STRUCTURALLY CONTROLLED RADIOACTIVITY IN THE UM BOGMA AREA, MIDWESTERN SINAI, EGYPT

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الخلاصـــة :

يتراوح عمر الصخور الرسوبية في منطقة أم بجمة من حقب الحياة القديمة (بالبوزويك) حتى الحقب الحديثة (الميوسين) ، وهى محدودة بمنكشفات من صخور القاعدة التابعة لأحقاب ما قبل (الكمبرى) ، وتمثل المنطقة التي تبلغ مساحتها حوالي ٥٠٠٠ كم٢ جزءاً أساسيا من وسط غرب سيناء بمصر .

وفي هذه الدراسة تـمَّ انجاز تخطيط التواجدات المشعة ودراسة علاقتها بالتراكيب من خلال استخدام القياسات الإشعاعية الجوية ، والقياسات المغناطيسية الجوية ، والملاحظات الحقلية الجيولوجية والتحاليل الكيميائية لبعض العينات الصخرية . كما تم تطبيق عدد من تقنيات التفسير للمعطيات المغناطيسية الجوية لتحديد الوجهات البنيوية وذلك مثل التحويل إلى القطب ، والترشيح ، والمشتقة الرأسية ، والتحليل الاحصائى للوجهات .

وقد أنتج ذلك خريطة بنيوية لصخور القاعدة للمنطقة المدروسة توضح أن الجزء الأوسط منها هو بنية حوضية (حوض وادى نتش) محاطة بواسطة مجموعات رئيسة من الصدوع المتجهة نحو شمال الشرق وشمال الغرب .

ومن الممكن أن تمثل تقاطعات هذه الصدوع (خاصة شمال ٢٥° شرق ، شمال الغرب) العامل المتحكم لتواجدات النشاط الإشعاعى ذات الأهمية بالمنطقة . وقد أثبت التحقق الحقلي وجود عدد كثير من التباينات الاشعاعية داخل حوض وادي نتش البنيوي خاصة عند تقاطعات مجموعات الصدوع المستـنـتجة ، حيث تتركز المواد المشعة .

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ABSTRACT

The Um Bogma area represents an essential part of mid-western Sinai, Egypt. Sedimentary rocks exposed in the area range in age from Paleozoic to Miocene and overlie non-conformably rocks of Precambrian age.

The delineation of radioactive occurrences in the area and the study of their relation to structures were achieved through the use of aeroradiometry, aeromagnetometry, geologic field observations, and chemical analyses of some rock samples. Various techniques, including reduction to the pole (RTP), filtering, vertical derivative, and statistical trend analysis, were applied to the collected aeromagnetic data to interpret major tectonic trends. Integration of such techniques has yielded a basement tectonic map for the study area that shows a structurally controlled basin (Wadi Abu Natash basin) in the central part of the area bounded by two major sets of faults trending N25°E and N25°W. Field observations have proved the existence of several radioactive anomalies within the Wadi Abu Natash structural basin mainly controlled by the intersections of these faults.

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INTRODUCTION

The Wadi Abu Natash structural Basin represents one of the economically important parts of midwestern Sinai. It is well known for both its exploited manganese/iron ore and its recently discovered uranium deposits. The area under study covers about 5000 km^2 and lies between long. 33° 10′ and 33° 30′ E and lat. 28° 50′ and 29° 10′ N (Figure 1).

Topographically, the area includes both moderately high mountains and flat plains. The mountains are composed of either sedimentary rocks or igneous/metamorphic basement complexes and are dissected by several wadis in different directions. Examples of Peneplained surfaces in the region are Dabbet El Qrei and Ramlet Hemyir.

The area is covered by different rock types that range in age from Pre-Cambrian to Miocene. These include the biotite schists at the base of Jabal Nukhul near Wadi Khaboba, the diorite–granodiorite complex at the base of Jabal Nasib, the pink granites at the base of both Jabal Adediya and Jabal Marahil, as well as the Cambrian Sarabit El Khadim Formation, the Early Eocene Thebes Formation and the Early Miocene Gharandal Group.

A photogeologic map, prepared for the study area at the scale of 1:40 000, was checked in the field and was reduced to the scale of 1:200 000 (Figure 2). A systematic airborne radiometric survey for the same area was carried out by the Geology and Raw Materials Department, Atomic Energy Establishment of Egypt, along parallel flight lines at N25°W and at 500 m spacing intervals, with an average ground clearance of 70 m and an average ground speed of 170 km/h.

An aeromagnetic survey was carried out by the Geological Survey of Occupied Palestine [1] at the scale of 1:500 000. The flights were conducted at an altitude of 1100 m above mean sea level. The regional gradient of the Earth's magnetic field was removed and the data were recontoured with an interval of 10 nanotesla by the senior author.

A ground radiometric survey was also carried out for the different rock types exposed in the area and a correlation between the airborne registered radiometric anomalies, those discovered during this study, and the geological structures as interpreted from aerial magnetic and radiometric maps was conducted.

Rock samples collected from the sites of radioactive locations were subjected to mineralogical and chemical analyses to identify the radioactive minerals present and to determine the uranium concentrations (Table 1).

Table 1. Uranium Concentrations of Radioactive Anomalies Discovered at Different Localities in Wadi Abu Natash, Um Bogma Area, Midwestern Sinai, Egypt.

(Chemical analyses from Isotope Geology Lab., 1988)

Sample Number	Locality	Rock type	eU in ppm
1	J. Hemyer	Sandstone	165
2		Ferruginous sandstone	105
3	Ramlet Hemyer	Clay	550
4		Sandstone	667
5	W. Khamila	Sandstone dyke	417
6	W. Nasib	Sandstone	1050
7		Shale	309
8	Abu Thora	Shale	585
9		Shale	350
10	J. Um Hamd	Sandstone	457
11		Silt	292
12	W. Sahu	Silt	522
13	W. Seih Sidri	Ferruginous sandstone	362
14		Ferruginous sandstone	241
15	J. Adediya	Granite	519

GEOLOGY OF THE UM BOGMA AREA

Most of the area under consideration is covered with Paleozoic rocks of different types extending from the Cambro–Ordovician sandstone with shale [2] to the Early Carboniferous dolomitic limestone of the Khaboba Formation [3]. These rocks are overlain by the Early Carboniferous sandstones and silts of the Abu Thora Formation. Southward, a continental Carboniferous–Permian clastic section of the Budra Formation [4] or Al-Qiseib Formation is exposed in Wadi Budra.

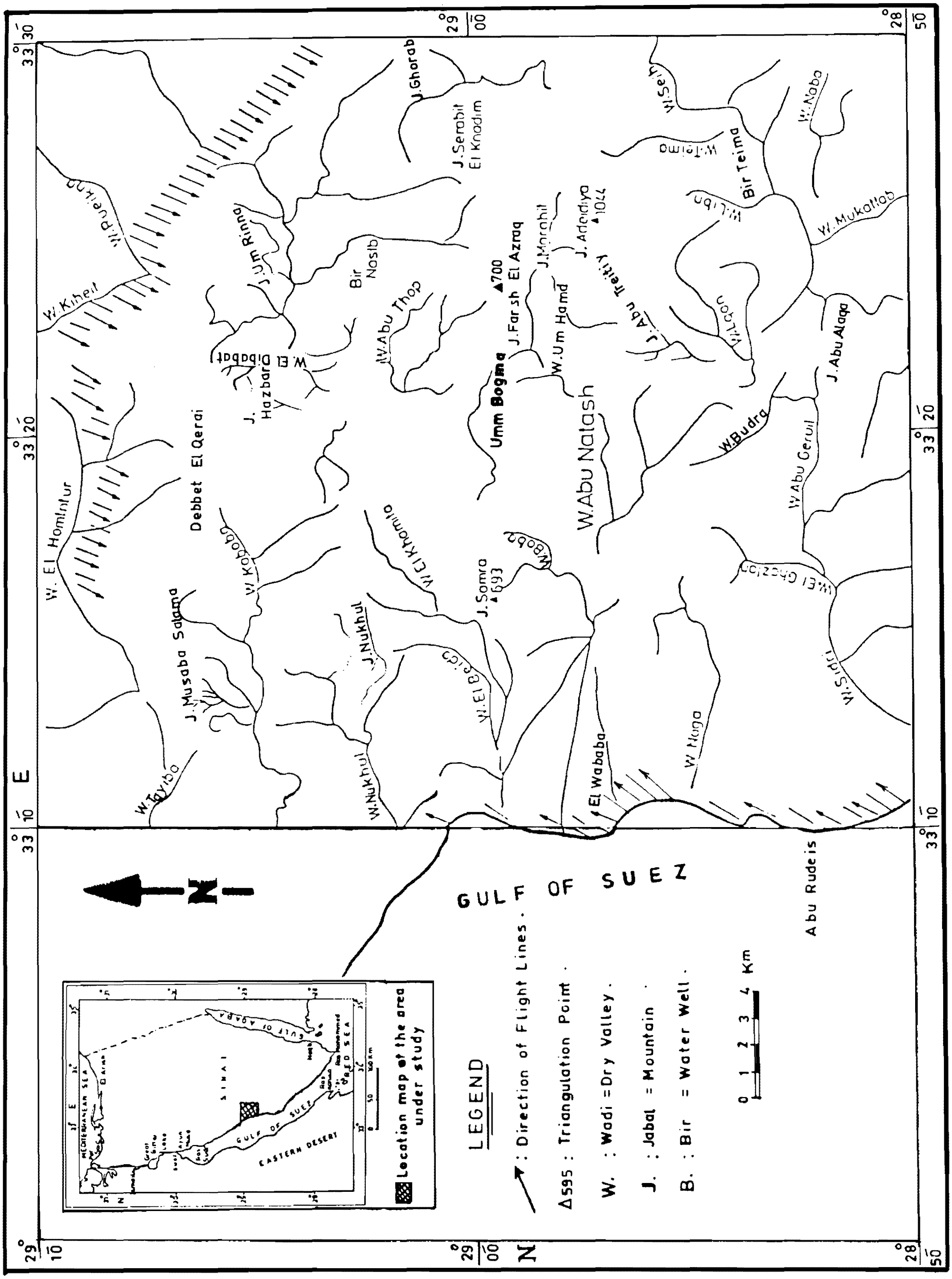

Figure 1. Topographic Map of the Um Bogma Area, Midwestern Sinai, Egypt.

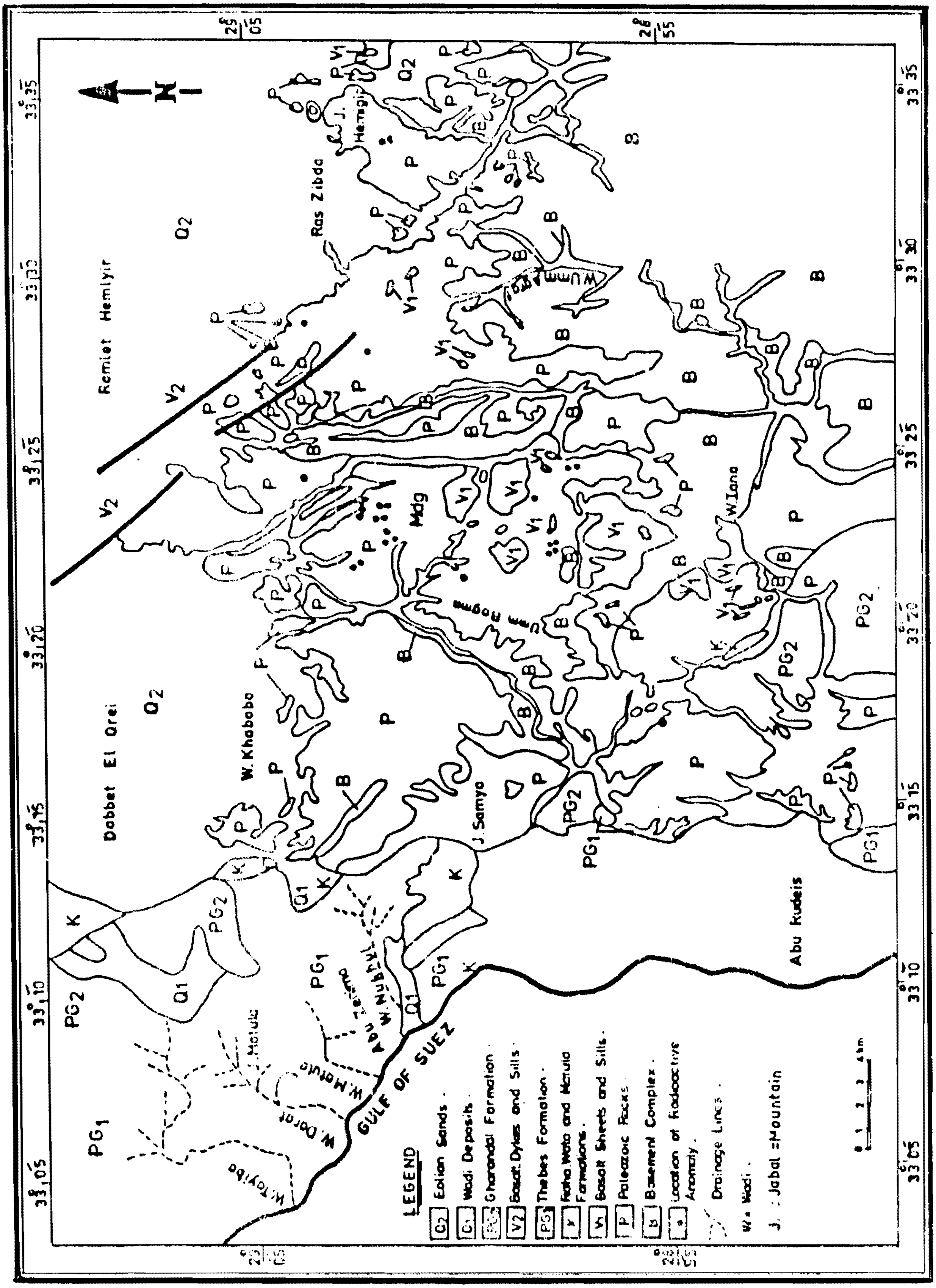

Figure 2. Geologic Map of the Um Bogma Area, Midwestern Sinai, Egypt.

The Early Cretaceous Nubia sandstone facies of the Malha Formation is exposed in several localities including the base of both Jabal Abu Alaqa and Jabal Nazzazat and in Wadi Mukattab. The Late Cretaceous Raha, Wata, Matulla, and Sudr Formations are well exposed in several localities (Figure 2). The Paleocene Esna Shale is locally exposed within some shapes overlain by the Early Eocene limestone with chert interbeds of the Thebes Formation. The Miocene Abu Alaqa Formation is observed in its type section (Jabal Abu Alaqa) and the conglomerate of the Gharandel Group is recorded at the intersection of Wadi Budra with Wadi Sidri. Basalts and dolerites are present as dykes, sills, and flows. These are either of Jurassic age [5], intruded in the Early Carboniferous Abu Thora Formation or of Oligo–Miocene age and intruded in both the Early Cretaceous Malha Formation and the Early Eocene Thebes Formation.

QUALITATIVE INTERPRETATION OF AERORADIOMETRIC DATA

The aeroradiometric map (Figure 3) was constructed primarily to locate radioactive anomalies in the area. It gives the radiometric background of each rock type and allows their mapping using the characteristic radioactivity level.

The minimum radioactivity measured in the study area varies between 1.7 and 3.4 Ur (one unit of radioelement concentration = one part per million

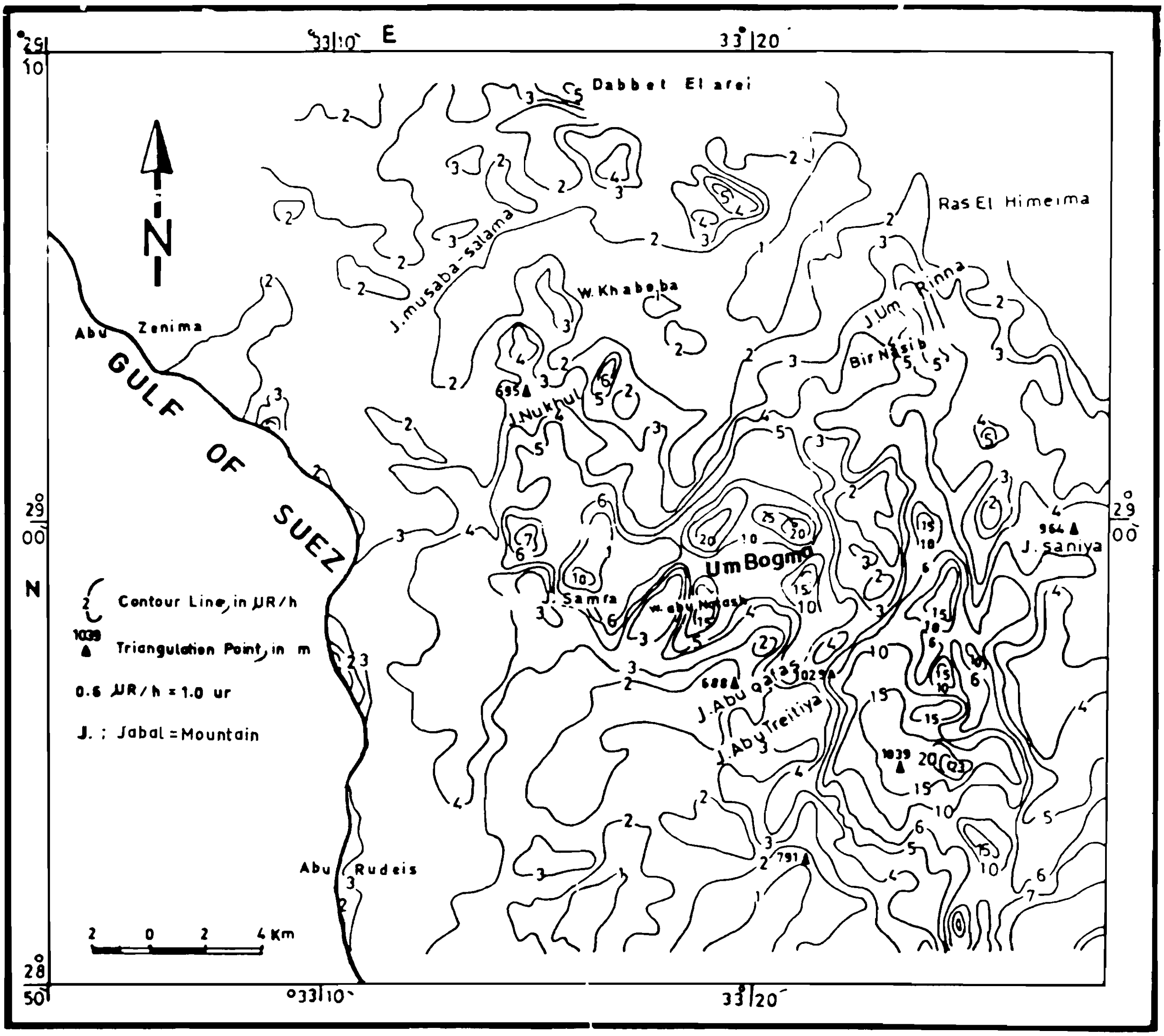

Figure 3. Aerial Radiometric Contour Map of the Um Bogma Area, Midwestern Sinai, Egypt.

uranium in equilibrium). This was recorded at both the northwestern part (which is covered by carbonate rocks) and the southwestern part of the studied area (which represents a coastal fan of major wadis known as Elwat Baba and Elwat Sidri). The north-eastern part, also shows a lower radioactivity level, at 1.0 μR/h (1.66 Ur), because it is covered with a thick sheet of wind-blown sands.

The highest radioactivity measured in the area is recorded in three zones as follows:

1. An elongated zone that extends for about 20 km in a N−S direction, with its northern extremity lying in the eastern part of the studied area, south of latitude 29°N at Jabal Farsh El Azrag (passing through Jabal Marahil, Jabal Adediya, and Wadi Um Hamd), and its southern extremity lying at Wadi Libn. The maximum intensity of this zone reaches 22 μR/h (38 Ur).
2. A zone of four closures which are arranged in a nearly circular form, the center of which is Jabal Um Bogma, with a maximum radioactivity measurement 25 μR/h (42 Ur).
3. A zone located at the southeastern part of Jabal Samra, with a lower radioactivity measurement of only 10 μR/h (17 Ur) in intensity.

RELATIONSHIP BETWEEN RADIOACTIVITY AND GEOLOGIC STRUCTURES

Several structural elements were identified, and fifteen sandstone, silt and clay samples were collected for chemical analysis (Table 1) during the field investigations. The structural elements identified in the field can be listed as follows:

1. At Jabal Nazzazat and near the base of the Esna shale, some pyrite veins were noticed trending NE and NW. These extend for about 60 to 70 m, and are altered in their exposed surfaces to hematite. Pyrite concretions had previously been recorded in the Sudr Formation at Jabal Musabba Salama [6].
2. In the Um Hamd area, a N60°E tending fault with a zone of 2−2.5 m width and an extension of about 500 m was recorded (Figure 4*a*). The two sides of this fault plane zone are composed of Paleozoic reddish brown sandstone with less than 1.0 μR/h (1.66 Ur) radioactivity, while the fault zone itself is enriched in iron−manganese minerals and has anomalous radioactivity of up to 16 Ur (9.6 μR/h). This fault zone is displaced by a N20°W trending fault which is void of any radioactivity (Figure 4*a*).
3. A sandstone dyke trending N65°E and extending for about 400 m with a width of 5−30 m was observed at Wadi Khamila. (Figure 4*b*). It traverses brown ferruginous sandstones equivalent to the Paleozoic Khaboba Formation, and is also observed at the eastern side of Jabal Ghorabi. This dyke is composed of ferruginous fine-grained sandstone, siltstone and kaolinite, and its two walls (contacts) represent a radioactive anomaly with as much as 417 ppm eU.

ISOLATION OF MAGNETIC ANOMALIES

Magnetic anomalies are usually classified into two main groups: regional and residual. The regional anomalies are generally of large areal extent, with high amplitudes, and are associated with the large and deeper features within and at the basement surface. The weaker and more localized anomalies (residual), however, are superimposed on the regional magnetic

Figure 4a. A N60°E Fault in Paleozoic Sandstone with Radioactive Anomaly. The fault plane is displaced by a NW fault (Wadi Sahu: Looking NE.)

Figure 4b. A Sandstone Dyke in Paleozoic Sediments (Wadi Khamila: Looking N65°E.)

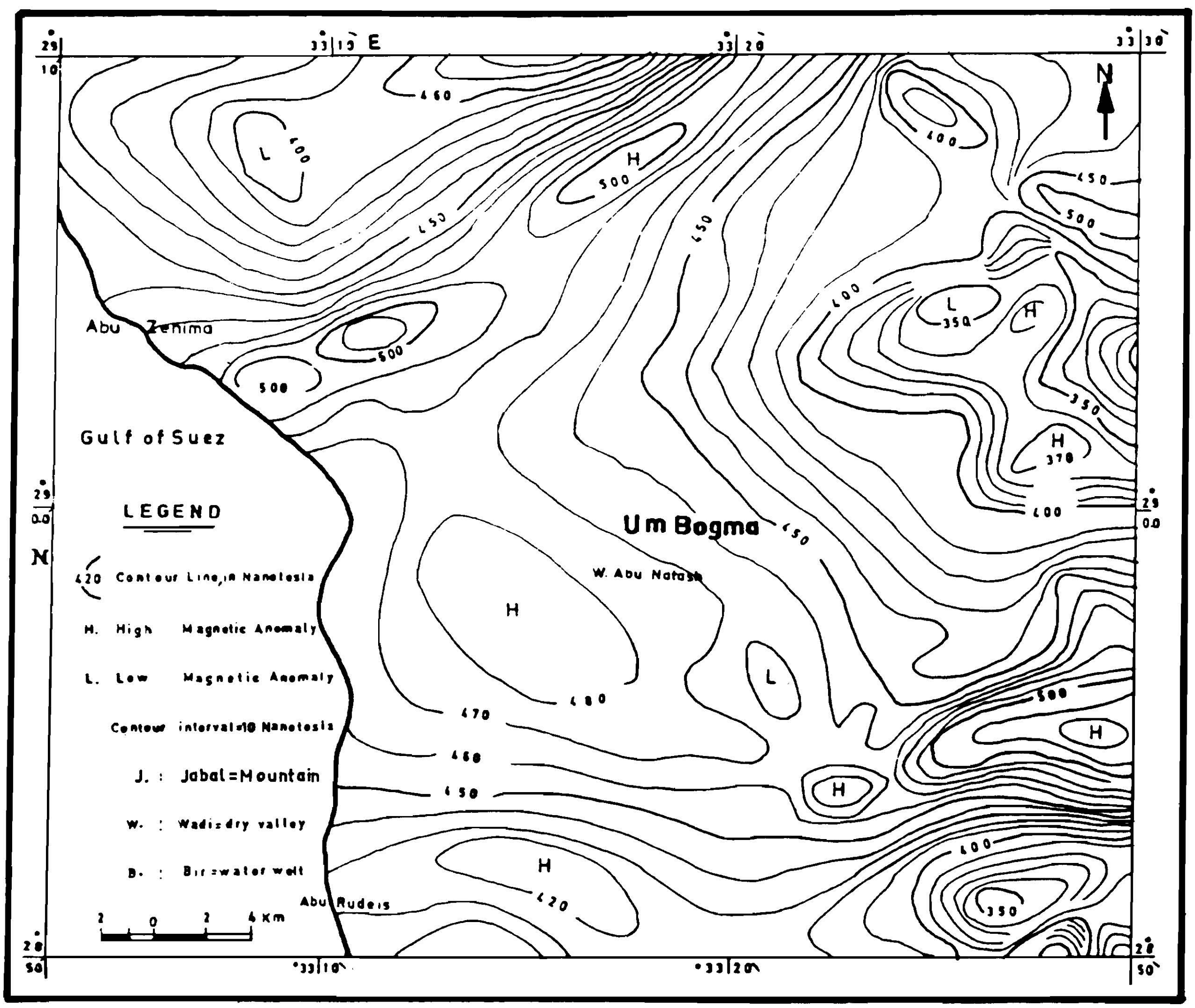

Figure 5. Total Intensity Aeromagnetic Map of the Um Bogma Area, Midwestern Sinai, Egypt.

pattern and are characterized by higher frequencies, and are usually of lower amplitude.

In order to separate the recorded magnetic anomalies as regional or residual (Figures 6, 7), the regional magnetic gradient of the Earth's field was removed and the data were recontoured at an interval of 10 nanotesla. The manual digitization of the total intensity aeromagnetic map was carried out on a grid pattern with a station spacing of one kilometre (Figure 5).

A second vertical derivative magnetic map (Figure 8) was constructed to assist in locating the different contacts or faults that delimit basement blocks as well as for better resolution of some superimposed anomalies.

MAGNETIC TREND ANALYSIS

The purpose of this technique is to indicate any possible relationship between magnetic and tectonic trends in the area. A standard method for portraying the two-dimensional pattern is to construct a frequency plot, showing the percentage of trends lying in various direction ranges [7].

A trend analysis was carried out for the existing magnetic maps as well as for the aeroradiometric map (Figure 3). The magnetic maps include: the total intensity (Figure 5), the regional magnetic-component (Figure 6), the residual magnetic component (Figure 7), and the second vertical derivative (Figure 8). Trends of the magnetic anomalies and of the steep magnetic gradients that separate different

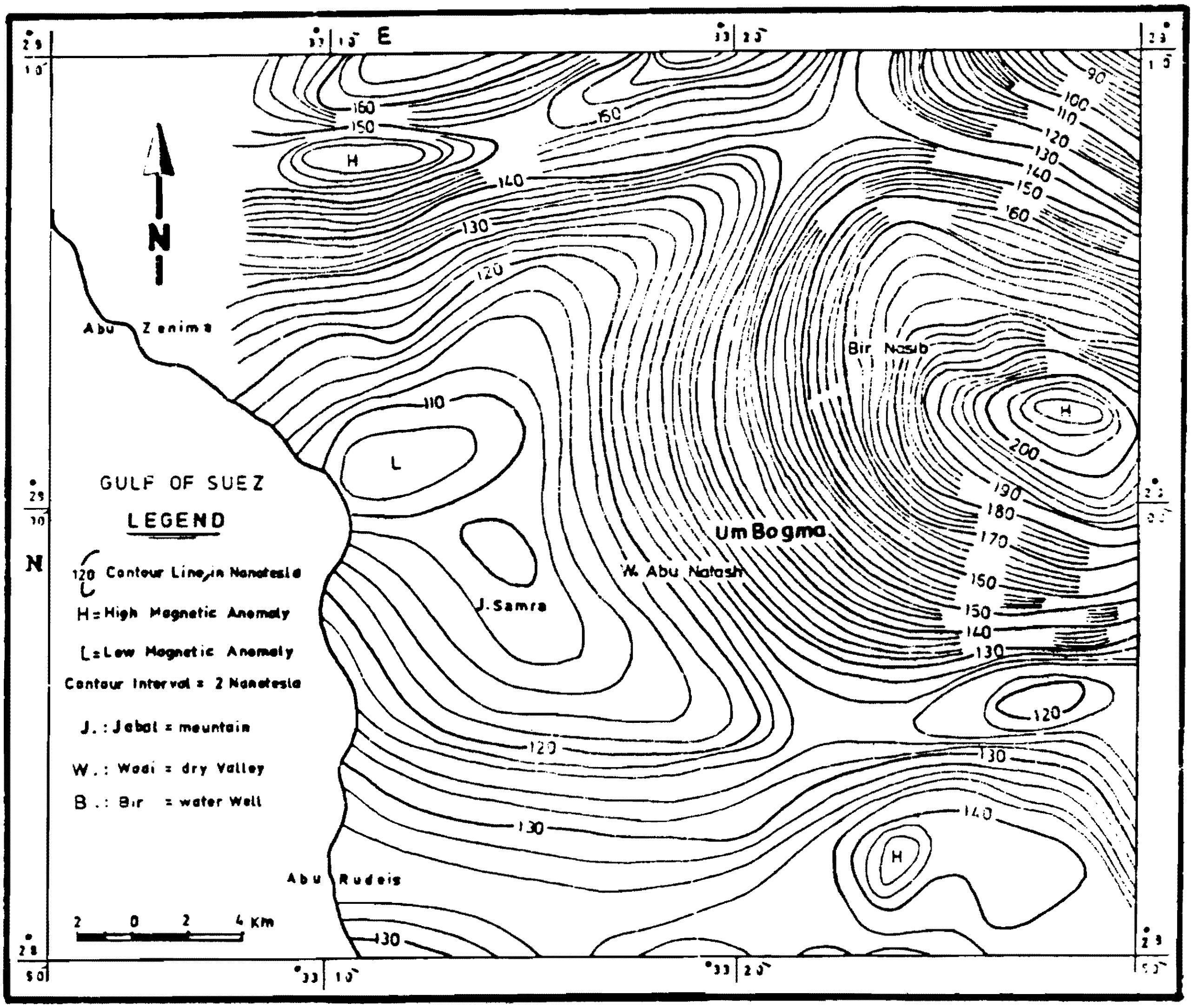

Figure 6. Regional Magnetic Component Map of the Um Bogma Area, Midwestern Sinai, Egypt.

magnetic anomalies were marked and traced. The length and direction of each trend were measured, and grouped in 10-degree "classes". The lengths of all trends within a certain range were summed up and calculated as a percentage of the total length of all trends. The results of this analysis are shown as rose diagrams in Figure 9.

DISCUSSION

The various peaks recorded in the five rose diagrams (Figure 9) represent the strikes of different fractures or of different tectonic trends in the area under consideration. The relative magnitudes of such peaks is regarded as a reflection of the magnitude and frequency of deformation resulting from different stresses that took place at different geological times. The main features interpreted by this trend analysis can be listed as follows:

1. Five major peaks affected the study area with the following trends in a decreasing order of magnitude: N65°E (Syrian arc or Qattara trend), N45°W (Gulf of Suez–Red Sea trend), N65°W (Najd trend), N15°W (NNW trend) and N25°E (Gulf of Aqaba trend).
2. The N15°W (NNW) trend is a strong tectonic trend in the regional magnetic component and is not reflected in the other rose diagrams. Therefore, this trend is considered to be a Precambrian basement trend since it shows only on the regional magnetic map (Figure 9b).

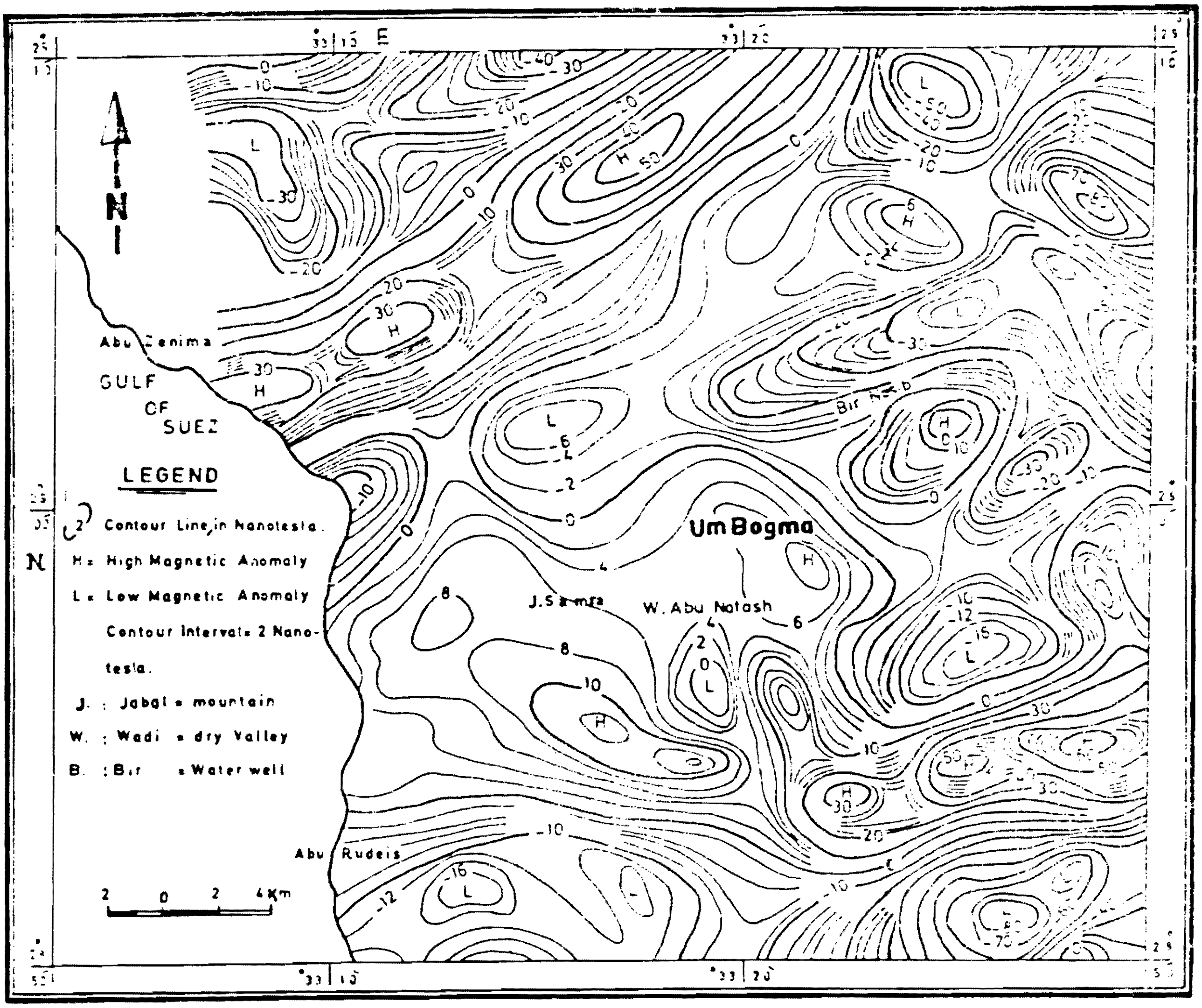

Figure 7. Residual Magnetic Component Map of the Um Bogma Area, Midwestern Sinai, Egypt.

Youssef [8], interpreted this northerly trending system of faults as probably due to deviating compressional force of the initial N10°W by about 10° west. He stated that these faults are limited in number and are mostly minor faults. Ghanem [9] described the fault trending in a N–S direction as being developed after the emplacement of the late orogenic plutonites. Meleik [10] described this system of fractures as an old one which might have been developed during the geosynclinal subsidence together with the E–W system of fractures. This trend is referred to in the literature as the "East African trend".

3. Good development of the N45°W (Gulf of Suez) and the E–W trends among residual and second vertical derivative magnetic maps and their absence from the rose diagram of regional magnetic trends (Figure 9*b*) may suggest their presence in the Phanerozoic sediments only.

The N45°W (Suez) trend is interpreted as one of two complementary shear fracture systems which probably resulted from a northern compressive force [11]. Youssef [8] interpreted the E–W trend as an ancient fracture system that has been originated by compressive stresses acted mainly from N10°W and S10°E which were later slightly shifted westward. This trend has been interpreted by Meshref and others [12] to be due to the couple force that affected north Africa during the Mesozoic time.

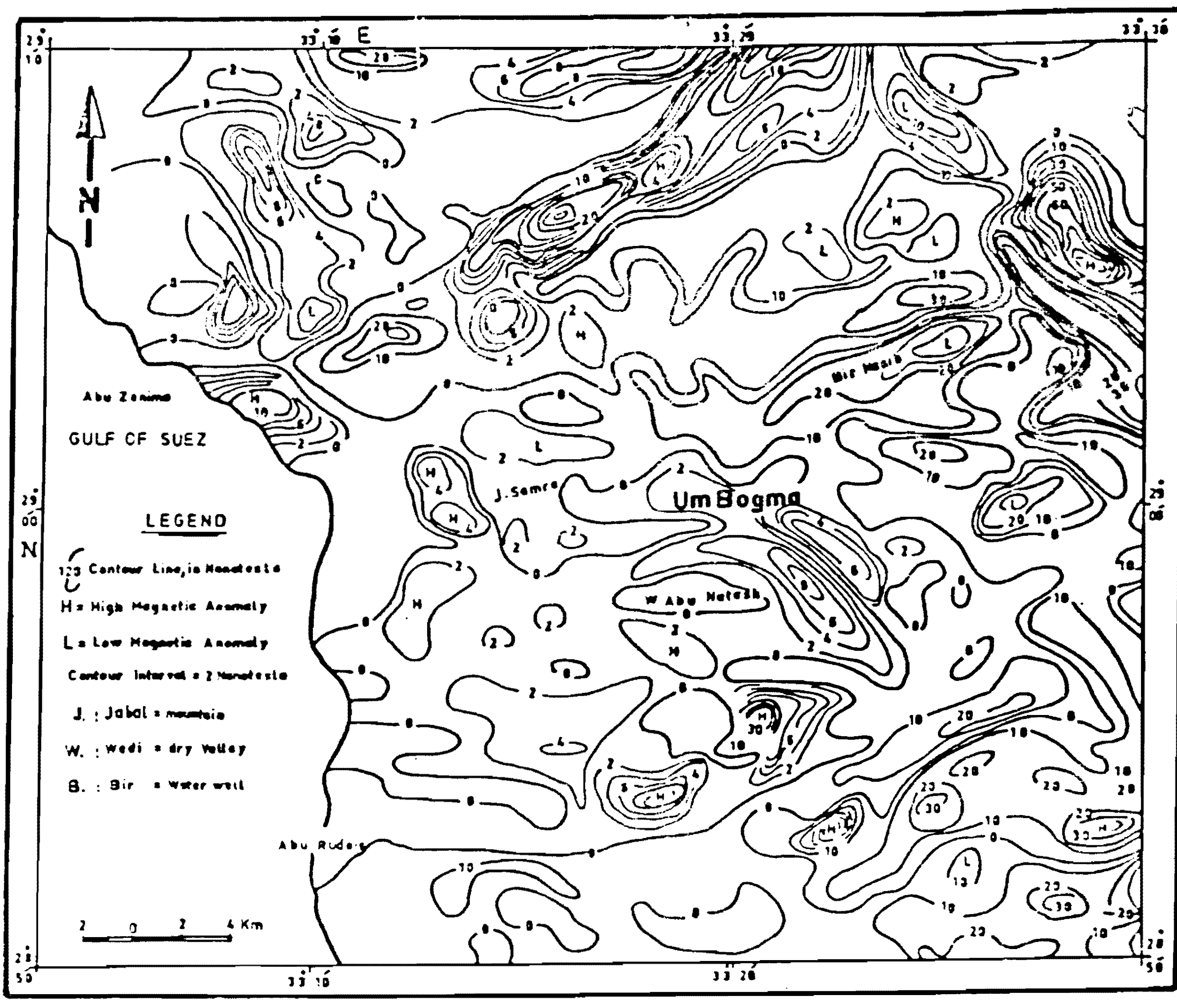

Figure 8. Second Vertical Derivative Magnetic Map of the Um Bogma Area, Midwestern Sinai, Egypt.

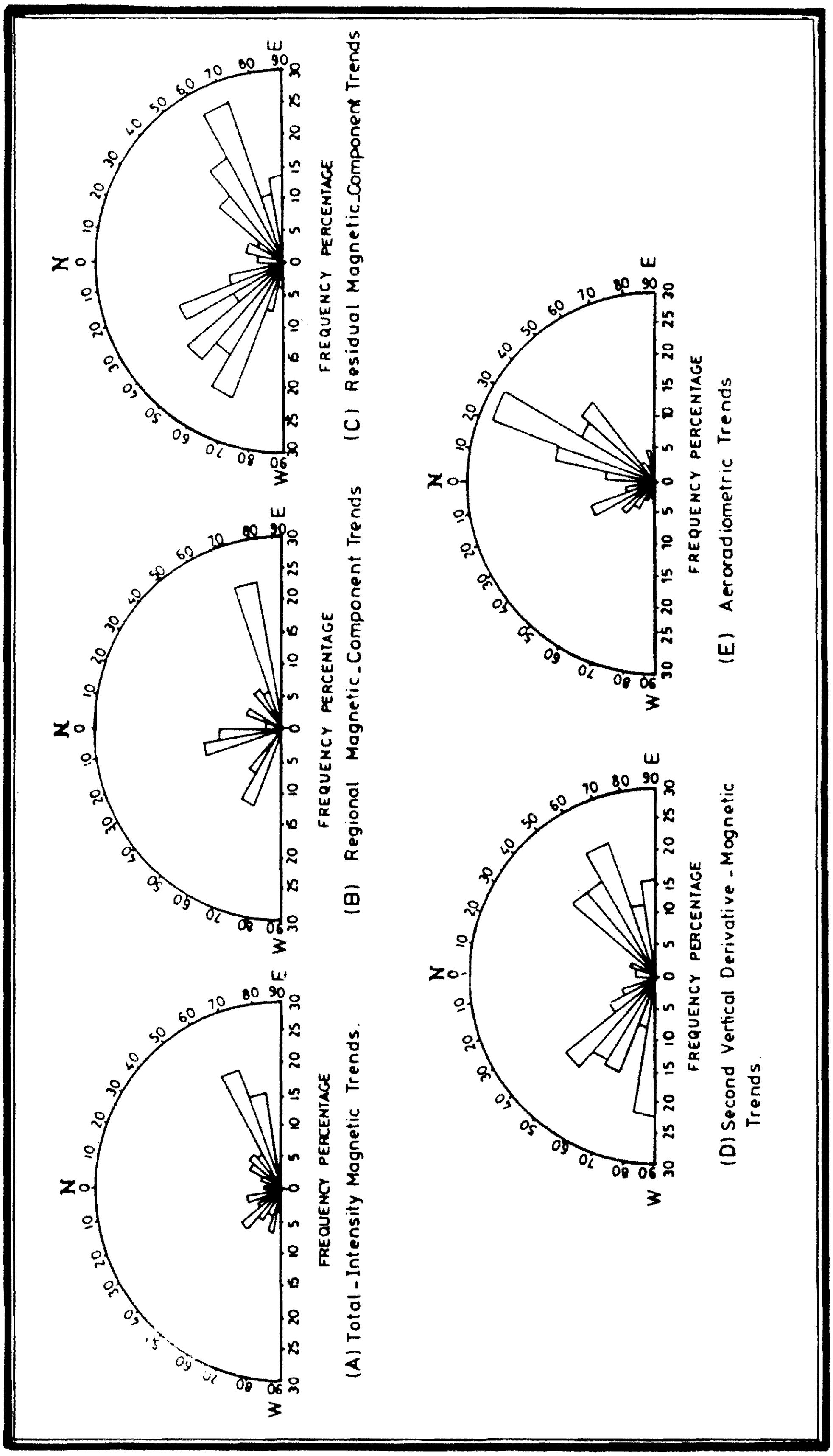

Figure 9. Azimuth–Length % Rose Diagrams for Various Magnetic and Radiometric Trends in the Um Bogma Area, Midwestern Sinai, Egypt.

4. The N65°E (Syrian arc), N65°W (Najd Fault system) and N25°E (Aqaba Fault system) trends are recorded in all the rose diagrams of different magnetic maps (Figure 9). Therefore, these tectonic trends are well developed in the area in both the Precambrian basement rocks and the Phanerozoic cover sediments.
5. The aeroradiometric trend analysis performed in the present study (Figure 9*e*) shows four main radiometric trends namely: the N25°E, the N45°E, the N25°W, and the N45°W trends. Among these trends, the N25°E trend is the most predominant. It is, therefore, recommended that fractures along such trend should be thoroughly investigated with respect to radioactive mineralization.

BASEMENT TECTONIC MAP

Moustafa [13], concluded that the field mapping of the Baba-Sidri area shows a steeply dipping, locally vertical or overturned, monoclinal flank dissected by a number of steep normal faults, at and close to the rift boundary. These structural features are interpreted to be the result of drape (forced) folding of the sedimentary cover over a deep-seated (basement) steep normal fault. Also, enormous drags, especially on the downthrown sides of major faults, as well as the existence of reverse faults and overturned rocks are anomalous features accompanying major normal faults in the Suez rift as reported by Moustafa and Abdeen [14].

Dobrin [15] mentioned that a basin is characterized by smooth contours and low magnetic relief, while the surrounding platform area shows steep gradients and high relief magnetic contours. The central part of the area under study (Wadi Abu Natash) is characterized by smooth magnetic contours and low magnetic relief, while the surrounding platform area shows steep gradients and high relief. The uplifted blocks are also characterized by a series of positive magnetic anomalies, whereas the downfaulted blocks are characterized by a series of negative magnetic anomalies.

The basement tectonic map (Figure 10) of Um Bogma area was constructed using surface geologic information, qualitative and quantitative interpretations of magnetic maps as well as the results obtained from the magnetic tectonic trend analysis. This map shows the following three striking features:

1. The presence of two major uplifted blocks (horsts I and II), one in the northwestern part of the studied area, and the other in its southwestern part. The trend of the northwestern uplifted block (I) is more or less ENE, whereas the trend of the southwestern one (block II) varies from WNW to E–W.
2. The presence of two down-faulted blocks or grabens (III and IV) within the interpreted Wadi Abu Natash basin itself.
3. The existence of two fault systems dissecting the area under investigation, the first trending ENE to NNE and the second trending NW. The NW fault system is younger, more frequent and cuts the relatively older ENE trend. Some of the NW and ENE interpreted faults are probably associated with vertical and/or horizontal displacements.

The two major uplifted blocks (I and II) bound the Wadi Abu Natash basin from north and south, while the four major faults designated F_1, F_2, F_3, and F_4 bound it from east and west (Figure 10). A relatively thick column of sediments is thought to occur in this structurally-controlled basin.

RELATIONSHIP BETWEEN THE TECTONIC PATTERN AND RADIOACTIVITY

Field observations, field radioactivity measurements as well as aeroradiometric data indicate that the NNE (or NE) and the NW fractures of the Wadi Abu Natash Basin are associated with radioactive anomalies, where the highest measurements are recorded (Figure 10).

New radioactive anomalies were discovered during the field check of the interpreted basement tectonic map (Figure 10), and the photogeological map (Figure 2) of the area. These new anomalies are associated with siltstone of the Early Carboniferous section of the Khabob Formation. Their activity is not very far from that recorded in the Abu Thora or in the Jabal Alloage which reaches 468 Ur.

CONCLUSIONS

The main conclusions derived from the present study can be summarized as follows:

1. The aeroradiometric map (Figure 3) shows an approximately rectangular zone of radioactive anomalies occupied by Jabal Samra, Jabal Um Bogma, Jabal Abu Natash, Jabal Um Hamd and Jabal Libn at the southeastern corner of the study area. The radioactivity within this zone reaches more than 42 Ur specially around Jabal Um Bogma.

2. The radioactive anomalies are either restricted within the Precambrian igneous rocks (Quartz veins in pink granites) or within sedimentary rocks (siltstone, shale, and sandstone) of the Early Carboniferous Khaboba Formation.
3. Magnetic trend analysis shows five major directions: N65°E, N45°W, N65°W, N15°W, and N25°E arranged in a decreasing order of magnitude. These are suggested to reflect tectonic trends.
4. There is a structurally-controlled basin in the Um Bogma area which is called the Abu Natash basin. It is bounded from east and west by four major faults (F_1 to F_4) and from north and south by two major horsts: I and II (Figure 10).
5. The NNE (or NE) and NW tectonic trends are found to be associated with mineralization and most of the radioactive anomalies are located within the Abu Natash basin. Field observations, field radioactivity measurements as well as aeroradiometric data support this conclusion.

ACKNOWLEDGEMENTS

The authors are deeply grateful to Prof. Dr. Ahmed A. Ammar, President of the Exploration Division, Nuclear Materials Authority, for faithful guidance, and critical reviewing of the manuscript.

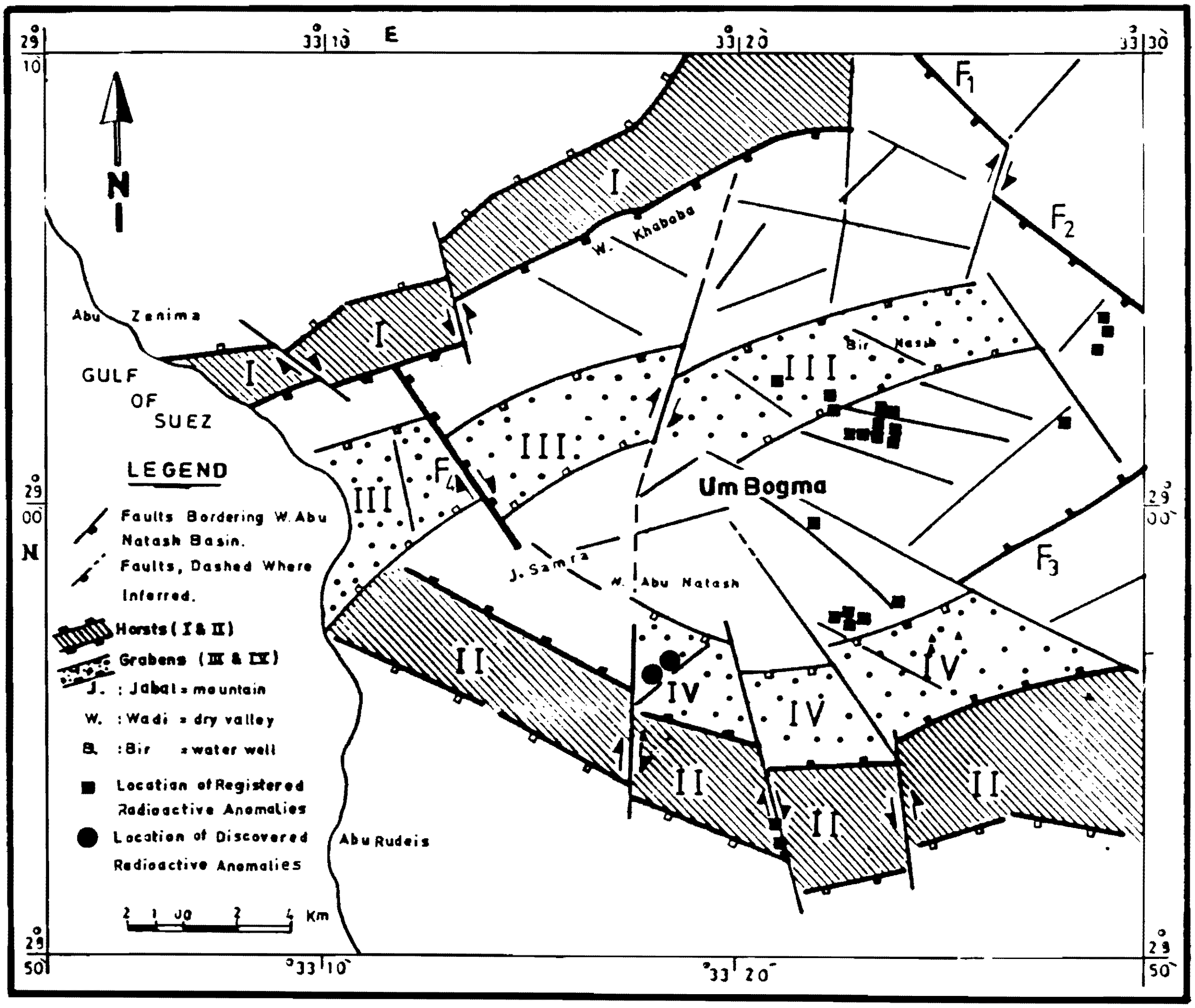

Figure 10. Basement Tectonic Map of the Um Bogma Area, Midwestern Sinai, Egypt.

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Paper Received 23 September 1990;
Revised 8 June, 14 September 1991.