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Interpretation of gravity and electrodrilling data in Kathib El Makhazin, Sinai Peninsula

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ABSTRACT

As a part of coal prospecting programme, some gravimetric and electrical investigations were carried out on Kathib El Makhazin area, located between Ayun Musa and Maghara, in Sinai, Egypt, along two traverses crossing a high gravity anomaly. These studies were proposed to verify the presence of the basement uplift expected to accompany the gravity anomaly, and to clarify peculiarities of the crystalline basement, which could be reflected on the sedimentary cover, and cause the coal-bearing formations to occur at comparatively small depths.

Gravimetric stations were spaced every 250 m along the traverses, whereas the electrical measurements, in the form of deep vertical electrical soundings, were conducted along the same traverses, at 3–6 km intervals.

The nature of the regional gravity high anomaly was investigated and a basement uplift was ascertained at a depth of about 1500 m. As a result, the coal-bearing horizons were expected to be encountered at a depth of about 700 m.

INTRODUCTION

Some coal fields are known to occur at Ayun Musa and Maghara, Sinai Peninsula, within the Jurassic sediments. Other coal fields are expected to occur between these two localities, in the same formations. A regional gravity anomaly, suspected to be due to an uplift within basement rocks, was recorded at Kathib El Makhazin, located between Maghara and Ayun Musa (Fig. 1). Consequently, coal-bearing horizons were expected to be at a considerably shallow depth in this location. In preparation for drilling, some gravimetric and electrical investigations were conducted to verify the presence of the basement uplift and roughly estimate its depth as well as the depth to the coal-bearing formations.

Geophysical measurements were carried out along two traverses totalling some 70 km in length, which were surveyed to cut the regional gravity anomaly and cross each other at the accessible site projected for drilling, on the basis of the regional gravity anomaly (Fig. 2). Along these traverses some 278 gravimetric stations, spaced every 250 m, were measured. Also, 12 vertical electrical soundings (VESs), spaced every 3–6 km, were executed along them (Fig. 2).

The data obtained were subjected to qualitative and quantitative techniques of interpretation.

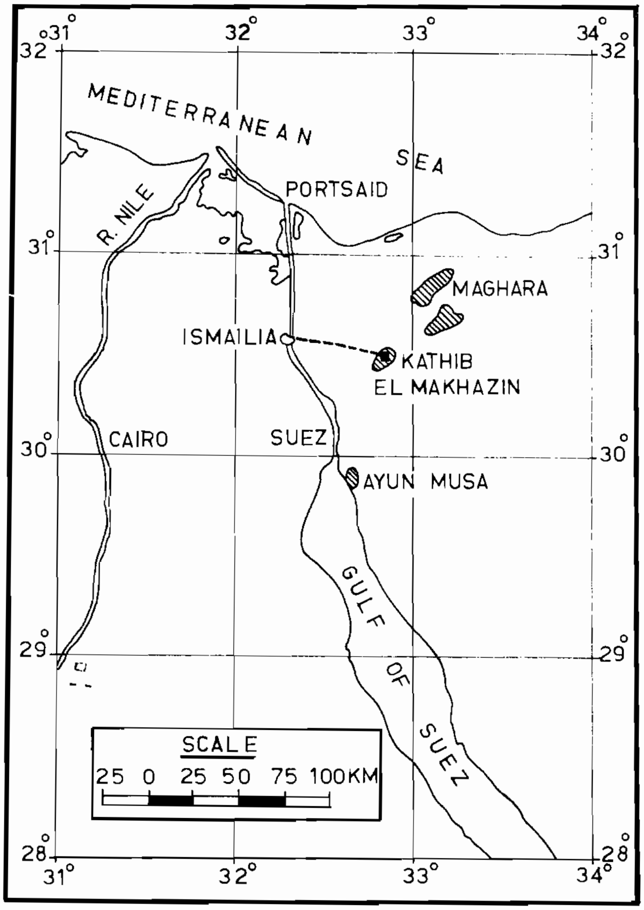

Fig. 1. Sketch map showing the location of Kathib El Makhazin area, Sinai. ■, Study area, -----, Ismailia–El Arish road.

GEOLOGICAL SETTING

Kathib El Makhazin is located in the north west of Sinai Peninsula, in between Ayun Musa and Maghara, 62 km east of Ismailia along Ismailia–El Arish road, at latitude 30°–30° 45′N, and longitude 32° 51′ 45″ E. (Fig. 1). It is covered by sand dunes and wadi deposits. The area has not been studied either geologically or geophysically, except for a very small scale regional gravimetric survey carried out along roads (Contovoi 1963). Thus, no data are available about the area or about the physical properties of its rocks. Geological data are based only on the results of investigations at Ayun Musa and Maghara coal fields, located some 50 and 70 km away, and upon the data obtained from the few and scattered oil wells.

The geological section in the area is expected to be composed of basement rocks represented by Pre-Cambrian schists, gneisses, and granites, overlain by a thick sedimentary cover of limestones, sandstones, shales, marls, clays, and lignites, belonging to Permo-Carboniferous, Triassic, Jurassic, Cretaceous, and Cenozoic ages (Said 1962).

Coal-bearing horizons in Maghara and Ayun Musa are associated with continen-

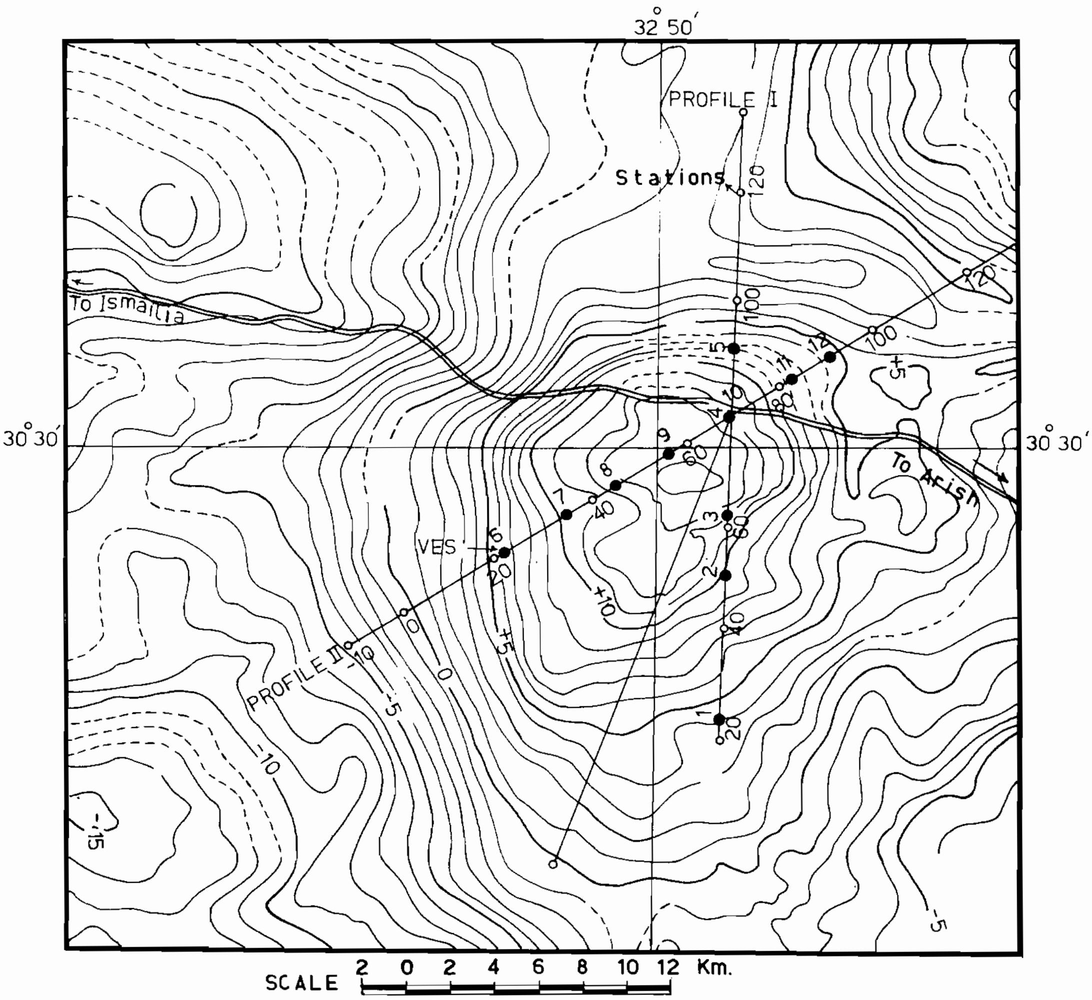

Fig. 2. Map showing the location of geophysical profiles and VESs within the gravity anomaly at Kathib El Makhazin area. A borehole was drilled near the location of VES 4.

tal, as well as shore continental sediments of the Jurassic times (Kochin and Bassyouni 1968).

Kathib El Makhazin, being a part of Sinai Peninsula, which in its turn is a part of the Afro-Arabian platform, is limited in SW and NE by a series of rift depressions. The platform basement has a blocky structure created by faults of NW, NE, and latitudinal trends (Said 1962). The block size and displacement amplitudes vary greatly. Uplifted blocks, with coal-bearing horizons occurring at small depths, are of commercial interest in coal prospecting.

FIELD SURVEYS

Some 278 gravimetric stations, and 12 deep vertical electrical soundings were measured along the two traverses, of length 36·5 and 33 km, which were surveyed to cross the previously recorded high gravity anomaly in the area. The two traverses cut each other at the location projected for drilling, and are situated very near to Ismailia–El Arish road (Fig. 2). Stations were spaced every 250 m along the traverses.

Gravimetric measurements were executed to ascertain the nature of the regional anomaly, and to delineate the peculiarities and structures of the crystalline basement. Askania GS-11 type gravimeter was used. It is an astatic gravimeter, with a double thermostat and a photoelectric measuring system.

Field readings were corrected for latitude, Bouguer, and free air corrections, as well as for diurnal variations and instrumental drifts. Terrain correction was neglected since the traverses were surveyed in an almost flat area. The corrected values were reduced to a conventional datum relative to a general base station for the whole area.

Vertical electrical soundings (VESs), were carried out to trace the upper boundary of basement rocks and, if possible, to subdivide the sedimentary section into geoelectrical horizons. These VESs were measured according to Schlumberger configuration.

As the sedimentary section in the area is thick, the maximum current line (AB) was extended to be 16 km. Measurements were carried out by a convey or unwinding of the wire along the traverses, the wire being cut into reels, each 500 m long. Separate wires were used for both small AB separations and measuring MN lines. Three telephones were used for communication between the operator and the two ends of AB lines. An electronic compensator of ESK-1 type was used. This is a Russian-built instrument, especially designed for D.C., voltage and current measurements under harsh conditions.

The data obtained were interpreted qualitatively, as well as quantitatively.

RESULTS

The gravimetric profiles obtained (Fig. 3) showed the same features of the regional anomaly previously recorded, which represents a relatively regional maximum of almost isometric form. The detailed survey indicated that the causative body is asymmetric; its northern limb is steeper than the southern one. Also, several local anomalies, which may reflect peculiarities and structures in the sedimentary cover, were revealed.

Generally, any gravity anomaly is caused by change in rock densities which may be explained either by change of depth to various objects, and in particular basement relief, or by lithological differences. According to the available geological information, change in depth of basement rocks is more probable.

Gravity profiles show a relatively gentle anomalous field which passes suddenly, on both limbs, with a large horizontal gradient into other levels, after which a relatively gentle field is again established. Qualitatively speaking, such a change of potential is usually observed over uplifted blocks, where a sudden change and a sharp difference in density of rocks in the horizontal plane is encountered. Accordingly, the vertical escarpment technique of interpretation was applied here.

A model for the supposed uplifted block was constructed according to calculations with vertical escarpment formula (Fig. 3). Gravitational effect of the supposed structure was calculated using a zone chart. This is more or less correlated with the observed gravitational field (Fig. 3). A density contrast of 0·3 g/cm^3 between sedimentary and basement rocks was used in the calculations.

Upward and downward calculations of the gravitational field were made (Andreev & Klushin 1965) for 1 and 2 km, to get the gravity anomalies which could be received if

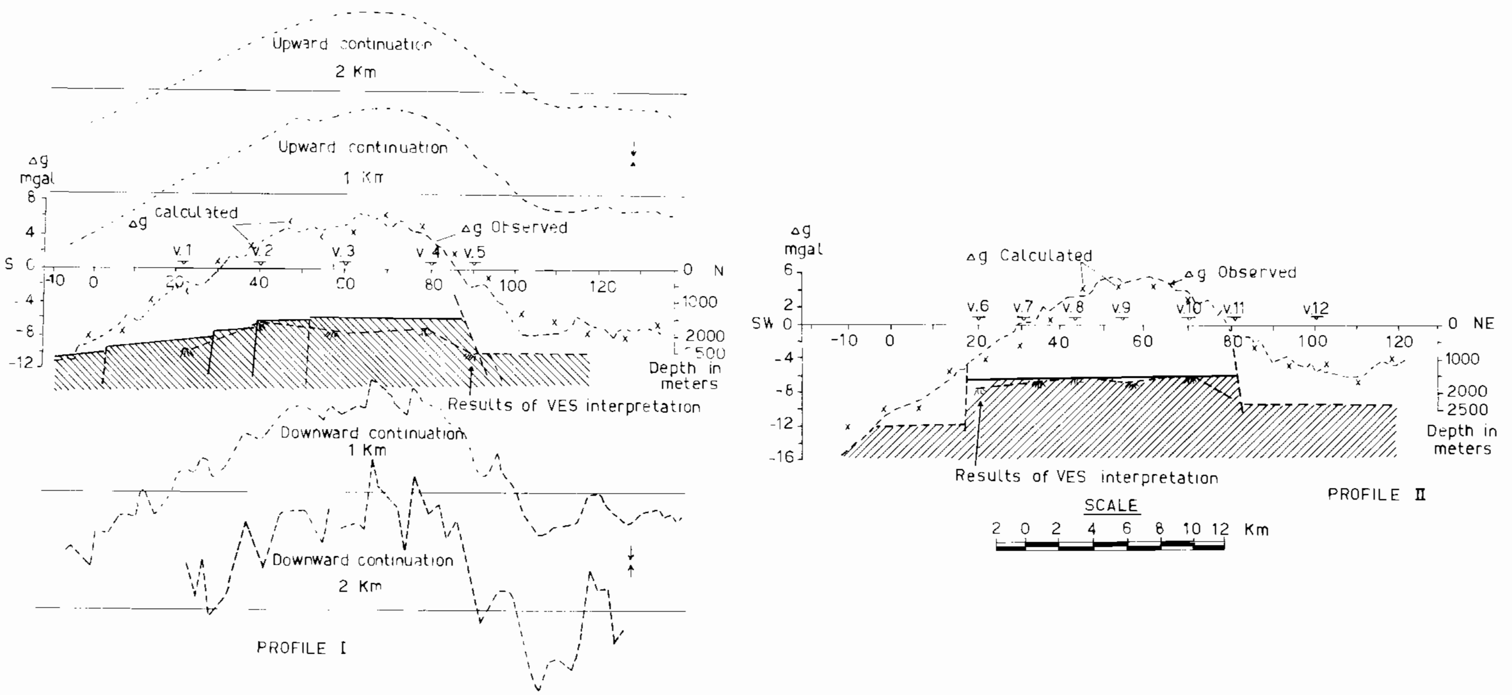

Fig. 3. Interpretation of gravity data measured at Kathib El Makhazin area.

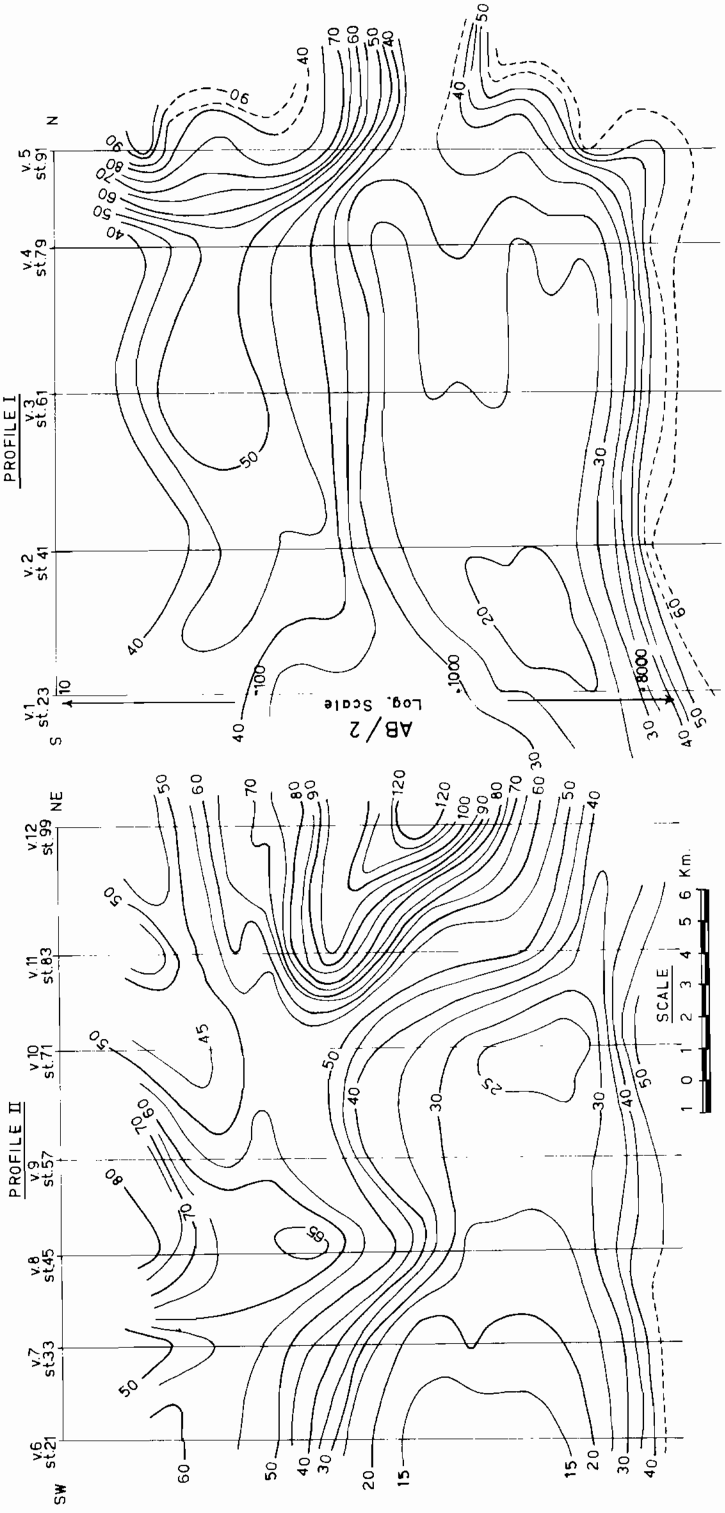

Fig. 4. Resistivity sections–Kathib El Makhazin area.

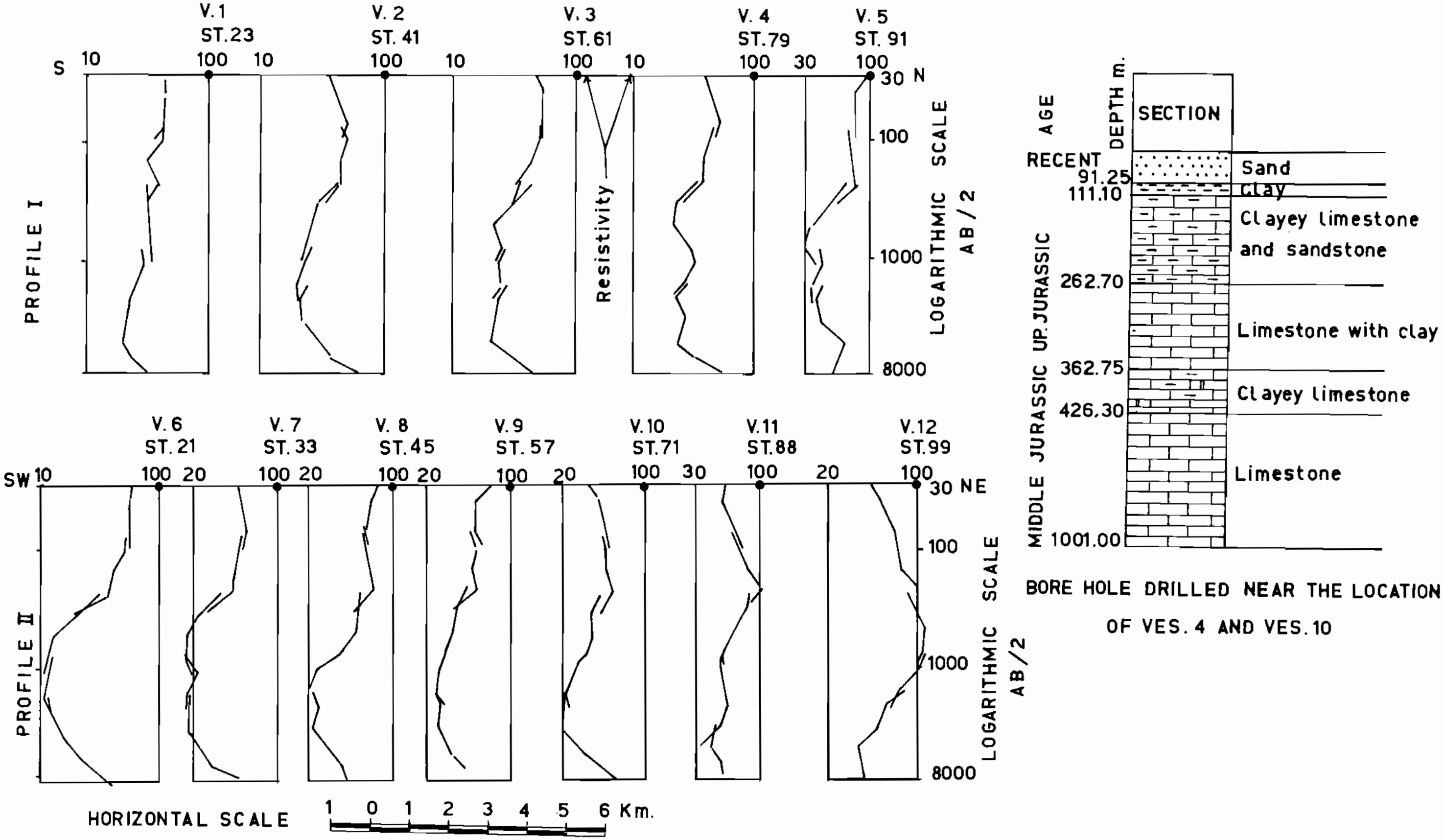

Fig. 5. Vertical electrical soundings conducted at Kathib El Makhazin and the borehole section drilled in the area.

measurements were taken at these levels (Fig. 3). When extending the field upwards, it becomes smoother and local anomalies disappear, while on extending downwards the field becomes more intensive and conspicuous as the extension reaches the disturbing body. The major regional anomaly remained almost unchanged with upward and downward extensions, which means the deeper occurrence of its source.

Moreover, these calculations were used to estimate the depth to the upper surface of the uplifted block, according to the vertical cylinder formulae (Sazhina & Grushinsky 1971). A depth of about 1600 m was estimated, whereas that calculated on the basis of the maximum value of observed gravitational field and its maximum gradient amounted to 1400 m, and vertical displacement of the down-thrown part of about 1300 m.

As to the geoelectrical results, curves of the 12 deep VESs, five along profile 1 and seven along profile 2, are shown in Fig. 4. All of them, except those of VESs 5, 11, and 12, exhibit good asymptotic right hand rising with an angle of about 45° with the horizontal, indicating the resistivity of the high ohmic crystalline basement. Sometimes, this asymptotic rising is disturbed, most probably due to the slope of basement rocks which may be at angles greater than 10–25°. Generally, the curves indicating basement rocks exhibit the minimum type curve, while others exhibit the maximum type curve. Resistivity of surface layers ranges from 40 to 100 ohm, corresponding to one or more geoelectrical horizons of deposits varying in humidity content and pattern of sorting. In the middle parts of the curves, represented by broad, distinct, or somewhat varying minimum, resistivity ranges from 11–20 ohm, indicating the sedimentary series forming the section.

A qualitative analysis of VES curves, and resistivity sections (Figs 4 and 5), shows that:

1. On correlating the two curves 4 and 10, of the VESs located very near to the drilled borehole and considered as crossed ones, a certain difference between their middle parts is distinguished. This may be attributed to anisotropy and nonhomogeneity of the sedimentary section.
2. The high ohmage horizon is gently dipping from borehole southwards, with slight variations in depth, whereas to the north it is abruptly submerged northwards.
3. In general, resistivity decreases in the southern direction. This may mean an increase of the clayey component in this direction.
4. A distinct boundary between the bottom of sands and underlying bedrocks cannot be detected, but a gradual transition of one horizon to another is observed.

The lack of data about the parameters of the geoelectrical section of the area, as no well logging for the borehole is available, and the difficulty of correlating and tracing any geoelectrical datum from one VES point to the other within the sedimentary section, complicated the interpretation of VES curves. So, interpretation was confined only to the horizon of the crystalline basement with infinitely high resistivity, which was considered as a key horizon.

Many techniques of quantitative interpretation were attempted to get the most reliable results. The most accepted estimations for depths to the crystalline basement (according to the graphical method of interpretation) are as follows:

Station	79/1	61/1	41/1	23/1	71/2	57/2	45/2	33/2	21/2
Depth (m)	1700	1920	1600	2550	1600	1700	1480	1720	1900

CONCLUSIONS

As a result of the present study, the following conclusions were reached:

1. Gravity profiles recorded a positive anomaly, about 25–26 km wide, in a north–south direction, and with amplitude of about 17 mgal. This anomaly could be correlated with that previously revealed by petroleum companies and confirms its presence. Similarly, the width of the anomaly in the east-west direction is nearly the same, about 25–26 km, and its amplitude is about 18 mgal, as defined from the regional Bouguer map. Consequently, this anomaly may be attributed to an isometric uplifted basement block bounded by several fault lines, or to a cylindrical body intruded in the sedimentary section which brought its horizons closer to the surface.
2. Vertical electrical sounding results emphasized the presence of such uplifted body within the crystalline basement. Depths to its upper surface were estimated at different locations. These depths vary from about 1500 m in the north to 2500 m in the south.
3. Kathib El Makhazin structure can be visualized as an asymmetrical body with a steep north flank, and a gently dipping roof to the south.
4. The northern boundary of the structure is manifested by an abrupt submerge of the crystalline basement roof with amplitude of about 1 km to the north of the borehole. This may be due to a fault line at this location affecting both basement and sedimentary rocks.
5. Detailed gravimetric studies revealed some local anomalies, most probably related to peculiarities in the sedimentary cover.
6. The decrease in apparent resistivity, observed in the southern direction, may be geologically explained by an increase of clay component in the sedimentary section in this direction.
7. The location of the drilled borehole was thought to be the most accessible and favourable site within the uplifted part of the structure, as it is very near to Ismailia–El Arish road, and far from the sand dunes. Drilling was stopped at the depth of 1001 m, before reaching the crystalline basement, due to some economical considerations, since no coal seams of commercial interest were met at this depth in spite of crossing the bearing formations of the Jurassic age with minimum resistivity (borehole section is shown in Fig. 4).

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تفسير نتائج دراسة جرافيمترية وجيوكهربية
بمنطقة كثيب المخازن ، شبه جزيرة سيناء

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خلاصة

أجريت بعض الدراسات الجيوفيزيائية باستخدام الطرق التثاقلية والكهربية في منطقة كثيب المخازن الواقعة بين منطقتى عيون موسى والمغارة في الشمال الغربى من شبه جزيرة سيناء ، وذلك في اطار برنامج للبحث عن الفحم في تلك المنطقة .

تمت القياسات على امتداد خطين قاطعين لشذوذ كبير في خريطة البوجير . وقد هدفت الدراسة الى ايجاد العلاقة بين الشذوذ التثاقلى وعمق الاساس الصخرى ، اذ أن أى ارتفاع في سطح الاساس الصخرى يؤثر بدوره في الصخور الرسوبية التى تعلوه مما يجعل الصخور الحاوية لتكوينات الفحم أقرب الى السطح . وأخذت القياسات التثاقلية على الخطين في محطات تبعد ٢٥٠ مترا عن بعضها البعض . أما القياسات الكهربية فقد كانت على صورة جسات كهربية رأسية عميقة في محطات تبعد من ٣ الى ٦ كيلو مترات عن بعضها البعض .

وقد أثبتت الدراسة وجود ارتفاع في سطح الاساس الصخرى تسبب في وجود هذا الشذوذ في عجلة الجاذبية الارضية ، ويبعد هذا الارتفاع حوالى ١٥٠٠ متر عن السطح . ونتيجة لذلك فانه من المتوقع أن تتواجد الصخور الحاوية للفحم على عمق حوالى ٧٠٠ متر من السطح .