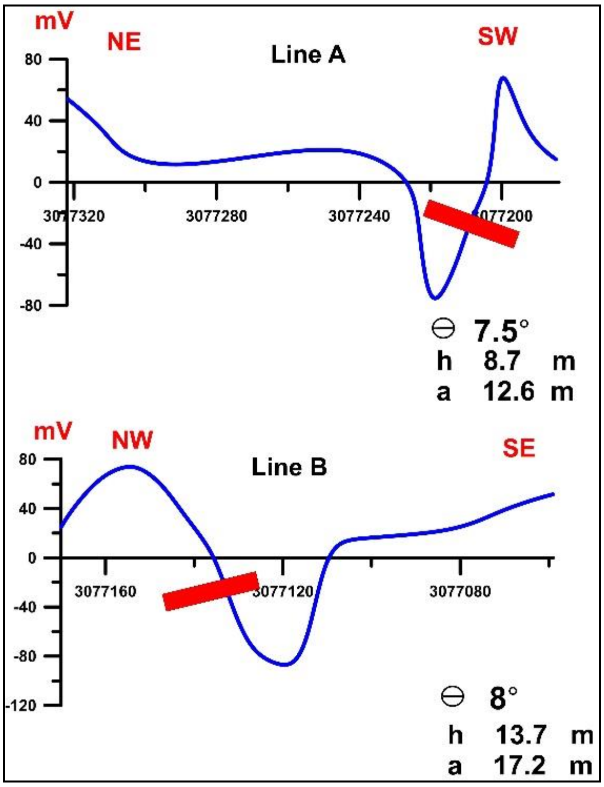

Fig. (13): The calculated parameters of SP profiles A, B along NE-SW and NW-SE directions, Wadi Makhrag El-Ebel area, Northeastern Desert, Egypt.
θ º = Polarization angle direction in degrees,
h = Depth to the center in meters and
a = Half-width in meters.

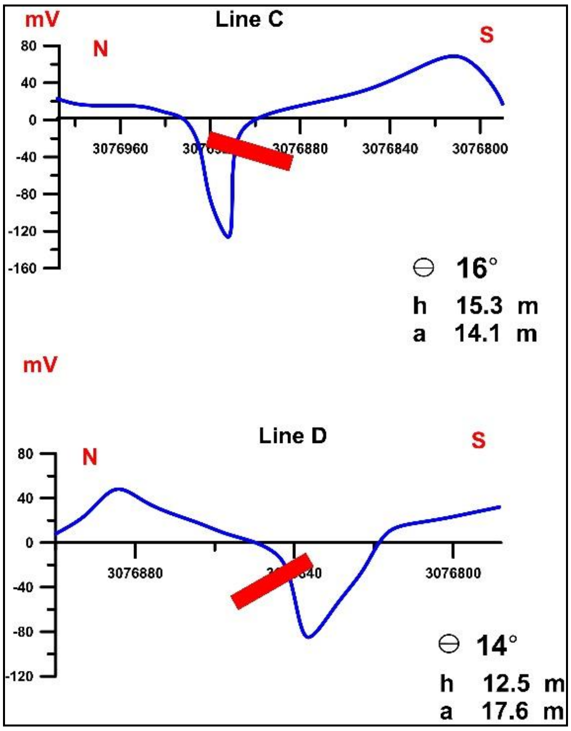

Fig. (14): The calculated parameters of SP profiles C, D along N-S, Wadi Makhrag El-Ebel area, Northeastern Desert, Egypt. θ º = Polarization angle direction in degrees, h = Depth to the center in meters and a = Half-width in meters

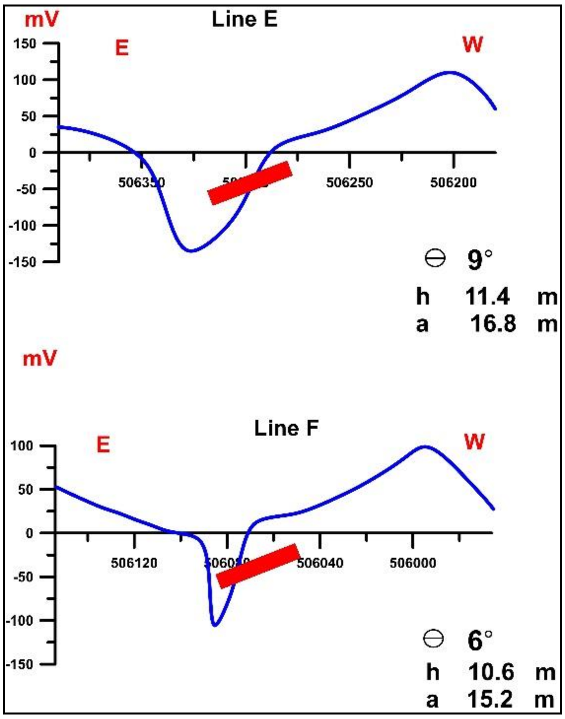

Fig. (15): The calculated parameters of SP profiles E, F along E-W and E-W directions, Wadi Makhrag El-Ebel area, Northeastern Desert, Egypt. θ º = Polarization angle direction in degrees, h = Depth to the center in meters and a = Half-width in meters.

The obtained results from the selected SP anomalies deduced that:

a) The calculated depths to centers of the selected SP anomalies are shallow, varying from 8.7 to 15.3 m and averaging about 12 m.

b) The half-widths of the anomalous causative bodies range between 12.6 m and 17.6 m, with a mean value of 15.6 m.

c) The polarization angles (θ), which reflect the dips of the anomalies of causative bodies range from 6º to 16º to the SW directions.

5. Data Integration

The integration between the two ground geophysical methods (gamma-ray spectrometry and SP) was conducted through the plotting of two stacked profiles (A-A' and B-B'), with their corresponding surface geology, that were illustrated on Figures (16 and 17). Fig. (1) illustrates the locations of the three profiles, the A-A' has E-W direction, and the other profile (B-B') was conducted in the N-S direction.

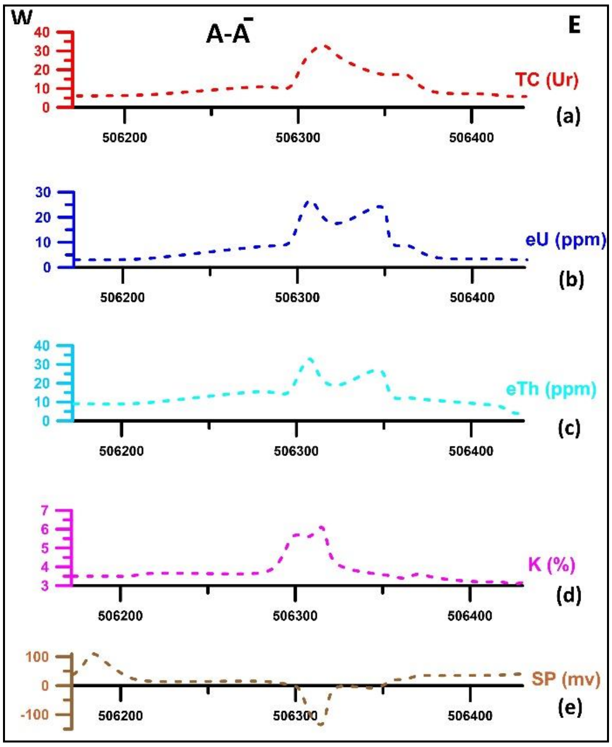

Fig. (16): Stacked TC (a), eU (b), eTh (c), K (d) and Self-potential (e) along profile A-A¯, Makhrag El-Ebel area, Northeastern Desert, Egypt.

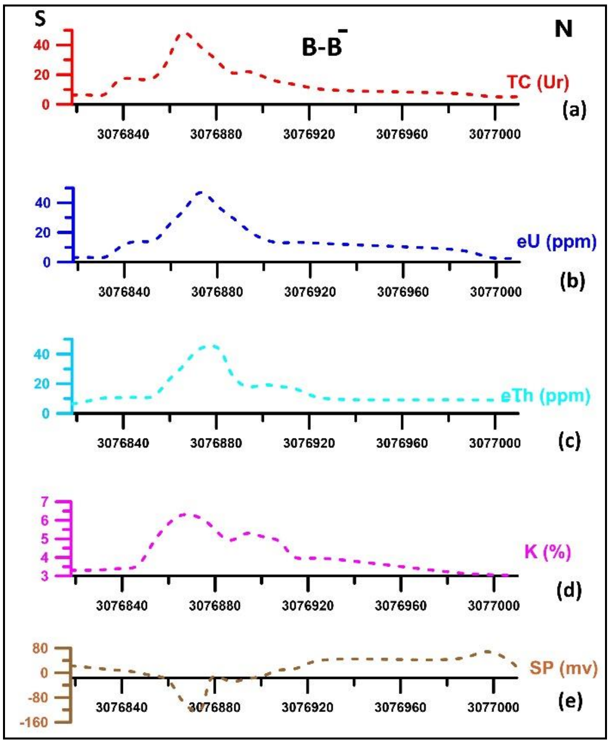

Fig. (17): Stacked TC (a), eU (b), eTh (c), K (d) and Self-potential (e) along profile B-B$^-$, Makhrag El-Ebel area, Northeastern Desert, Egypt.

The two stacked profiles show that the high values of the equivalent uranium are associated with the copper (Cu) and pyrite located in the mineralized quartz veins and dolorite dykes (Abdel Wahed et.al., 2010), while the younger granites display a normal range of radioactivity. The mineralization can be easily detected from the SP profile, where it shows high negative anomalies due to the increase of mineralization content. Through application of the ground gamma-ray spectrometry and SP methods, there was a very good agreement as concerning the special distribution of the high anomalies equivalent uranium (eU) corresponding with the strong negative SP anomaly related to the Cu-eU mineralization.

CONCLUSIONS

The integration between Gamma-ray spectrometry and Self-Potential studies for Makhrag El-Ebel area prospect area Northeastern Eastern Desert, Egypt, enabled the identification of the concentration and spatial distribution of the three radioactive elements eU, eTh and K in the area, and obtaining information about the lateral and vertical variations for both the lithology and anomalously high radioactive localities at depth.

The gamma-ray spectrometry data revealed that the study area has a relatively wide radioactivity range, oscillating from 3.25 to 67.3 Ur, 1.72 to 52.8 ppm, 2.04 to 64.2 ppm and from 0.83 to 6.3 %, for the total count (Tc), equivalent uranium (eU), equivalent thorium (eTh) and potassium (K), respectively.

A uranium composite image map was constructed to identify and outline the uranium anomalous zones.

The high negative amplitudes of SP data (from about -44.2 to -147.2 mV) can be related to strong surface mineralization or shallow ore bodies. The anomalous zones are associated with younger granite which has fracture fillings Cu- and barite mineralization and basic dyke which is located in the central southern part of the selected area, associated with near-surface radiometric anomalies.

There is a good correlation between the anomalously high radioactivity parts, as inferred from the ground gamma-ray spectrometric survey and the Self-Potential anomalies in the study area.The gamma-ray spectrometer data may be useful in searching for non-radioactive minerals such as copper and barite if there is a recognized geochemical relationship between the mineral and one or more of the natural radioelements, eU, eTh or K.

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