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Magnetic and Radiometric Trends Associations and their Relation to Uranium Remobilization in Gabal El Gedan, Eastern Desert of Egypt

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ABSTRACT. A two-dimensional trend analysis for the magnetic and gamma-ray spectrometric data of G. Idid El Gedan area North Eastern Desert, Egypt, is conducted through the application of autocovariance function technique, tô define the relation between the trends of surface and subsurface structures, as well as any significant relation reflecting radioelement mineralization control. Furthermore, the degree of remobilization of uranium in each rock unit is shown as reflected from the trend variations of uranium and thorium with their ratio.

Introduction

Location and Topography

Gabal Idid El Gedan area, is located in the North Eastern Desert, Egypt, and it covers a total surface area of about 2400 km^2 (Fig. 1).

The most conspicuous feature of the study area is the rugged, highly-dissected Precambrian terrain. It is noticeable that the area is characterized by numerous independent wadis draining towards the Red Sea and Wadi Qena, with an E-W direction (Fig. 2).

Surface Geology

The geology of the study area is based on the geologic maps (Dardir and Abu Zeid 1972, Francis, 1972 and Qena quadrangle published by the Egyptian Geological Survey, 1978). It includes the following rock units (Fig. 3):

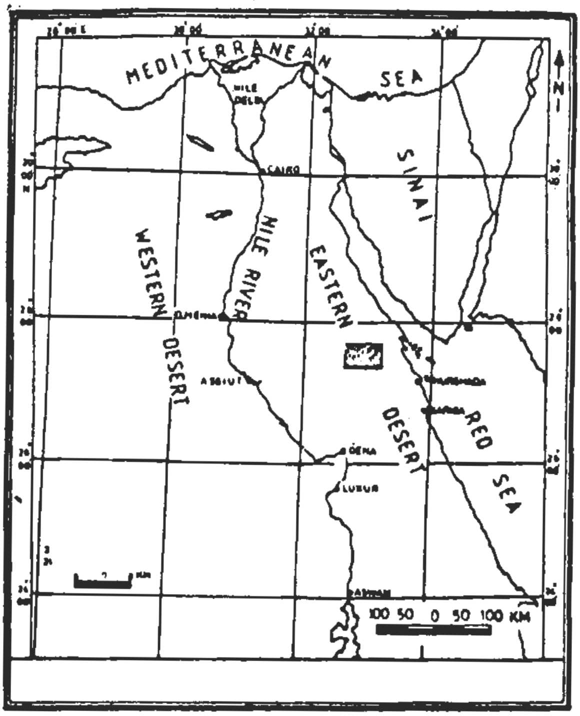


FIG. 1. Location map of the study area.

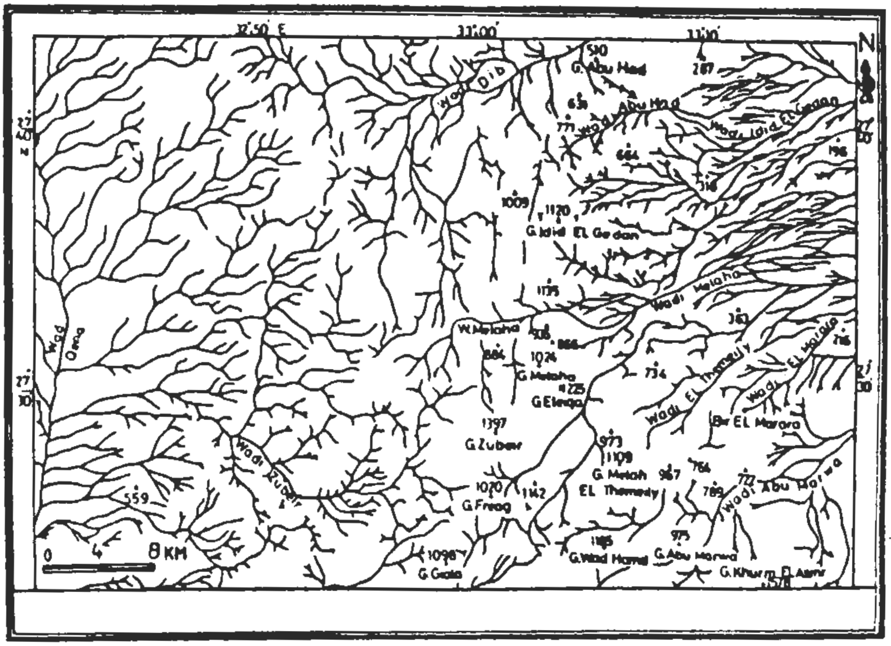


FIG. 2. Surface drainage map of the study area.

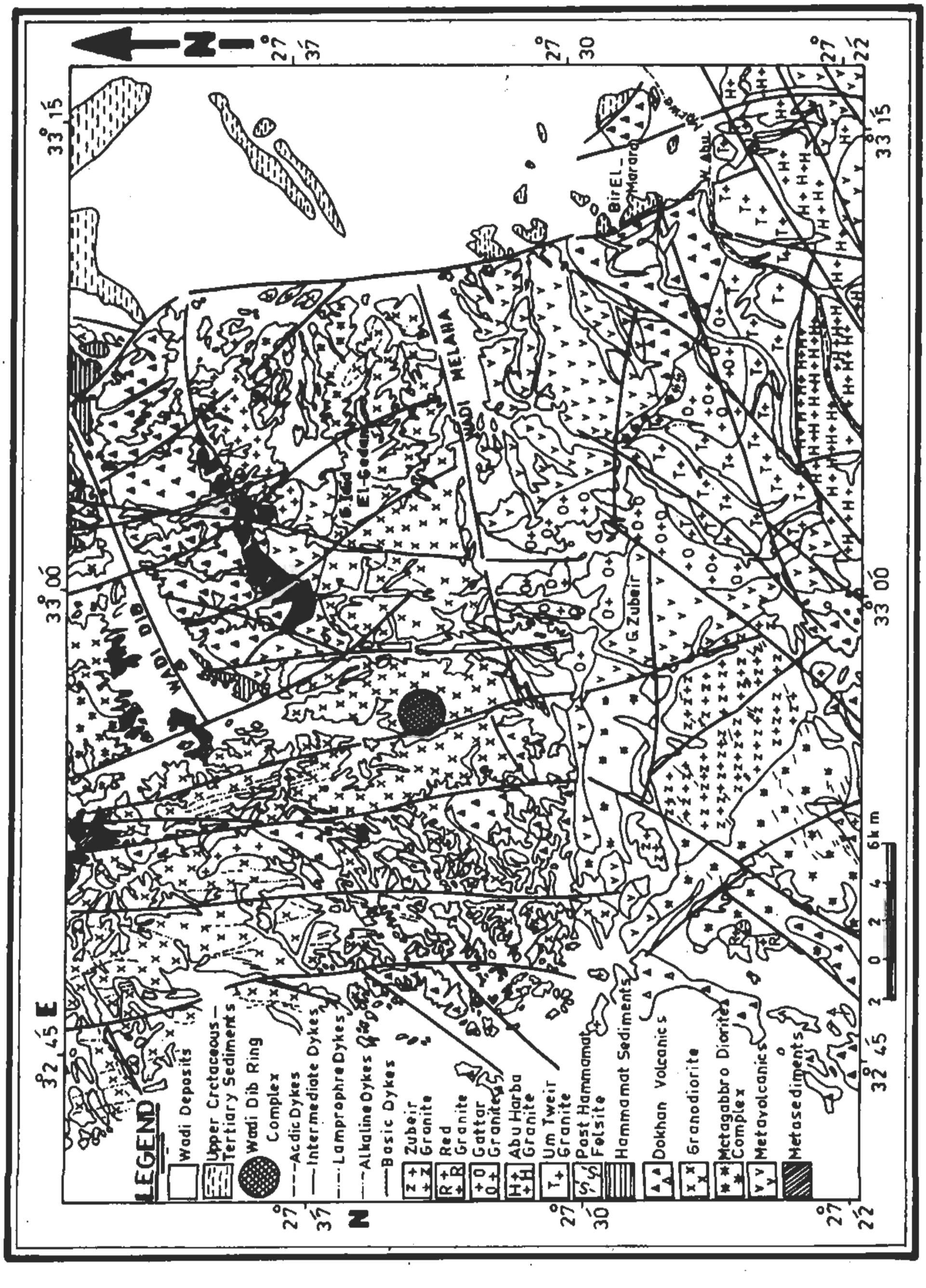


FIG. 3. Compiled geological map of G. Idid El Gedan area, eastern desert, Egypt. (After Dardir and Abu Zeid 1972 and Francis 1972).

Mesozoic to Cenozoic	Wadi deposits Upper Cretaceous-Lower Tertiary Sediments
Cambrian	Ring complex Post granite dykes Younger granitoids Hammamat sediments Dokhan volcanics
Precambrian	Pink granodiorites Metagabrro-diorite complex Metavolcanics Metasediments.

Precambrian rocks cover the majority of the area and are bounded from the east by outcrops of Quaternary Wadi deposits, Upper Cretaceous-Lower Tertiary sediments, and from the west by Wadi deposits.

Dardir and Abu Zeid (1972) and Francis (1972) mapped the portion of the Eastern Desert between lat. 27°00′ and 28°00′N (including the study area). They mentioned that this area is dissected by two major groups of longitudinal and transverse faults. The first group includes faults with N-S, NNE and NNW trends. Due to the active role of these faults, a very conspicuous uplifted block represented by the Red Sea basement mass is formed, and is bordered from the west and east by tectonic depressions filled by sediments. The second group includes faults with an ENE to NE trends, normal to the Red Sea axis. The major faults of this group are those running along W. Dib, W. Abu Had and W. Melaha, as far as the area under study is considered.

Folding is represented by a series of roughly parallel synclinal and anticlinal folds trending E-W and ENE-WSW directions.

Geophysical Survey

In 1983, the Eastern Desert of Egypt, was included in an airborne radiometric and magnetic surveying programme carried out by Aero-Service Division, Western Geophysical Company of America. The purpose of this survey was to provide data which would assist in identifying and assessing the mineral, petroleum and groundwater resources of the region (MPGAP). The whole program was sponsored by AID.

The following flight specifications were used in the airborne surveying carried out by Aero-Service, 1984:

1. Flight altitude: 120 meters terrain clearance.
2. Flight line direction: Northeast-Southwest.
3. Traverse flight line spacing: 1.5 km.
4. Tie line spacing: 10 km.

5. Twin engine Cessna-Titan, type 404 aircraft (Aero Service, 1984).

Data Analyses

I. Statistical Trend Analysis

In the present work, trend analysis was quantitatively carried out using the statistical technique of the two-dimensional autocovariance function (Horton *et al.* 1964). It was applied to the reduced to north pole aeromagnetic data (R.T.P.) regional and residual magnetic-component maps at the 1.0 and 2.1 km interfaces, as well as spectrometric data: total count (Tc), eU, eTh and K %.

The main targets of application of such trend analysis for the aerial magnetic and spectrometric data was to show the following :

a. To detect if any association is present between the radioelement mineralization and structural trends in the area under consideration. El Shazly and El Ghawaby (1974) found that the hydrothermal uranium occurrences of Wadi Zeidun and other areas in the Easten Desert of Egypt are tectonically controlled.

b. To what extent does the surficial trend (as deduced from spectrometric data) conform with the combined surface and subsurface trends (as deduced from magnetic data).

II. Remobilization of Uranium

There is evidence that uranium is one of the first elements to become remobilized during metamorphism (Heier 1965). That is due to the fact that uranium can easily form the soluble uranyl ion (UO_2^{++}), particularly in hexavalent state, and consequently it becomes very mobile (IAEA 1988).

Uranium may be transported under late-hydrothermal conditions and be precipitated away from thorium and potassium (IAEA 1988). Consequently, the trend defined in the variations of uranium and thorium with their ratios reflects the amount of remobilization of uranium that has occurred with the magmatic plutons (Charbonneau 1982).

The same author concluded that ground investigations of three granitic bodies having radioelement enrichment indicate relationships between uranium and thorium concentration which may be useful in assessing their uranium potentiality.

Results and Discussion

I. Geophysical Trends

The resultant autocorrelograms of aeromagnetic maps (RTP, regional, and residual magnetic-component) at the two assigned interfaces, are presented in Fig. 4, 5.a, 5.b, 6.a & 6.b, and that of aerospectrometric maps (Tc, eU, eTh & K) are presented in Fig. 7.a, 7.b, 8.a & 8.b. The study of these nine autocorrelograms shows that they provide an important diagnostic tool; since they not only reveal the pronounced directional trends of the surface and subsurface structures, which can be de-

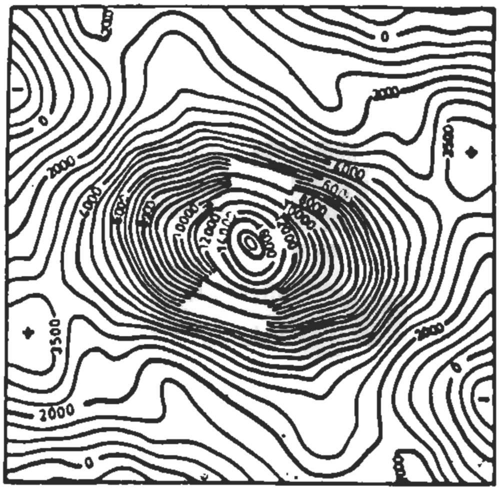


FIG. 4. Autocorrelogram of the R.T.P. magnetic map of G. Idid El Gedan area, N.E.D., Egypt.

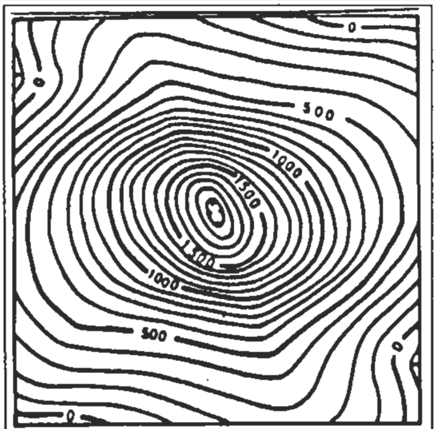


FIG. (5.a). Autocorrelogram of the regional magnetic component map at interface 2.1 km, G. Idid El Gedan area, N.E.D., Egypt.

FIG. (5.b). Autocorrelogram of the residual magnetic component map at interface 2.1 km, G. Idid El Gedan area, N.E.D., Egypt.

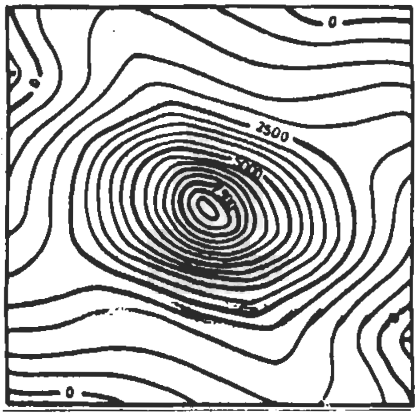


FIG. (6.a). Autocorrelogram of the regional magnetic component map at interface 1.0 km, G. Idid El Gedan area, N.E.D., Egypt.

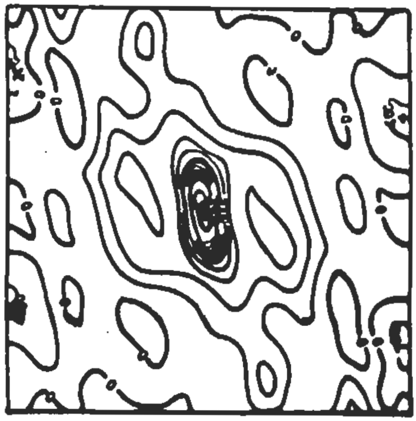


FIG. (6.b). Autocorrelogram of the residual magnetic component map at interface 1.0 km, G. Idid El Gedan area, N.E.D., Egypt.

termined to an accuracy of degrees, but also define the directions of secondary trends.

The trend directions as traced from the five autocorrelograms of aeromagnetic maps are shown in Fig. 9. Meanwhile, the trend directions as traced from the four autocorrelograms of aerospectrometric maps are shown in Fig. 10. The dominant trend directions are indicated by heavier lines, marked B, while the secondary trend directions of the negative and positive regions of the autocorrelograms are indicated by reversed and normal arrows, marked S and S′. The results of this analysis are summarized in Table 1 which shows the major and minor trends as interpreted from the various magnetic and spectrometric data.

The correlation between the different trends is discussed hereafter, as well as any significant relation reflecting mineralization control:

a. It is evident that the major (dominant) trend of the subsurface structures (as deduced from magnetic analysis) is NNW-SSE (Atalla trend), while that of surficial and near-surface structures (as deduced from spectrometric analysis) is NW-SE (Gulf of Suez-Red Sea trend). This indicates that there is a deviation or anticlockwise rotation in the dominant or principal trend toward the west by about 10-15°.

b. The NE-SW (trans-African) deep-seated structures (as traced from the autocorrelograms of regional magnetic-component maps (Fig. 5.a and 6.a) are highly conformable with surface structures (as traced from the autocorrelograms of all spectrometric maps; Fig. 7.a, 7.b, 8.a & 8.b). This conformance suggests that there might be radioelement mineralization, regardless of its economic, controlled by the NE structures and having a deep-seated source, *i.e.* dyke system for example. This is supported by the opinion of Stern *et al.* (1984) who concluded that there is an abundant subparallel dyke swarms in the North Eastern Desert of Egypt having NE-SW to E-W as well as N-S trending sets which are much less common.

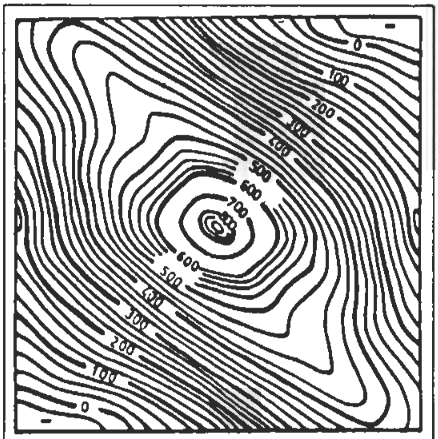


FIG. (7.a). Autocorrelogram of the total count map of G. Idid El Gedan area, North Eastern Desert, Egypt.

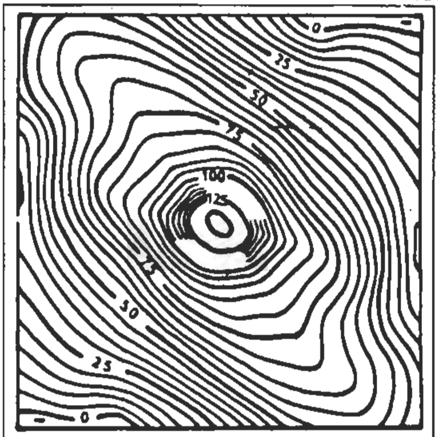


FIG. (7.b). Autocorrelogram of the uranium map of G. Idid El Gedan area, North Eastern Desert, Egypt.

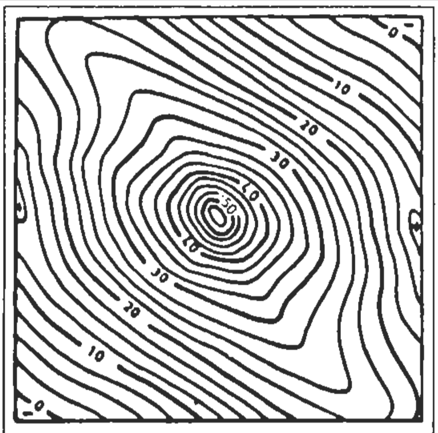


FIG. (8.a). Autocorrelogram of the potassium map of G. Idid El Gedan area, North Eastern Desert, Egypt.

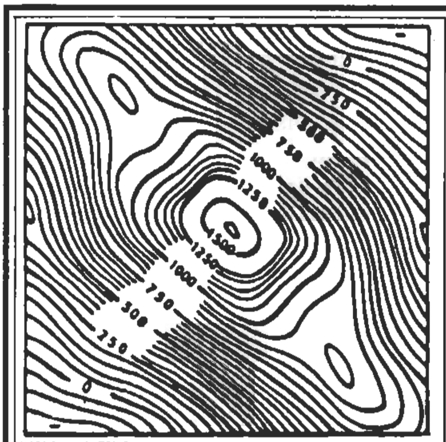


FIG. (8.b). Autocorrelogram of the thorium map of G. Idid El Gedan area, North Eastern Desert, Egypt.

Based on Anderson's theory of faulting (1951), the major axis of the stress ellipsoid is perpendicular to the dominant trend; marked B in Fig. 9 & 10, while S and S′ would be the conjugate shear sets, for maximum principal stress. It is believed that the area under consideration is subjected to a maximum principal stress oriented ENE. This conclusion is highly confirmed with the opinion of El Gaby (1983), El Ramly *et al.* (1984), El Bayoumi and Greiling (1984), Kroner (1985), and El Gaby *et al. (1988); these authors* believed that the Pan African belt was created by compression from an easterly direction.

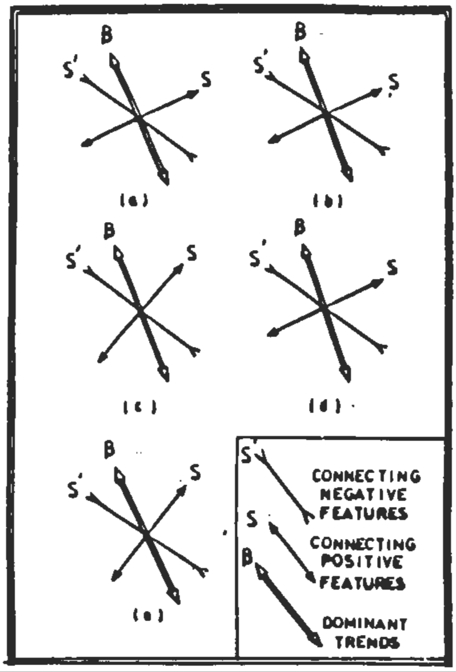


FIG. 9. Trend directions traced from the autocorrelogram of: a) R.T.P, (b,d) residual magnetic component maps of interfaces 2.1, 1.0 km (c,e) regional magnetic component maps at interfaces 2.1, 1.0 km.

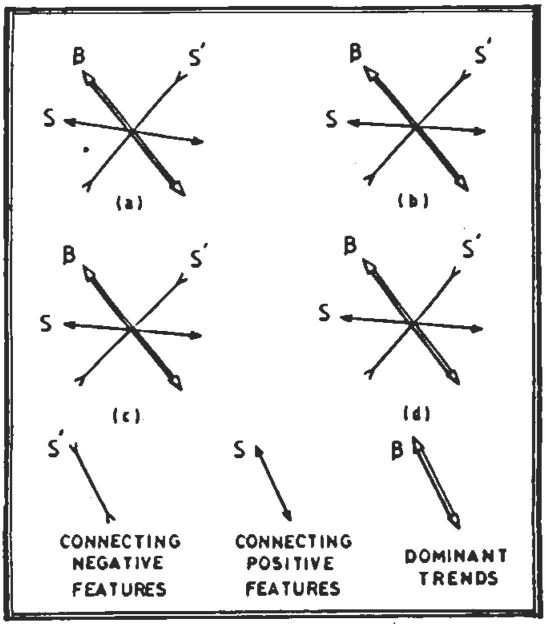


FIG. 10. Trend directions traced from the autocorrelogram of spectrometric maps: a) eU map, b) eTh map, c) Ke map and, d) T.C. map.

Furthermore, El Gaby *et al.* (1988) mentioned that two tectonic trends, namely NNW-SSE and ENE-WSW, prevail in the Eastern Desert and Sinai. There is no consensus whether these two trends are coeval or which trend is the primary one. They added that the Eastern Desert seems to be affected by a principal compressional stress from the ENE, and probably due to continental collision after the closure of the oceanic tract, the first order left-lateral Najd-fault system of Arabia and its complimentary right-lateral and Qena-Safaga and Idfu-Mersa Alam shear zones were created (Fig. 11).

The major regional trends in the area could be discussed, in general, as follows.

TABLE 1. The trend directions determined from the two-dimensional autocovariance function of aeromagnetic and spectrometric data.

Data / Trends	Aero-magnetic data					Aero-spectrometric data			
	Reduced to the north pole	Regional-magnetic component		Residual-magnetic component		TC	cU	eTh	K
		Interface (in km)							
		1.0	2.1	1.0	2.1				
NNW-SSE (G. Atalla trend)	N24°W*	N25°W*	N22°W*	N18°W*	N20°W*	-	-	-	-
NW-SE (Gulf of Suez-Red Sea trend)	N55°W	N55°W	N54°W	N55°W	N55°W	N36°W*	N39°W*	N39°W*	N36°W*
NE-SW (Trans-African trend)	-	N39°E	N41°E	-	-	N40°E	N40°E	N43°E	N44°E
ENE-WSW (Syrian arc or Qattara trend)	N66°E	-	-	N65°E	N66°E	-	-	-	-
E-W (Tethyan trend)	-	-	-	-	-	N85°W	N82°W	N86°W	N84°W

*Refer to the major (dominant) trend directions.

1. NNW-SSE (Atalla) Trend

This trend was revealed as a major trend on all types of magnetic data (Fig. 4, 5.a, 5.b, 6.a & 6.b). Meanwhile, it is lacking on all types of spectrometric data (Fig. 7.a, 7.b, 8.a & 8.b). It is a prominent direction of faulting and dyke intrusion in the North Eastern Desert of Egypt, particularly this study area (Dardir and Abu Zeid 1972, Francis 1972, Mussa and Abu El Leil 1982). In addition, it is a prominent fault trend in the South Eastern Desert of Egypt (Hunting 1967).

In some specific zones of the Southeastern Desert of Egypt, the NNW faults are characterized by deep penetration into the earth's crust that may reach the upper mantle (Krs *et al.* 1973). The left lateral NNW-SSE second-order shear, which dominates in the Eastern Desert of Egypt, was nominated Attala trend by El Gaby *et al.* (1988). It seems to be the most important among all other trends, and plays the most

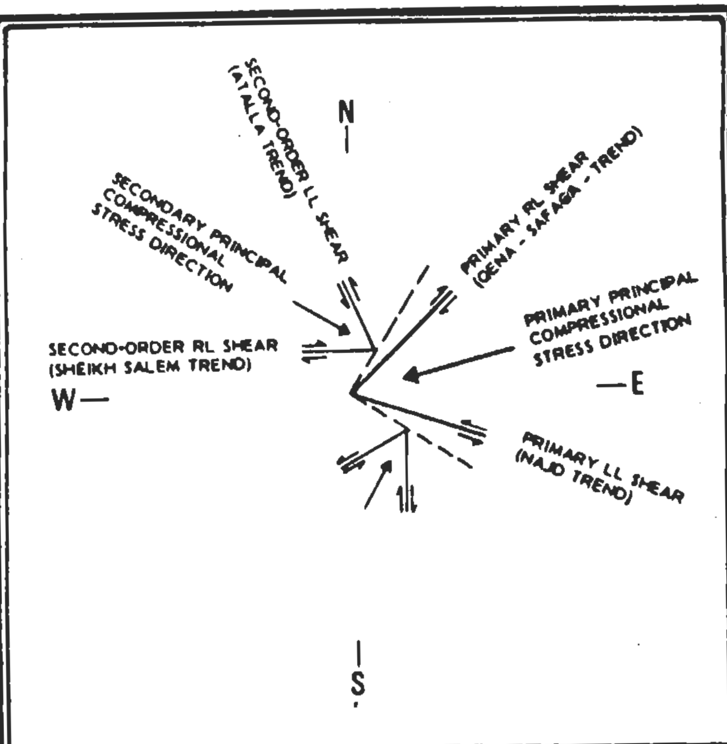


FIG. 11. Major shear trends in the eastern desert of Egypt (after El Gaby *et al.*, 1988).

effective role in the structural framework in the area under study. Makris *et al.* (1988) stated that, in eastern Egypt and the Gulf of Suez, the trends of the gravity anomalies are aligned in a NNW-SSE trend which is associated with the Miocene and post-Miocene opening of the Red Sea and the Gulf of Suez.

2. NW-SE (Gulf of Suez-Red Sea) Trend

The NW-SE trend was registered as a major direction from the spectrometric data and as a minor one from the magnetic data. It is considered to be one of the most important fault systems which affect the Precambrian Basement rocks and acting on the overlying sediments in the Gulf of Suez and Red Sea regions (Abdel Gawad 1969).

The interpretation of the Bouguer anomaly map of the northern part of Egypt by Riad (1977), has shown the presence of almost parallel shears striking in a NW-SE direction which are probably related to the interaction of the European and African plates.

3. NE-SW (Trans-African) Trend

This trend is developed as a minor trend on the autocorrelogram of the spectrometric and regional magnetic-component data (Fig. 5.a, 6,a, 7.a, 8.a & 8.b). This means that, it represents the surface as well as the deep-seated structures. Furthermore, it is believed that, from the point of view of radioelement mineralization prospection, this trend must be of prime concern. It is referred to in the literature as the Trans-African trend.

El Shazly (1966) explained the NE-SW structural trend as transversal fractures to the major NW-SE trends along which huge plutons were emplaced. Ammar *et al.* (1983) stated that this trend is reflected on both radiometric and magnetic anomalies. Therefore, it could be considered valuable, as mineralization of economic importance either radioactive or magnetic or both could be connected with this system of fractures. The right lateral NE primary shear, which dominates in the Eastern Desert of Egypt, is nominated "Qena-Safaga trend" by El Gaby *et al.* (1988).

4. ENE-WSW (Syrian Arc or Qattara) Trend

This trend was revealed as a minor trend on the autocorrelograms of the magnetic data except the data of the regional magnetic component data (Fig. 4, 5.b & 6.b). Meanwhile, it is not evident on the spectrometric data. It is referred to in the literature as the Qattara or Syrian arc trend or North Sinai fold trend. Meshref (1982) concluded that Northern Egypt seems to be affected by three tectonic events. One of them, the middle one "the Cretaceous event", which resulted in the ENE (Syrian arc) trending structure. Therefore, it was explained as to be due to the couple of force affecting north Africa at that time.

The ENE-WSW trend is considered to be a prominent direction of folding (or down-faulted and uplifted blocks) in the area under consideration (Dardir and Abu Zeid 1972, and Francis 1972). Generally, the Syrian arc trend is the principal controlling direction of major folding in the unstable shelf region. It runs east-northeast across Egypt and is a predominant trend of the major axes of folds in Northern Sinai.

5. E-W (Tethyan or Mediterranean) Trend

The E-W trend was developed as a minor trend as evident from the autocorrelograms of spectrometric data (Fig. 7.a, 7.b, 8.a & 8.b). Meanwhile, it was not recorded on that of the magnetic data. It is referred to in the literature as the "Teythyan or Mediterranean trend" and its right lateral second-order shear, in the Eastern Desert of Egypt, is called "Sheikh Salem trend" by El Gaby *et al.* (1988). It is a common basement direction of the exposed Precambrian rocks of Egypt. El Shazly (1966) considered this trend as the oldest tectonic trend affecting the Egyptian basement rocks, where it started by the Late Geosynclinal stage during the Precambrian Orogeny.

Meshref and El-Sheikh (1973) concluded that the E-W or N85°E trend is interpreted to be the result of a northern compressive force with major release in the vertical direction, *i.e.* the principal stress axis (P) was a N-S horizontal, the least-stress axis (R) being vertical, and the intermediate stress axis (Q) being E-W. These directions coincide with El Shazly's opinion (1966) where he stated that the fold axes and faults were trending in an E-W direction due to pressure exerted from the north.

II. Remobilization of Uranium

Uranium, which has two valency states, is most susceptible to transportation under late hydrothermal conditions and/or weathering processes, especially under hot-humid conditions and be precipitated away from thorium and potassium. Moxham (1960) reported the eU tend to increase erratically with increasing K. This reflects the greater mobility and, therefore, impermanence of U under hydrothermal and supergene conditions, which is observable in many mineralized areas.

Heier (1965) considered regional metamorphism as a potentially active process of element fractionation, involving migration of the elements. He observed that much of the uranium and thorium in rocks appears to be in leachable positions, possibly adsorbed on mineral surfaces rather than in distinct mineral lattice positions. So, uranium and thorium would, therefore, be more easily affected by metamorphic process.

The trends defined in the variations of uranium and thorium with their ratios reflect the amount of remobilization of uranium that has occurred within the plutons. An increase in the U/Th ratio with uranium indicates post magmatic remobilization. An inverse correlation between U/Th ratio and Th indicates radioelement distributions that were at least partly governed by magmatic processes. The relationships between radioelement concentrations and their ratios are detectable from airborne radiometric maps and profiles allowing the users some insight on the uranium potential of any intrusion (Charbonneau 1982).

The trends defined in the variations of uranium and thorium with their ratio in each rock unit are represented on Fig. 12 to 19; a tentative interpretation of the trends shown on these figures is as follows :

A. It can be seen from Fig. 12a that the bulk of granodiorite unit (occurred in the vicinity of the Wadi Dib ring complex) is characterized by increasing U/Th ratio strongly with uranium abundance, but not with thorium. Such relations indicate that there has been strong remobilization, *i.e.* post magmatic redistribution of uranium. Dyke swarms which are prevailing in this rock unit may be one of the causes of such remobilization and this could be favourable economic criterion, because uranium may have concentrated into deposits within or near the plutons.

B. The radioelement distribution of the granodiorite unit (occurred north Wadi Dib, Fig. 12.b) is at least governed by magmatic processes, where U/Th ratio varies directly with uranium concentration and inversely with thorium concentration.

C. The relationships between U/Th ratio, uranium and thorium in the Um Tweir, Abu Harba and Qattar granitic intrusions (Fig. 13.a) suggest that radioelement distribution is at least governed by magmatic processes.

D. Besides, it can be seen from (Fig. 13.b) that, Wadi Zubeir granites and associated Quaternary deposits, are characterized by increasing U/Th ratio strongly with uranium but not thorium. These relations suggest remobilization of uranium.

E. In the case of Upper Cretaceous-Tertiary Sediments (Fig. 14.b) and Wadi deposits (Fig. 14.a), the U/Th ratio varies directly with uranium concentration and in-

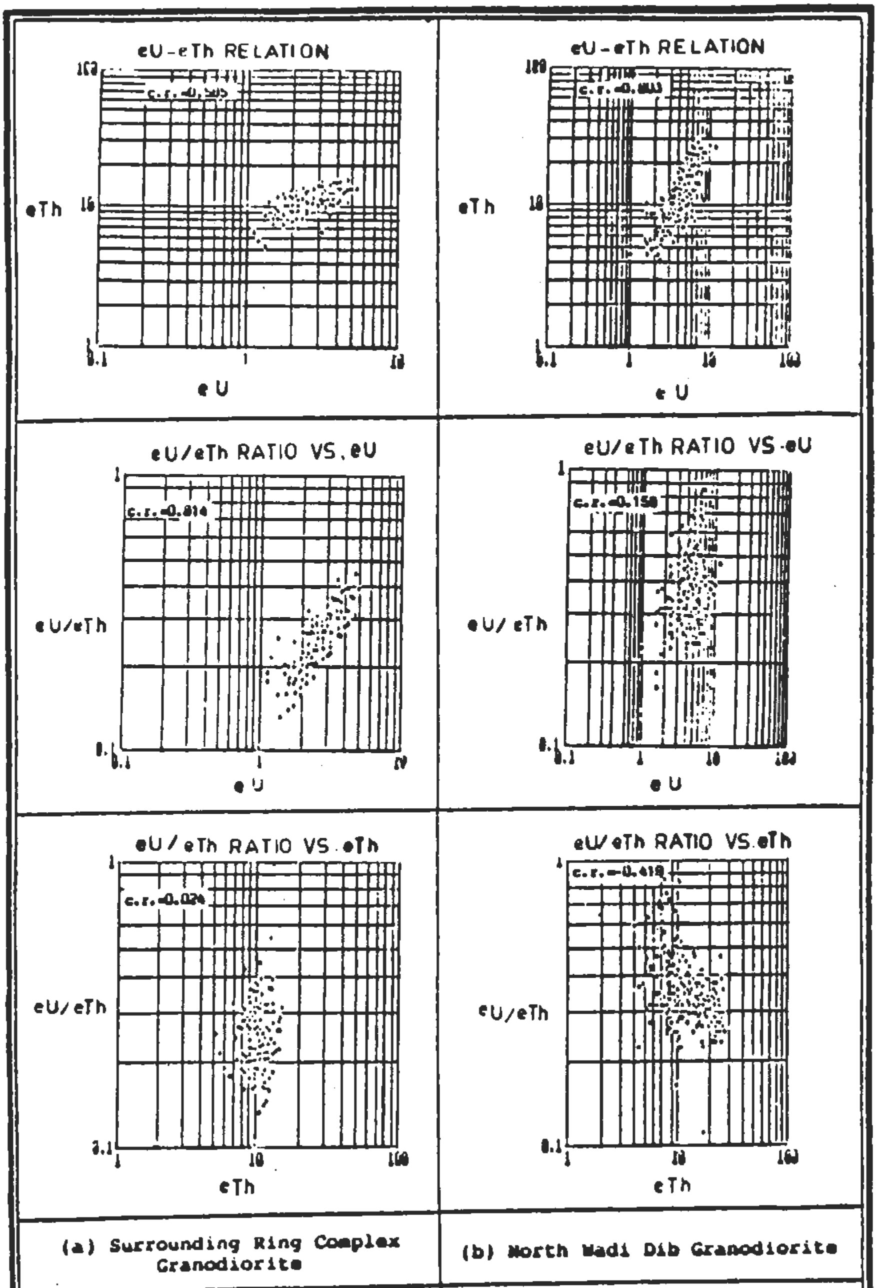


FIG. 12. Variations of uranium, thorium with their ratio for granodiorites.

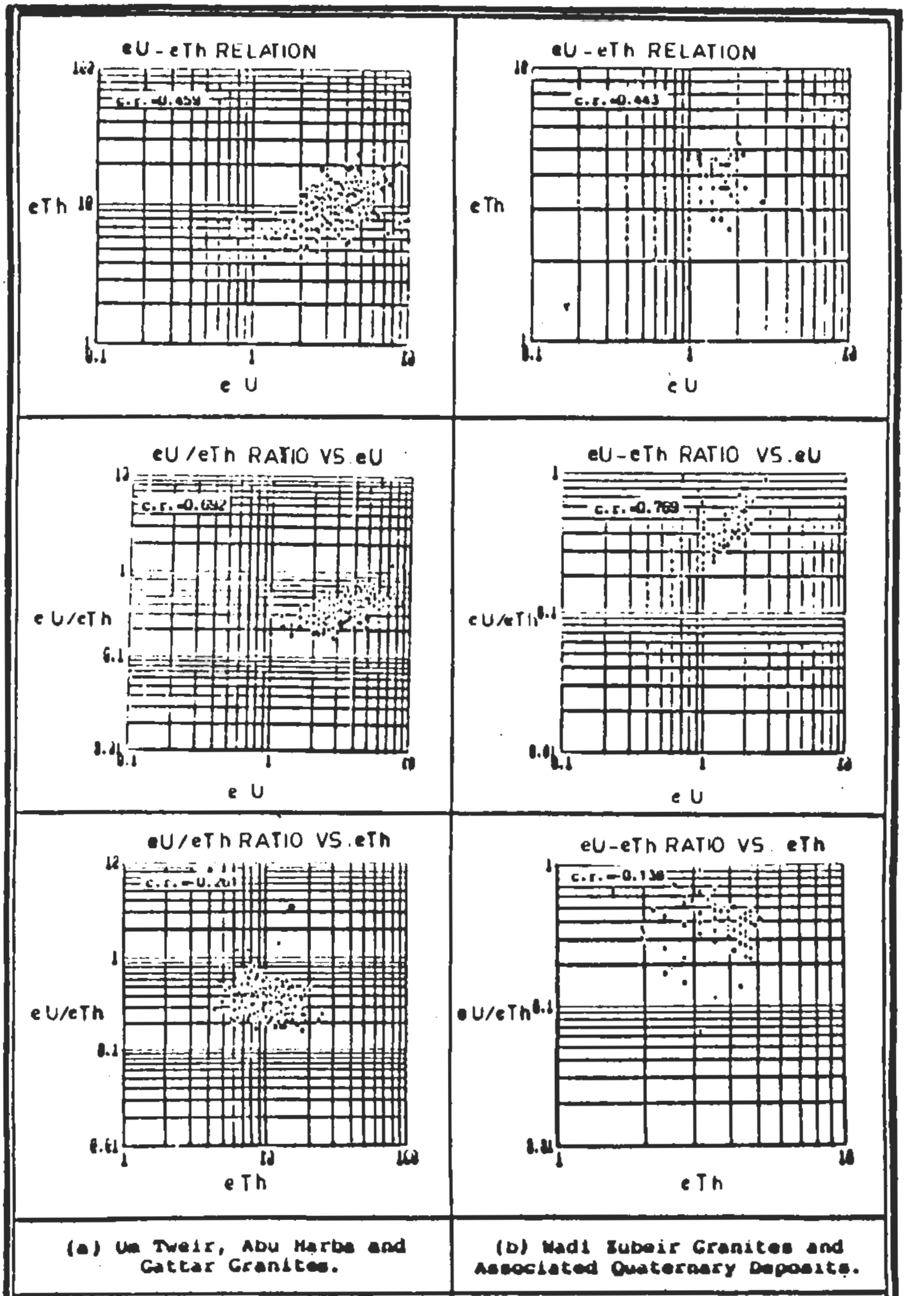


FIG. 13. Variations of uranium, thorium with their ratio for granites.

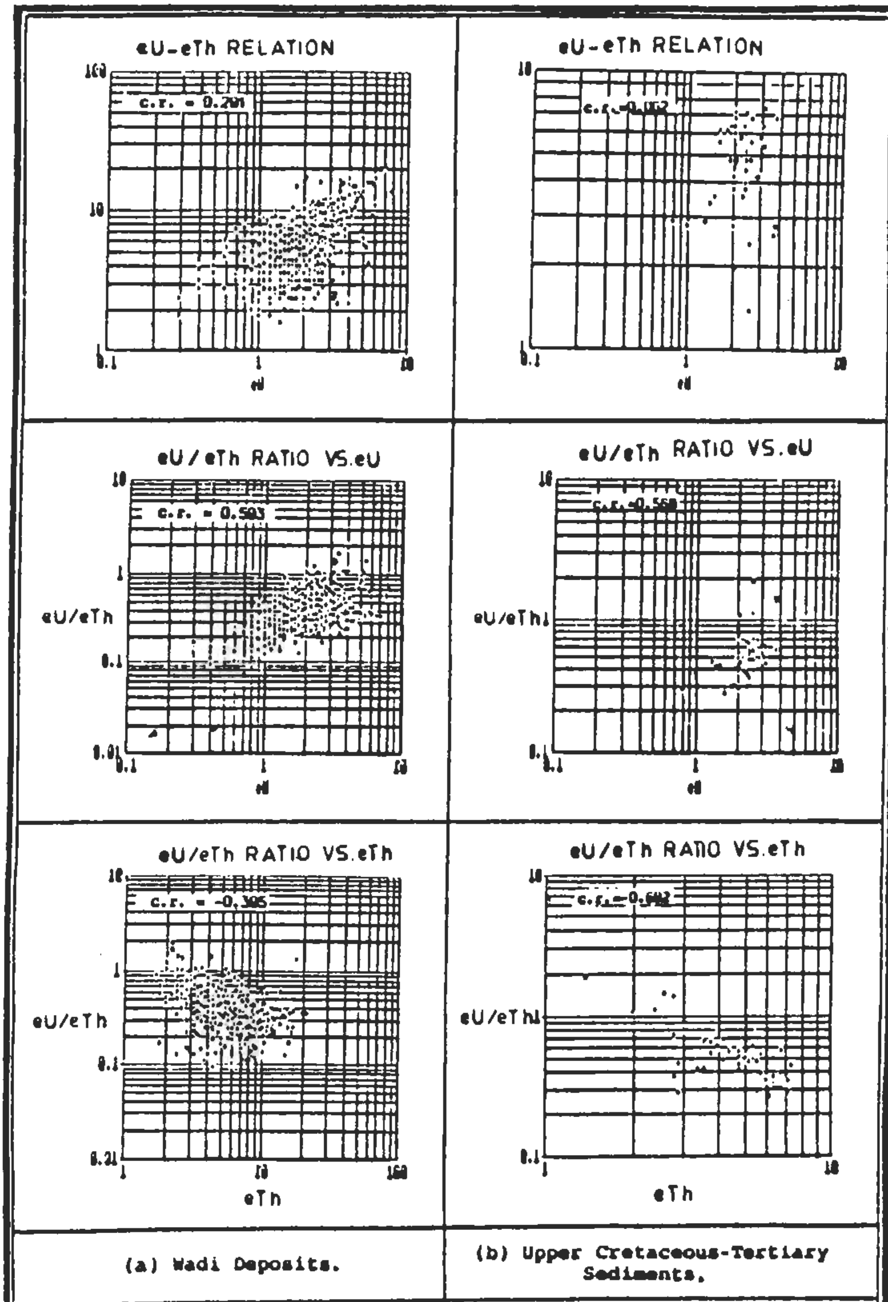
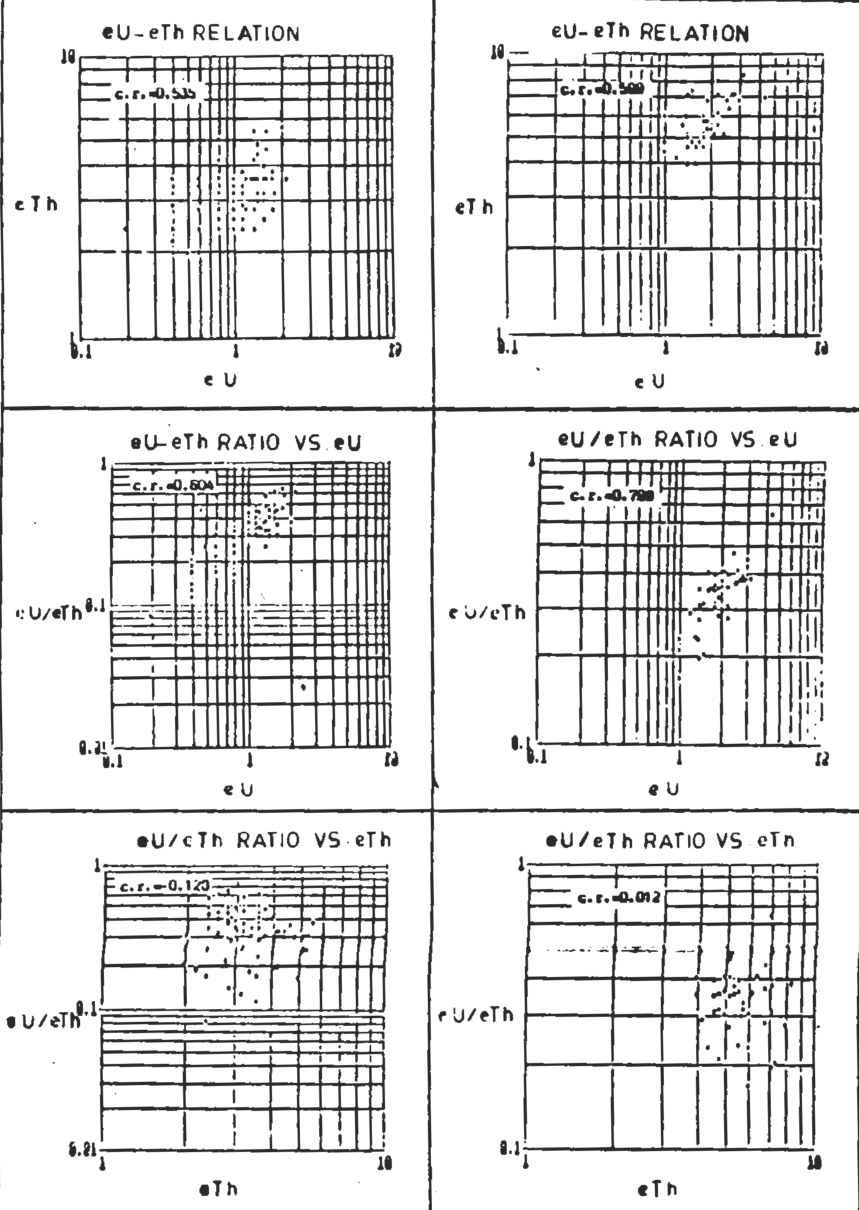


FIG. 14. Variations of uranium, thorium with their ratio for wadi deposits and Upper Cretaceous-Tertiary sediments.



(a) North Wadi Zubeir Metagabbro-Diorite Complex.

(b) North Wadi Melaha Metagabbro-Diorite Complex.

FIG. 15. Variations of uranium, thorium with their ratio for metagabbro-diorite complex.

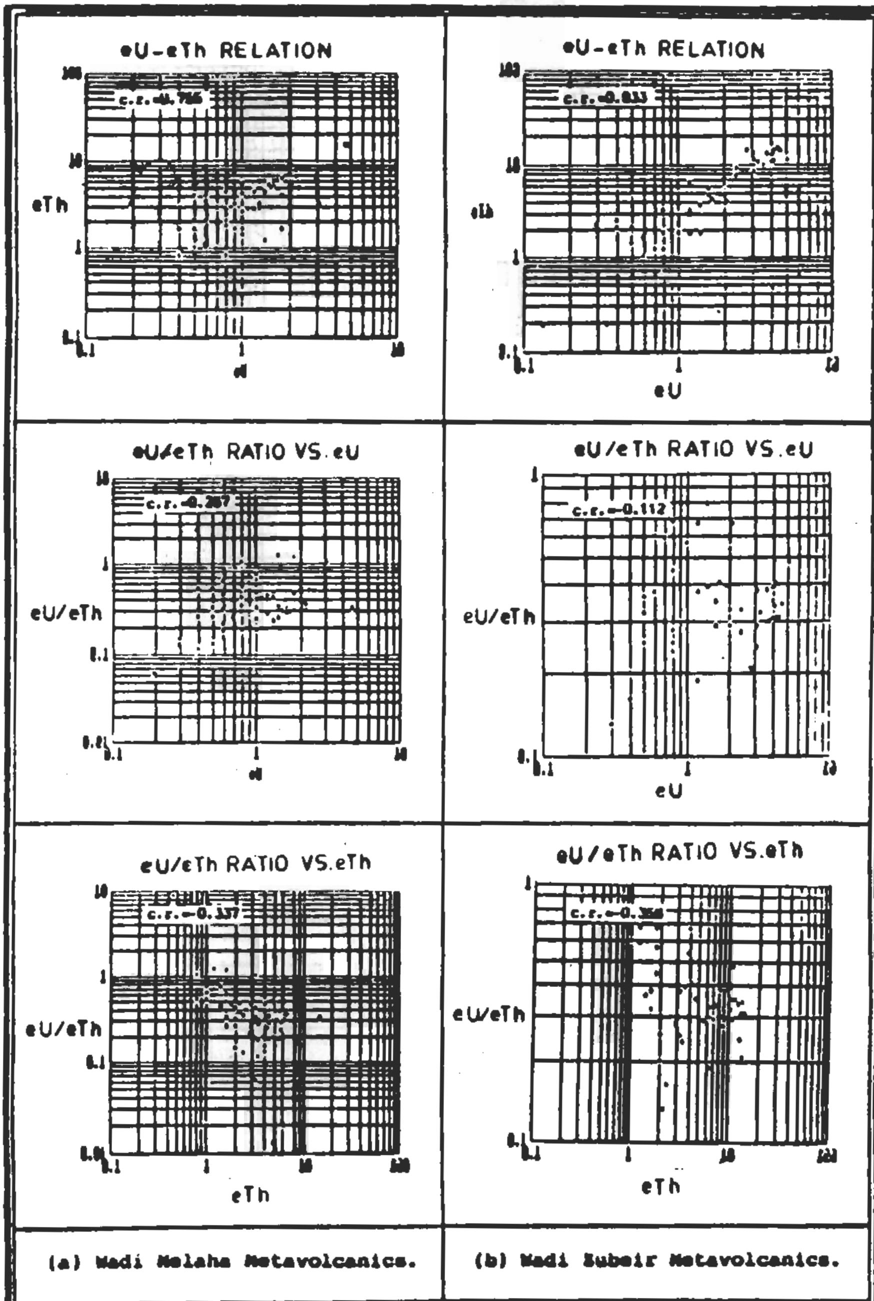


FIG. 16. Variations of uranium, thorium with their ratio for south Wadi Melaha and Wadi Zubeir metavolcanics.

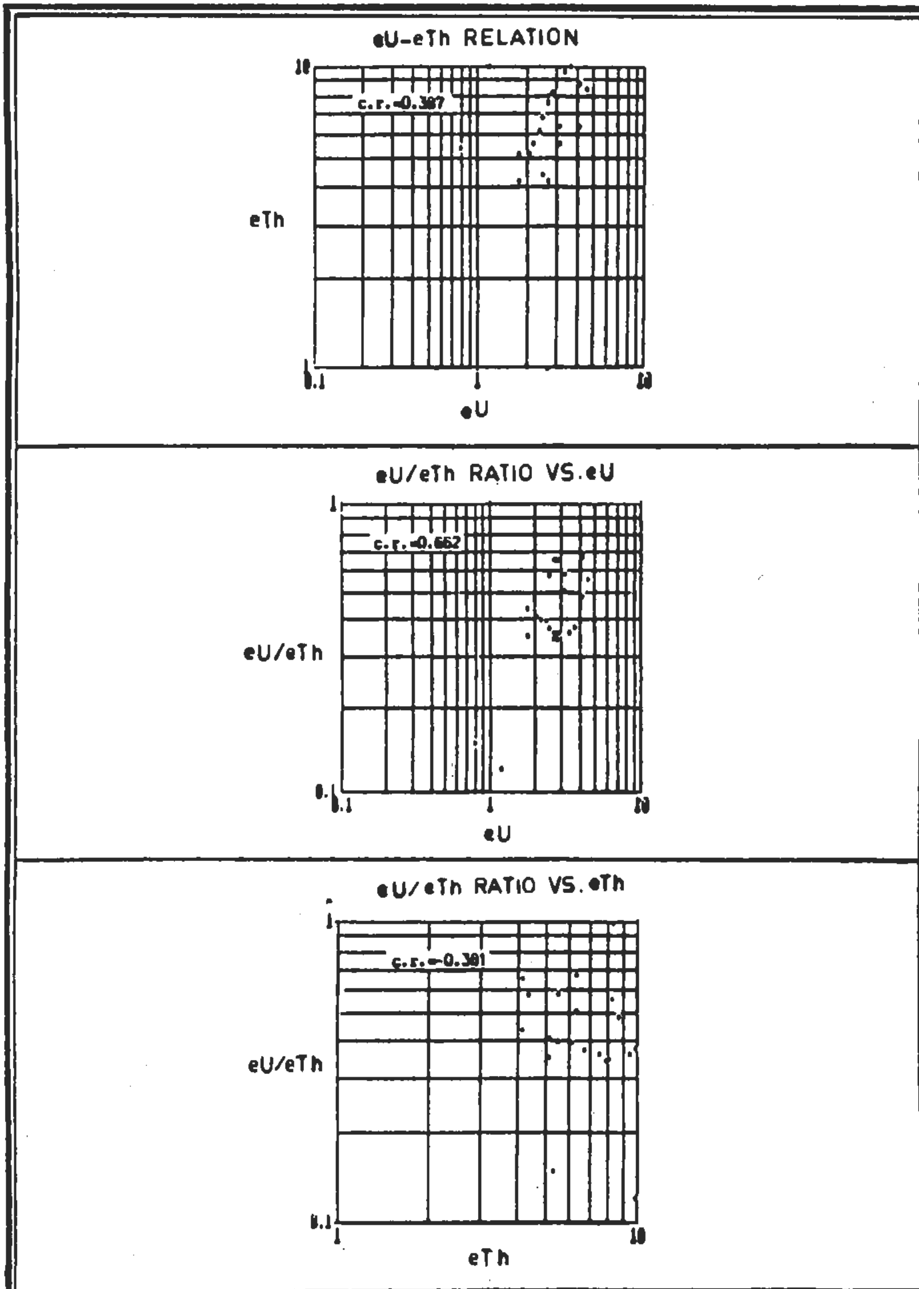


FIG. 17. Variations of uranium, thorium with their ratio for Wadi Abu Had metavolcanics.

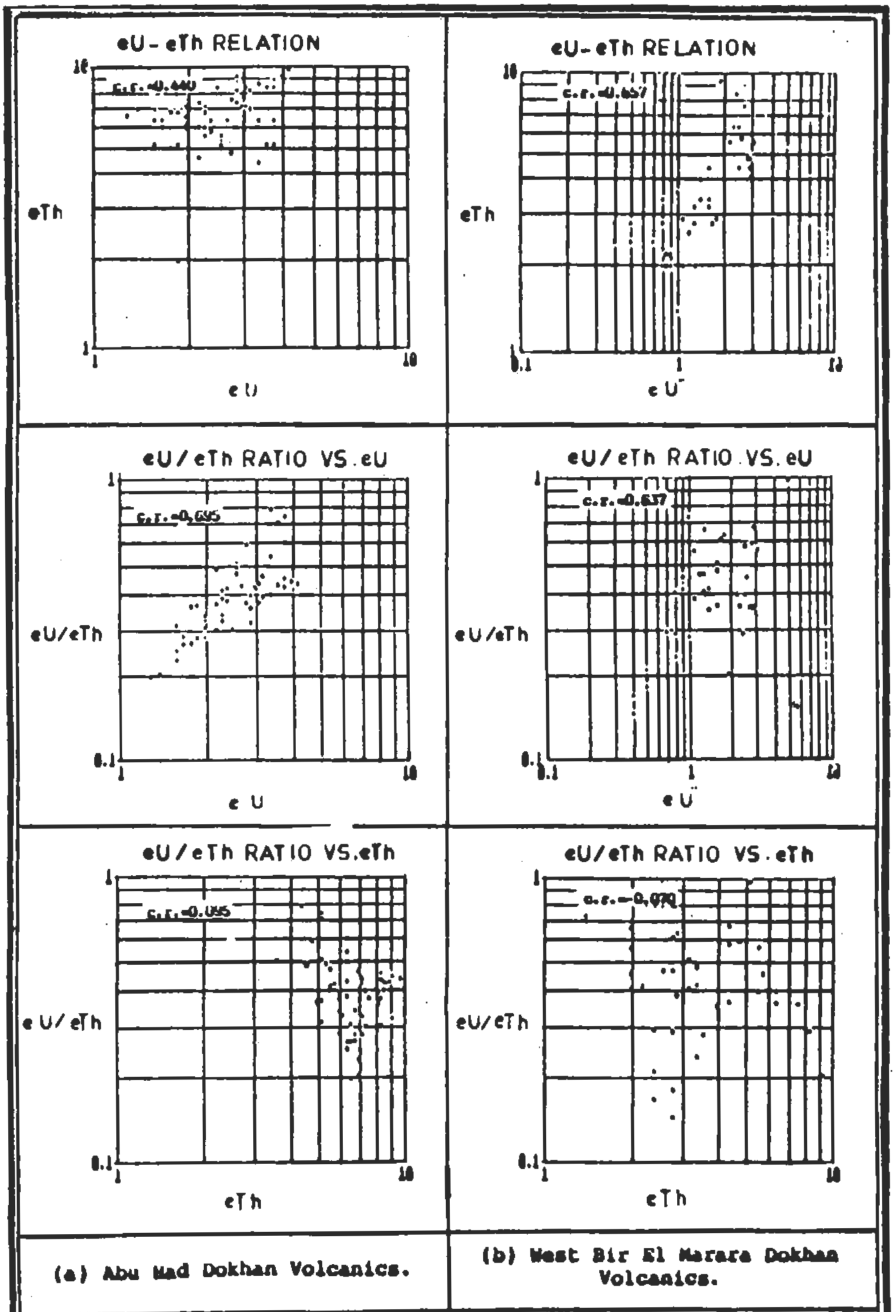


FIG. 18. Variations of uranium, thorium with their ratio for Abu Had and West Bir El Marara Dokhan volcanics.

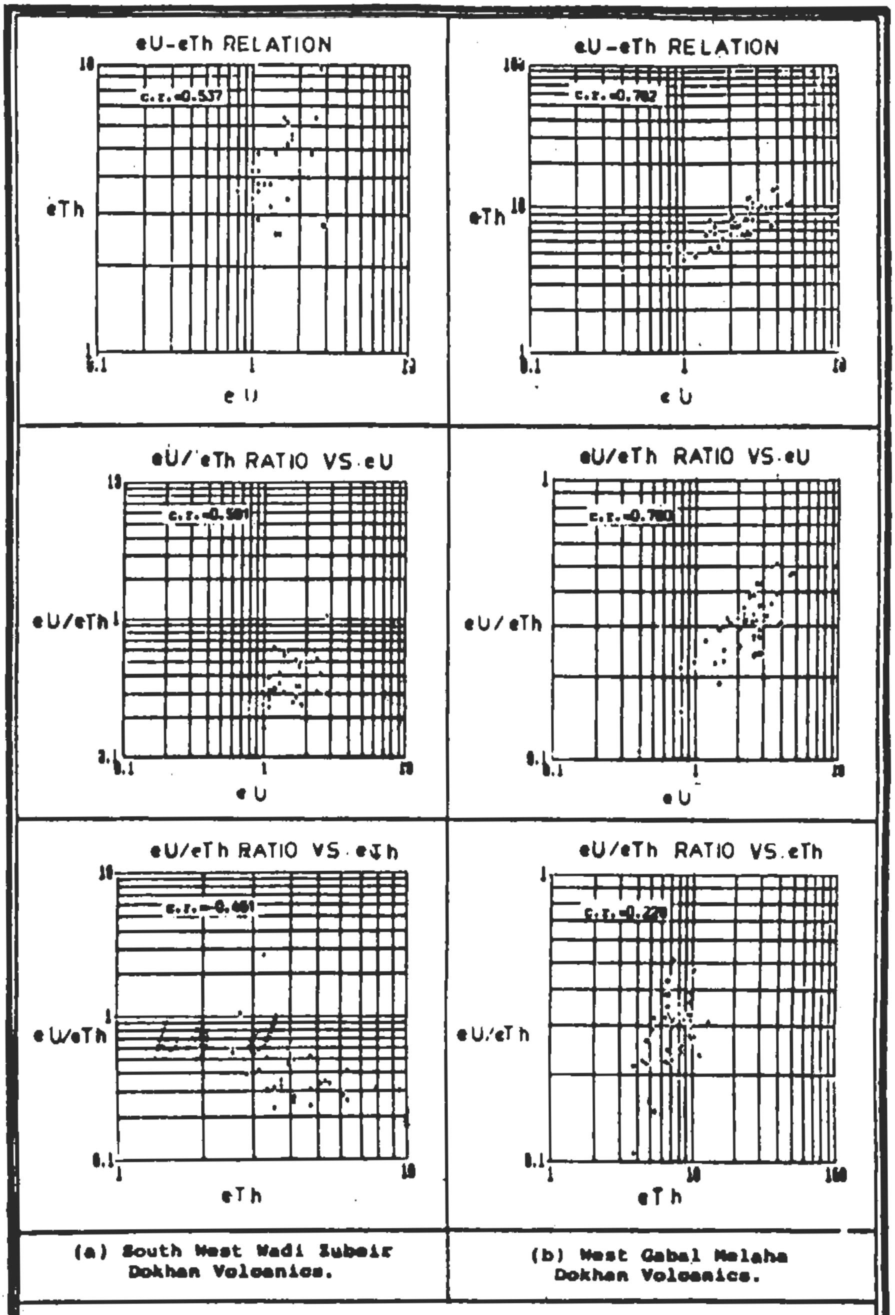


FIG. 19. Variations of uranium, thorium with their ratio for south west Wadi Zubeir and west Gabal Melaha Dokhan volcanics.

FIG. 20. Geomorphic lineament map of G. Idid El Gedan area, eastern desert, Egypt.

versely with thorium concentration. These relations reflect that thorium has remained relatively immobile in these sedimentary rocks.

F. The relationships between U/Th ratio, uranium and thorium in the Metagabbro-Diorite Complex; of North Wadi Zubeir (Fig. 15.a) and of North Wadi Melaha (Fig. 15.b), suggest a limited redistribution of uranium.

G. In the case of Metavolcanics of Wadi Melaha (Fig. 16.a), Wadi Zubeir (Fig. 16.b), and West Wadi Abu Had (Fig. 17); the U/Th ratio varies directly with uranium concentration and inversely with thorium concentration. This reflects that no mobilization of uranium has occurred.

H. In the case of Metavolcanics of G. Abu Had (Fig. 18.a), West Bir El Marara (Fig. 18.b), and West G. Melaha (Fig. 17.b), the U/Th ratio increases strongly with uranium but not thorium, suggesting post magmatic redistribution of uranium. Meanwhile, in the case of Dokhan Volcanics of the South West, Wadi Zubeir (Fig. 19.a), the U/Th ratio varies directly with uranium content and inversely with thorium concentration. These relations suggest that thorium was fixed in the early stages of magmatic evolution.

In the previous discussion, it is realized that some redistribution of uranium which could have affected its correlation with thorium and their ratio, may have occurred due to weathering (near-surface) phenomena. Figure 20 shows the geomorphic lineament pattern of the study area which may act as a preferred pathway for migrating mineralizers.

Summary and Conclusion

The application of statistical trend analysis to the aeromagnetic and gamma-ray spectrometric data is devoted mainly to show the relationship among them and to geologic structures as well as the relationship between the radioelement mineralization and structural trends' structures. The results of such analysis can be summarized as follows :

1. The dominant trend of the subsurface structures is the NNW-SSE trend, while that of the surficial structures is the NW-SE trend. This indicates that there is a gradual deviation in the dominant trend towards the west by about 10-15° upwardly.
2. The area under consideration is subjected to a maximum principal stress oriented ENE or NE-SW; perpendicular to the dominant trend.
3. It is recommended that the NE structures (as traced from the regional magnetic component maps) and the surface structures (as traced from all spectrometric data), must be of prime importance from the point of view of radioelement exploration.

The trends of the variations of uranium and thorium with their ratio reflect the amount of remobilization of uranium that has occurred within the different rock units. The tentative interpretation of their trend variations within granodiorite (in the vicinity of the ring complex), Wadi Zubeir granites (including its overlying Wadi deposits), and Dokhan Volcanics of G. Abu Had, West G. Melaha and, west Bir El Marara, suggests that post magmatic redistribution of uranium has occurred. Dyke swarms which are prevailing in the granodiorites and W. Zubeir granites may be one of the causes of such remobilization.

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صحبات الاتجاهات المغنطيسية والراديومترية وعلاقاتها بإعادة تحرك اليورانيوم في جبل إيديد الغيدان في منطقة الصحراء الشرقية في مصر

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المستخلص . تم عمل تحليل ثنائي الأبعاد للمنغنطيسية ومعلومات طيفية لأشعة جاما لمنطقة جبل أيديد الغيدان بمنطقة الصحراء الشمالية الشرقية بمصر بوساطة تطبيق طريقة دالة التباين الإسهامي الذاتي ، وذلك لتحديد العلاقة بين الاتجاهات السطحية والتراكيب تحت السطحية ، وكذلك أية علاقة واضحة تعكس التحكم في التمعدن الإشعاعي . إضافة إلى ذلك ، تم إيضاح درجة إعادة تحرك اليورانيوم في كل وحدة صخرية من خلال اتجاهات التغيرات في اليورانيوم والثوريوم ونسبتيهما .