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Tectonic Implications of the Northern Part of Gulf of Suez Region as Revealed from the Lineament Analysis of Landsat Imageries

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ABSTRACT. Processing on lineaments revealed from photo-satellites imageries of the northern part of the Gulf of Suez region has been carried out. Imageries of Landsat exhibit lineaments that reflect topographic surface features surrounding the water covered area of the Gulf of Suez. The lineaments were differentiated according to their frequencies, thicknesses and lengths. Azimuth frequency distribution of groups of the different differential parameters was investigated for each azimuth interval of N 10º to the east and N 10º to the west.

Geographic information system (GIS) was applied in the different combinations of distributions for the two azimuth categories (N to E) ~ (S to W) and (N to W) ~ (S to E). Tectonic implications and identifications of the paleogeologic events that produced shearing and rifting effects along the major trends of Gulf of Suez, Gulf of Aqaba, North South and East West are emphasized. More light is thrown on the nature of the causative tectonisms, which includes their origins, intensities and the general framework of the structural settings.

Introduction

Lineaments can be defined (O' Leary *et al.*, 1976) as "mappable, simple or composite linear features of a surface, whose parts are aligned in a rectilinear or slightly curvilinear relationship which differs distinctly from the patterns of adjacent features and reflects a subsurface phenomenon".

Lineaments on the land surface of the study area are formed by a variety of landscape elements, including topographic drainage alignments which are supposed to reflect the invisible subsurface structure (either of shallow, intermediate or deep origin).

Study Area

The Gulf of Suez lies at the northeastern corner of Egypt between longitudes 32º40′-33º45′E, and latitudes 27º-25′-30º00′ (Fig. 1). It is a shallow and narrow water body located between the Eastern Desert and Sinai Peninsula. It extends for about 350 km, from the southern tip of Sinai Peninsula to the Suez city, with an average width of about 65 km, and an average depth of 50 m. It covers an area of approximately 20,000 km^2 from Suez to Hurghada cities, and takes the direction of clysmic trend, N10º W-S 10ºE.

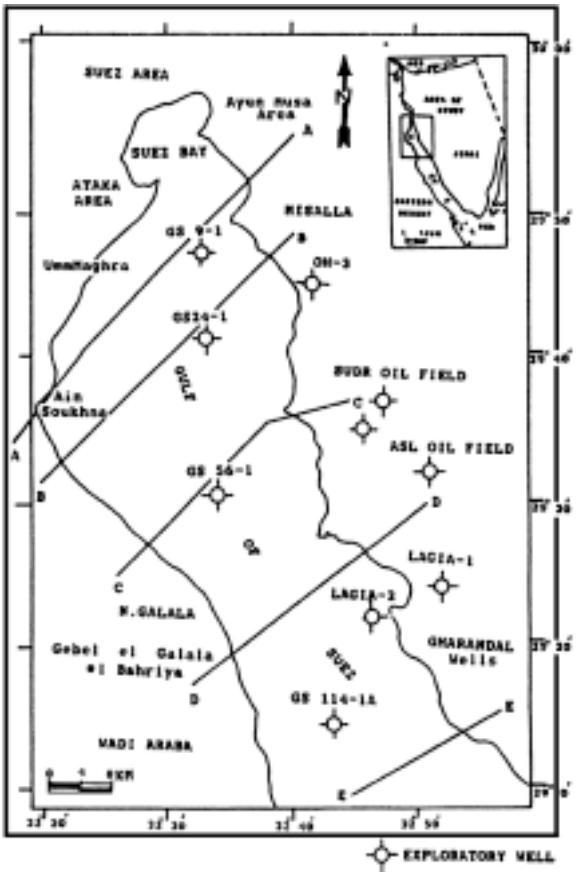

FIG. 1. The location map of the study area.

The Gulf of Suez basin represents an intensively faulted area which has origin of movements that have been active since early Paleozoic (Beleity *et al.,* 1986). The subsidence had been occurred along a zone of weakness following the clysmic set of fractures.

The Gulf of Suez can be divided into four tectonic provinces delineated by three lines which deviate slightly from the direction of the Gulf of Aqaba and extend northsouth,

from Ras Zaafarana, Ras Shukeir and Gemsa, respectively (Meshref *et al.*, 1976; Hagras, 1986). These four provinces had formed two highs (Ayun Musa and Araba-Zeit blocks) alternating with two lows (Abu Zenima and Hurghada basins).

Methods of Analysis

1. The landsat-image of the study area and its surrounding, Fig. (2), are divided into 65 regular squares (of size 290.25 km^2). Each square is 15.689 km, in latitude direction and 18.5 km, in longitude direction.

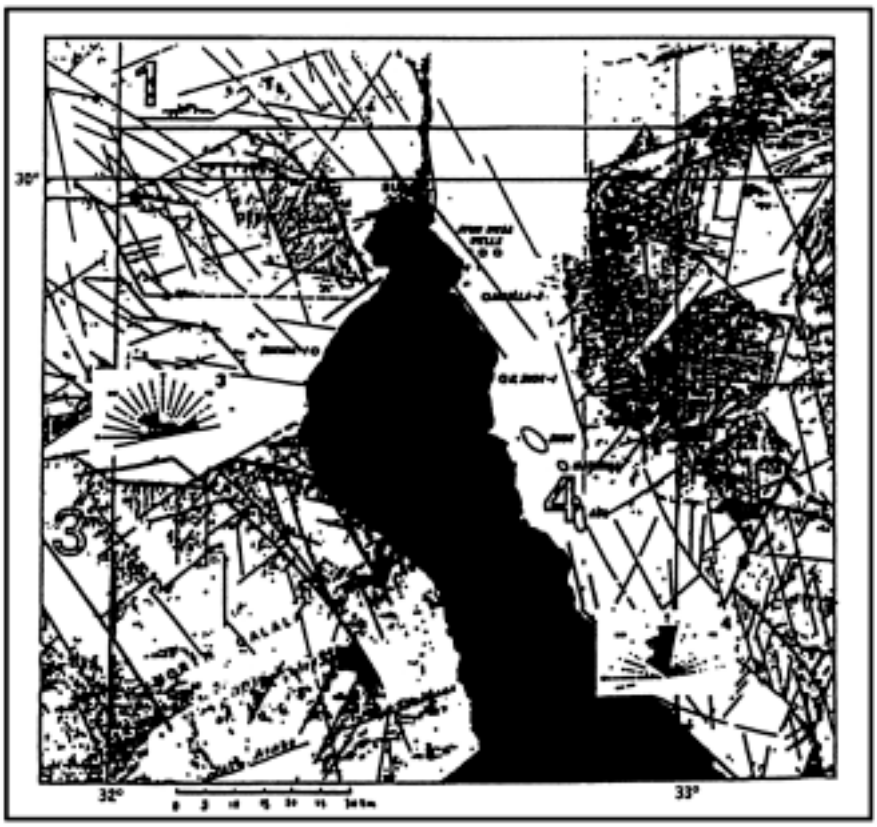

FIG. 2. The landsat-image of the study area.

2. For each square, the frequencies of lineaments are determined visually, the azimuth of each lineament is observed, the thicknesses of lineaments are categorized as thick, medium and thin, and the length of each lineament of these categories, is measured.

3. Distribution maps for frequencies, lengths and thicknesses (thick, medium, thin) in each azimuth deviation of 10º east and west were performed.

4. The closures in each type of these contour maps are presented and processed in

terms of number of intersected area. Thereafter, these intersected areas were presented in distribution contour maps.

The subsurface structure can be found by the study of lineament features on the land surface as follows:

1. The lineament frequency gives an indication about the origin of tectonism. As the lineament frequency becomes higher, the origin of tectonism is seemed to be shallower. If the origin of tectonism is deep, the overburden layers and sedimentary section masked a part of the effect of tectonic activity, there the lineament frequency is low.
2. The lineament length gives an information about the intensity of tectonism. As the lineament length increases, the intensity of tectonism is high. If the lineament length decreases, the intensity of tectonism is low.
3. The lineament thickness gives an information about the general structure framework of the study area. The thick lineaments give a criterion on the causative shallow range structure, the medium lineaments show the causative intermediate depth range structure.

Results and Discussion

We shall discuss analysis of lineaments in terms of their frequency, length and thickness.

1. Lineament Analysis in Terms of their Frequency

The intersection map of the eastward lineaments in terms of azimuth-frequency is shown in Fig. (3). The compiled contour map of azimuth-frequency of eastward lineaments (Fig. 4), reveals three main directions, Gulf of Suez, E-W and N-S trends. The origin of the Gulf of Suez trend is shallow, while the E-W trend has an intermediate origin and the N-S trend has a deep origin.

FIG. 3. The intersection map of the eastward lineaments in terms of azimuth-frequency.

FIG. 4. The compiled contour map of azimuth-frequency of eastward lineaments.

The intersection map of the westward lineaments in terms of azimuth-frequency is shown in Fig. (5). The compiled contour map of azimuth-frequency of westward lineaments (Fig. 6), reveals the two main trends of Sinai, *i.e.*, the Gulf of Suez and Gulf of Aqaba trends.

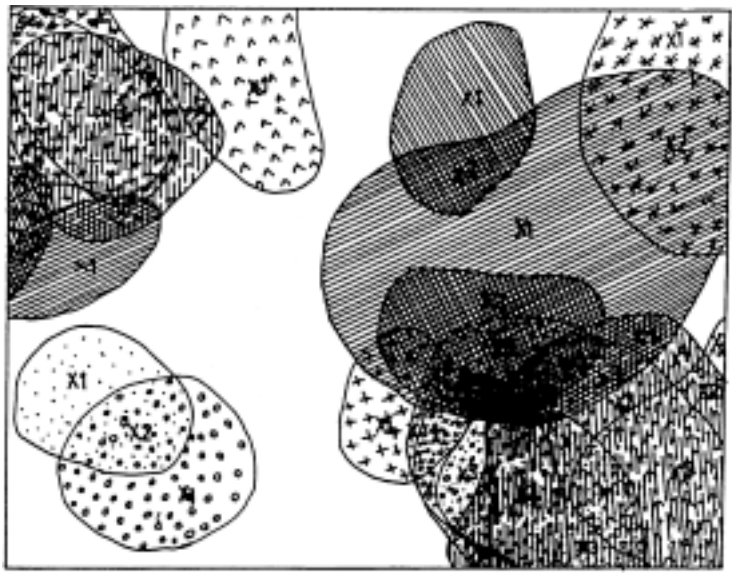

FIG. 5. The intersection map of the westward lineaments in terms of azimuth-frequency.

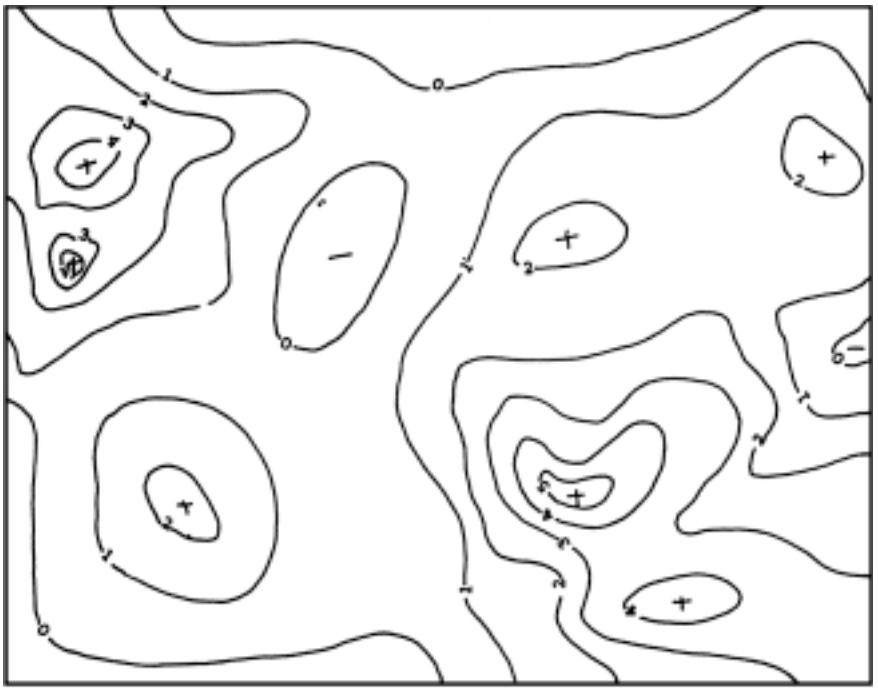

FIG. 6. The compiled contour map of azimuth-frequency of westward lineaments.

The Gulf of Suez trend is very clear and of shallow origin, while the Gulf of Aqaba trend has a deep origin.

2. Lineament Analysis in Terms of their Length

Recalling that the analysis of lineament length gives information about the intensity of tectonic forces, Fig. (7) shows the intersection map of lineaments in terms of azimuth-length of the eastward lineaments. The compiled contour map of azimuth-length of eastward lineament of Fig. (8), reveals that the tectonic stress in the direction of Gulf of Aqaba is strong, while in the direction of Gulf of Suez the tectonic stress is moderate. In E-W direction, the tectonic stress is weak.

The intersection map of the westward lineaments in terms of azimuth-length is shown in Fig. (9). The compiled contour map of the westward lineaments in terms of azimuth-length (Fig. 10) shows that intensity of the tectonic stresses in the two directions of Gulf of Suez and in E-W is strong. While the intensity of tectonic stress in the direction of Gulf of Aqaba is weak.

3. Lineament Analysis in Terms of their Thickness

The analysis of lineaments in terms of azimuth-thickness gives an information about the general structure framework of the study area where we get the following remarks:

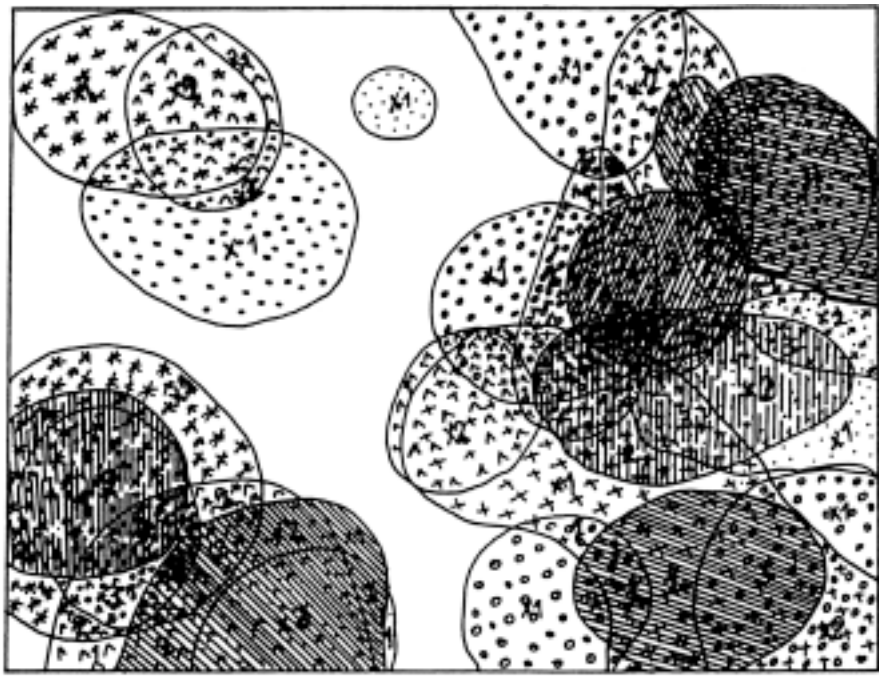

FIG. 7. The intersection map of the eastward lineaments in terms of azimth-length.

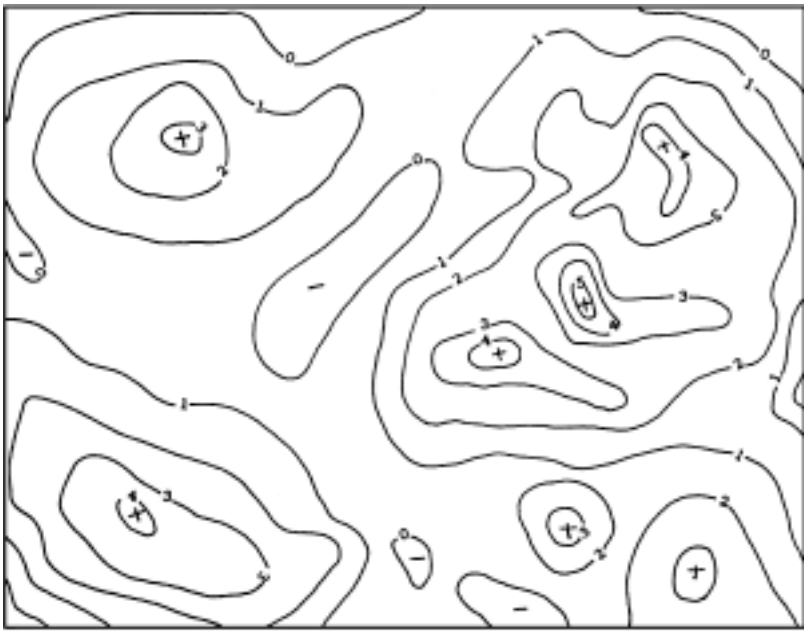

FIG. 8. The compiled contour map of azimuth-length of eastward lineaments.

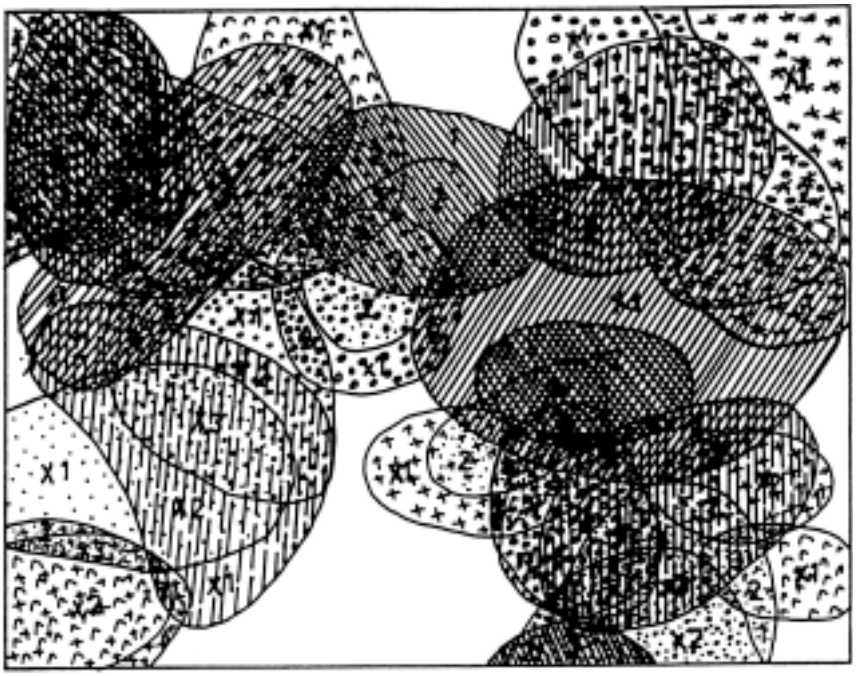

FIG. 9. The intersection map of the westward lineaments in terms of azimuth-length.

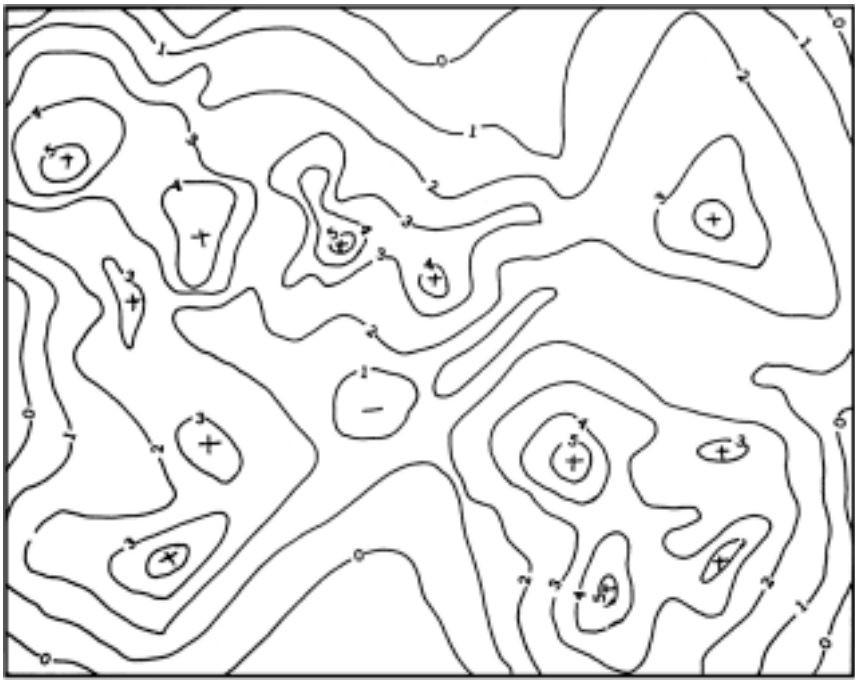

FIG. 10. The compiled contour map of azimuth-length of westward lineaments.

a. For Thick Lineaments

The intersection map of the eastward thick lineaments in terms of azimuth-thickness is shown in Fig. (11). The compiled contour map of eastward lineaments in terms of azimuth-thickness (Fig. 12), shows that general structure framework of the Gulf of Aqaba is shallow, while the framework structure of the Gulf of Suez is not present.

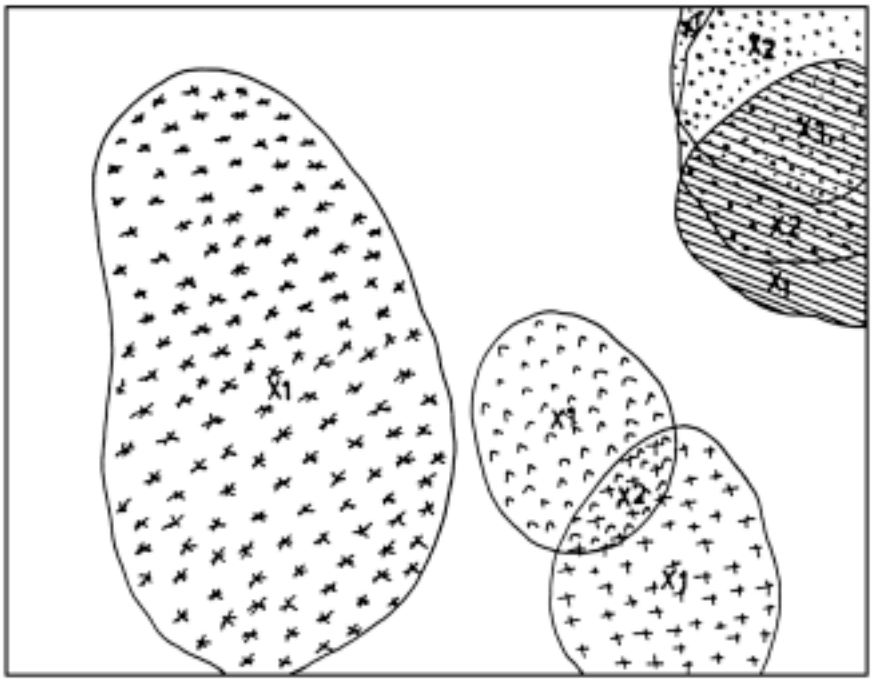

FIG. 11. The intersection map of the eastward thick lineaments in terms of azimuth-thickness.

The intersection map of the westward thick lineaments (azimuth-thickness) is represented in Fig. (13). The compiled contour map of thick westward lineaments in terms of azimuth-thickness (Fig. 14) reveals that the only general structure framework present is in E-W direction. This structure is characterized by shallow range structure.

b. For Moderate Thickness Lineaments

The intersection map of eastward lineaments in terms of azimuth-moderate thickness is shown in Fig. (15). The compiled contour map of moderate thickness eastward lineaments (Fig. 16), shows that the only general structure framework present is in N-S direction and is characterized by intermediate depth range structure. The intersection map of westward moderate lineaments (azimuth-moderate thickness) is shown in Fig. (17). The compiled contour map of the westward moderate thickness lineaments Fig. (18), shows that the general structure framework of Gulf of Suez is clear and of intermediate depth range. Also, in the N-S direction, the general structure is of intermediate depth.

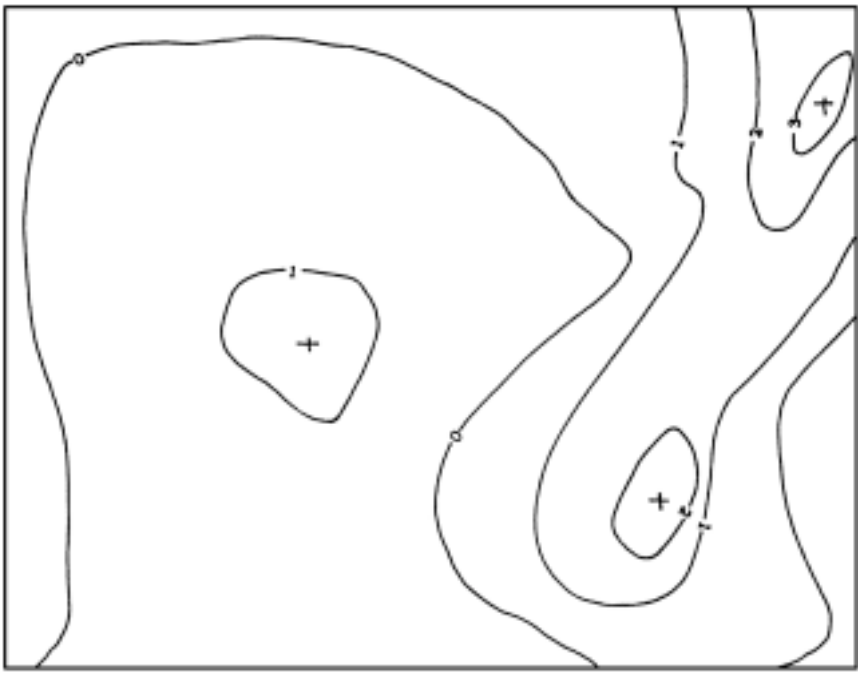

FIG. 12. The compiled contour map of azimuth-thickness of eastward thick lineaments.

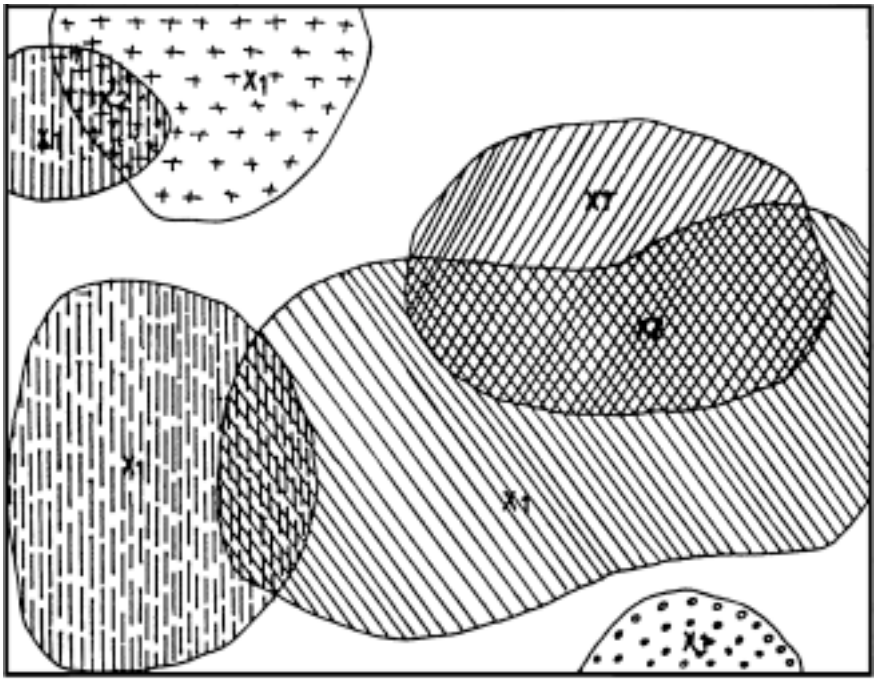

FIG. 13. The intersection map of the westward thick lineaments in terms of azimuth-thickness.

FIG. 14. The compiled contour map of azimuth-thickness of westward thick lineaments.

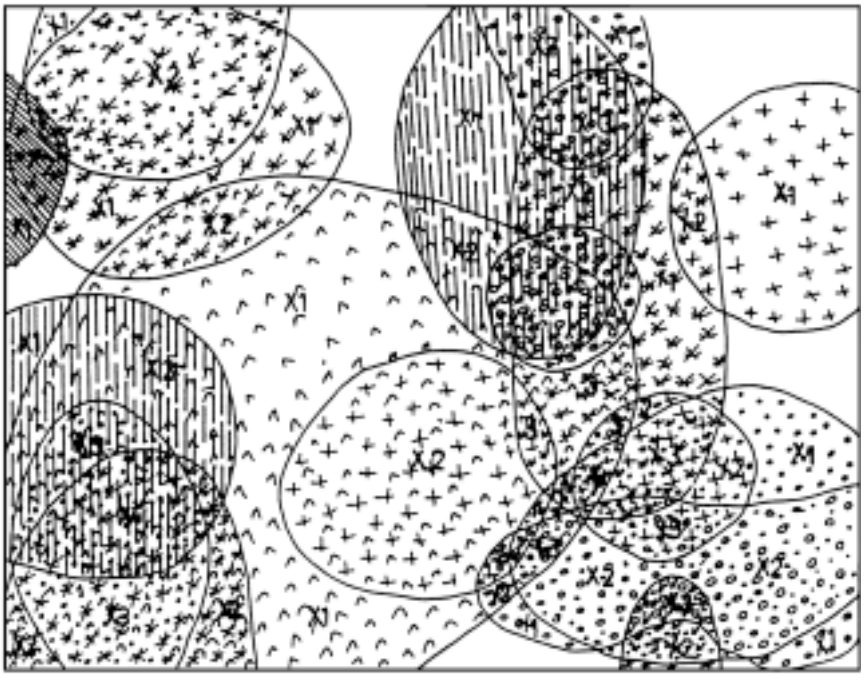

FIG. 15. The intersection map of the moderate eastward lineaments in terms of azimuth-thickness.

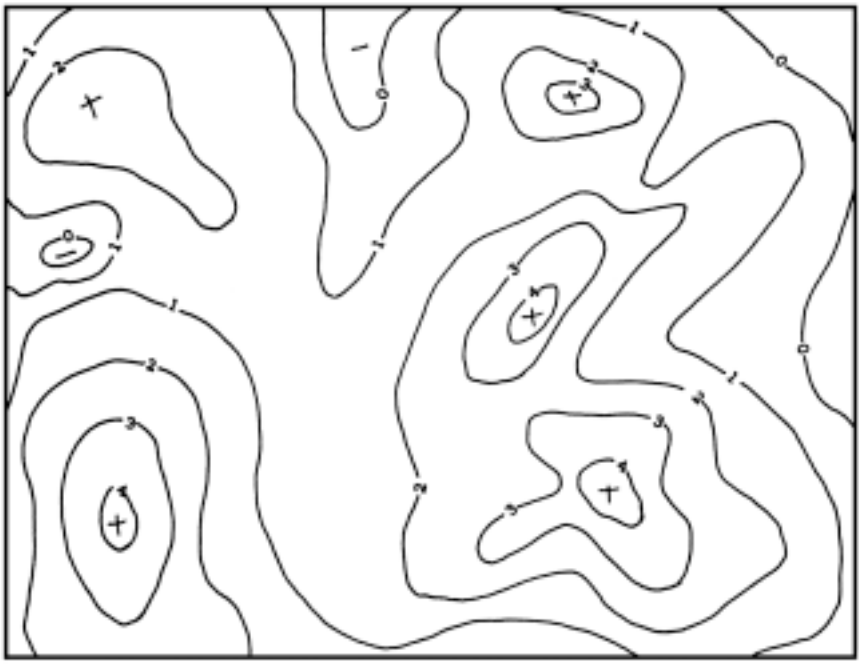

FIG. 16. The compiled contour map of azimuth-thickness of eastward moderate lineaments.

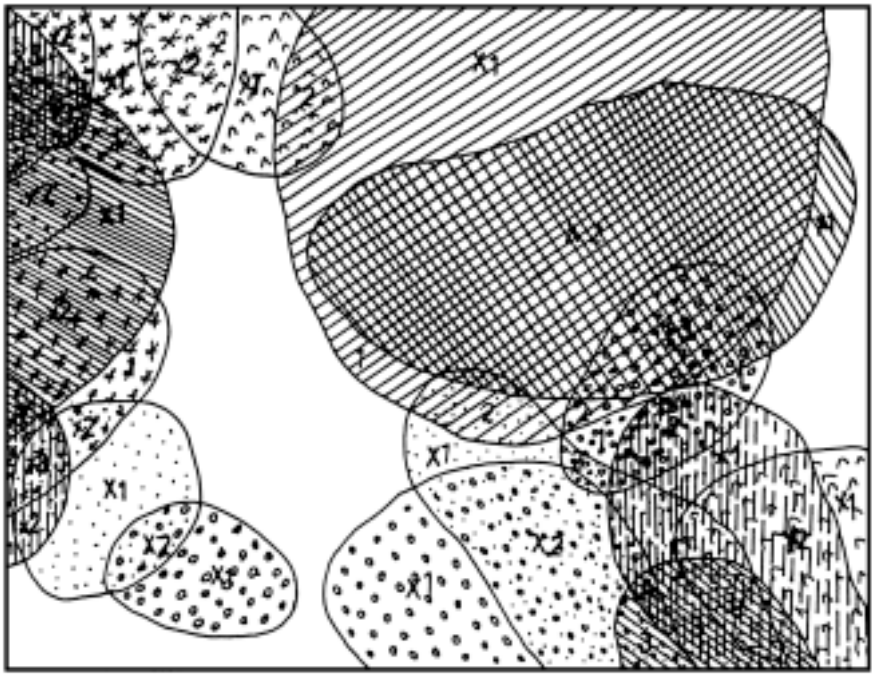

FIG. 17. The intersection map of the moderate westward lineaments in terms of azimuth-thickness.

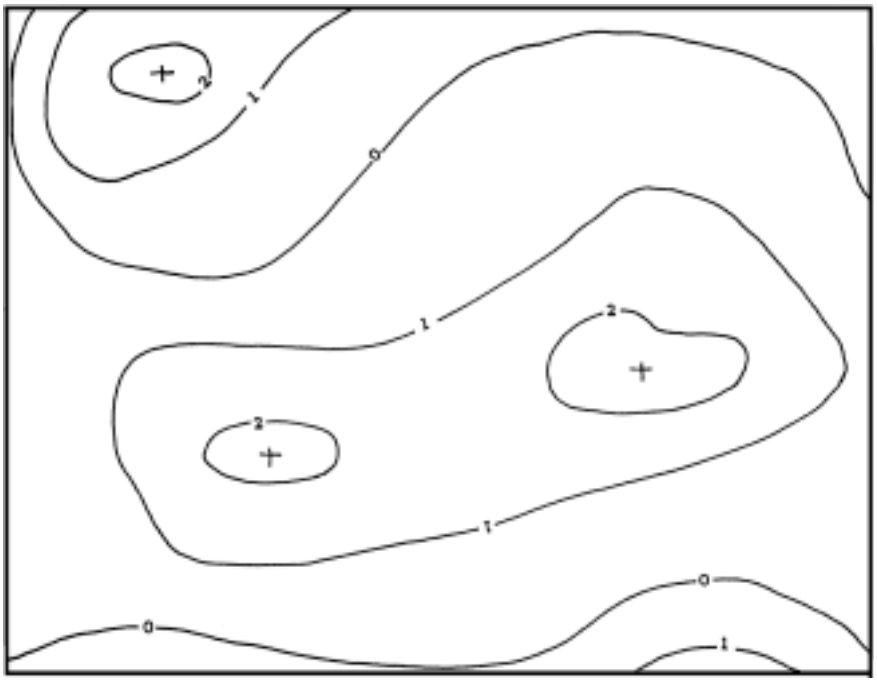

FIG. 18. The compiled contour map of azimuth-thickness of eastward moderate lineaments.

c. For Thin Lineaments

The thin lineaments of the eastward are not present. Only the intersection map of thin westward lineaments is shown in Fig. (19). The compiled contour map of thin westward lineaments (Fig. 20), shows that the general structure framework of the Gulf of Suez is clear and of deep range structure.

Summary and Conclusions

The result obtained given in Table 1 reveals the following:

1. The origin of tectonism of the Gulf of Suez trend is shallow from both eastern and western lineaments. The origin of tectonism of the Gulf of Aqaba trend is deep from western lineaments only. The N-S trend has a deep origin of tectonism from eastern lineaments, while the E-W trend is of intermediate origin of tectonism from eastern lineaments.
2. The intensity of tectonism of the Gulf of Suez trend is moderate as exhibited by the eastern lineaments and strong as exhibited by the western lineaments. While the intensity of tectonism of the Gulf of Aqaba trend is strong as revealed from the eastern lineaments and weak as revealed from the western lineaments. For N-S direction trend, the intensity of tectonism is not clear and the E-W direction trend has a weak intensity of tectonism as shown by eastern lineaments and a strong intensity as shown by western lineaments.

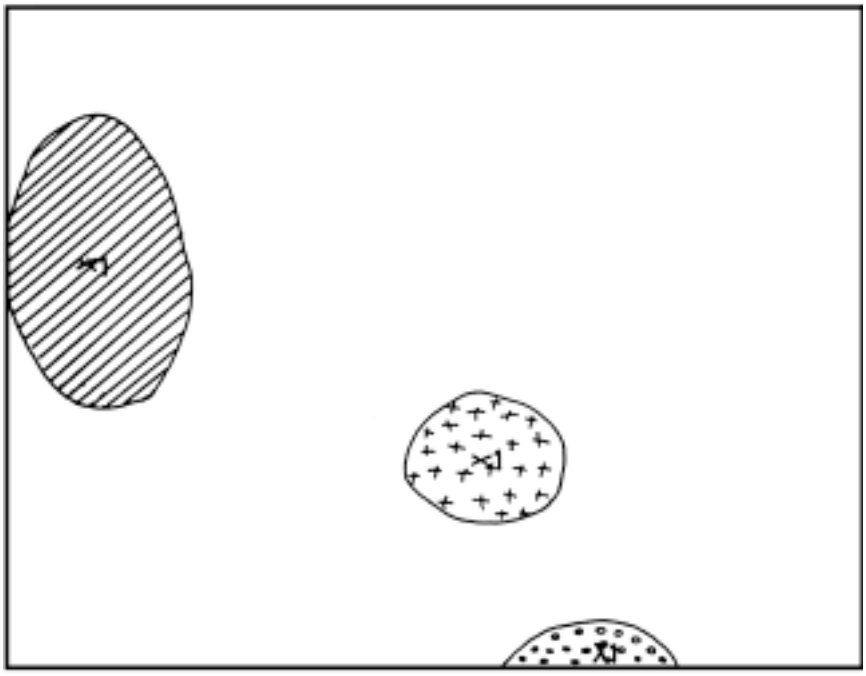

FIG. 19. The intersection map of the thin westward lineaments in terms of azimuth-thickness.

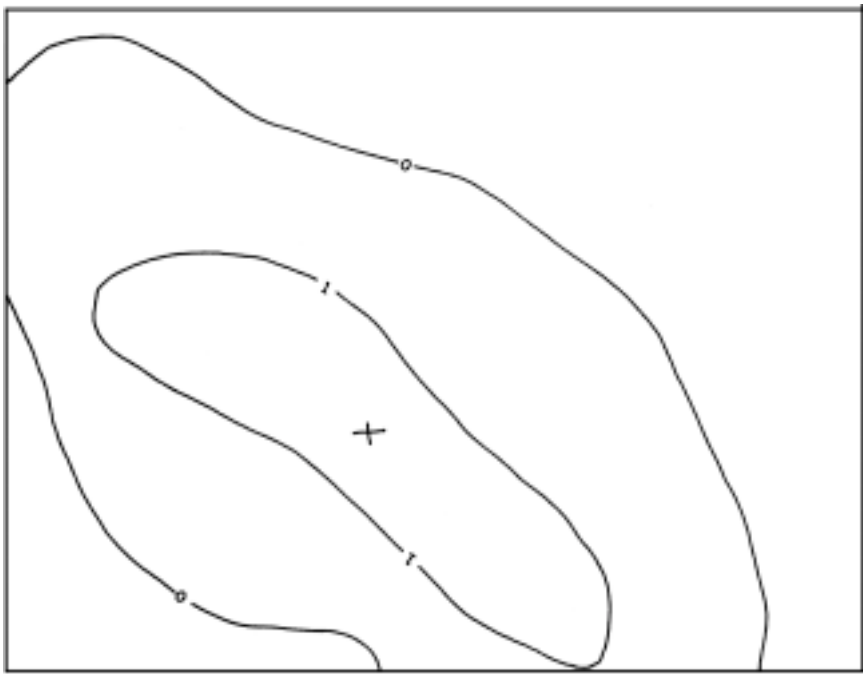

FIG. 20. The compiled contour map of azimuth-thickness of westward thin lineaments.

TABLE 1. Results of the lineament parameters of the Gulf of Suez.

	Gulf of Suez trend	Gulf of Aqaba trend	N - S trend	E - W trend
Origin of tectonism				
Eastern lineaments	Shallow	–	Deep	Intermediate
Western lineaments	Shallow	Deep	–	–
Intensity of tectonism				
Eastern lineaments	Intermediate	Strong	–	Weak
Western lineaments	Strong	Weak	–	Strong
General structure framework				
a. Thick lineaments (Shallow range structure)				
Eastern lineaments	–	Shallow	–	–
Western lineaments	–	–	–	Shallow
b. Medium lineaments (Intermediate range structure)				
Eastern lineaments	–	–	Intermediate	–
Western lineaments	Intermediate	–	–	Intermediate
c. Thin lineaments (Deep range structure)				
Eastern lineaments	–	–	–	–
Western lineaments	Deep	–	–	–

3. The general structure framework of the Gulf of Suez trend is of intermediate depth range structure by studying the western medium lineaments and of deep range structure by studying the western lineaments. The general structure framework of Gulf of Aqaba trend is of shallow depth range structure as seen from eastern thick lineaments. In N-S direction trend, the structure framework is of intermediate depth range structure as seen from eastern medium lineaments. While E-W direction trend has a shallow structure framework as seen from western thick lineaments, and of intermediate depth as seen from eastern medium ones.

We conclude that, the Gulf of Suez trend has a strong tectonic activity with shallow origin, which give indications for reasons of earthquake occurrences in Gulf of Suez region. While the Gulf of Aqaba trend has a deep origin of tectonism with strong intensity. The effect of hazards in the Gulf of Suez trend is a little bit more than that in the Gulf of Aqaba trend. In N-S direction trend, the origin of tectonism is deep, but the intensity of tectonism is not identified. In E-W direction trend, the origin of tectonism is of moderate range and the intensity of tectonism is weak from eastern lineaments and strong from western lineaments.

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التفسيرات التكتونية للجزء الشمالي من منطقة خليج السويس من واقع التحليل الخطي لصور القمر الصناعي

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المستخلص . تم تشغيل الصور الخطية للقمر الصناعي الخاصة بالجزء الشمالي لمنطقة خليج السويس وقد تبين من هذه الصور الخطية أنها تعكس طبوغرافية المظاهر السطحية المحيطة بالمساحة المائية لخليج السويس . وقد تم التفاضل بين هذه المظاهر الخطية من حيث تكرارها وسمكها وأطوالها المختلفة ، مع دراسة التوزيعات التكرارية الاتجاهية لمختلف المعاملات التفاضلية بفترة اتجاهية من اتجاه الشمال ١٠ْ شرقًا ومن اتجاه الشمال ١٠ْ غربًا .

وبتطبيق نظم المعلومات الجغرافية على هذه المجموعات وتكويناتها لكل من المجموعتين : شمال شرق – جنوب غرب ، شمال غرب – جنوب شرق . فقد أوضحت التفسيرات التكتونية والتعرف على الأحداث الجيولوجية القديمة التي أوجدت التأثيرات القصية والتمزقية على امتداد اتجاهات كل من خليج السويس ، خليج العقبة ، اتجاه شمال – جنوب فاتجاه شرق – غرب .

ويحتوى البحث على تفصيلات أكثر عن طبيعة المسببات التكتونية والتي تشمل المصادر التكتونية ، شدتها والإطار العام للأوضاع التركيبية .