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GEOELECTRICAL STUDY TO EVALUATE THE FACTORS AFFECTING THE GROUNDWATER POTENTIALITIES IN EL-QUSAIMA AREA, NORTHEAST, SINAI

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A geoelectrical resistivity sounding survey was carried out in and around, El Qusaima area in the northeastern part of Sinai peninsula. The main objective was to evaluate the groundwater potentiality of the area, using the technique of vertical electrical sounding. The interpretation of the obtained data revealed that the groundwater is present in carbonate rocks, affected to large extent, by fissures and fractures. It was also found that the density of fissures and fractures as well as the effect of the other structural elements govern the groundwater potentiality in the area.

Keywords: geoelectrical resistivity, vertical electrical sounding, Sinai peninsula, el-qusaima

In the northeastern part of Sinai peninsula, human activities depend on groundwater rather than surface water. Therefore, extensive groundwater exploration is highly required to face the needs of such activities. The drilled wells in this area revealed that groundwater exists in carbonate rocks at different levels. Moreover, groundwater potentiality in such rocks varies from one locality to another.

The present geoelectrical work is a trial aiming at delineating the subsurface geologic settings and studying the factors affecting the groundwater potentiality in El Qusaima area lying at the northeastern part of Sinai peninsula (Fig.1). The surveyed area extends to the northwest of El Qusaima area and extends along El Qusaima - El Hassana road, crossing Wadi El Muweilah and Wadi El Arish (Fig.2).

Different studies including geomorphological, geological, hydrogeological and geophysical surveys were carried out by many authors in the central part of Sinai. Among those are the studies of Shata (1956 and 1960), Ghorab (1961), Said (1962), El Shazly *et. al.* (1974), El Ghazawi (1989 and 1999), the Japan International Cooperation Agency (JICA) (1992), Shabana (1993) and Hassanin (1997).

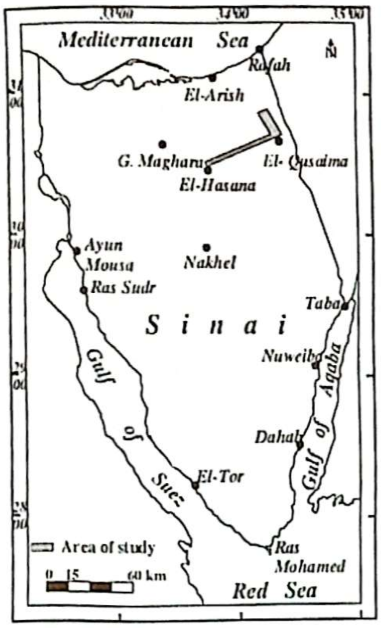

Fig (1) Sinai Peninsula - Egypt.

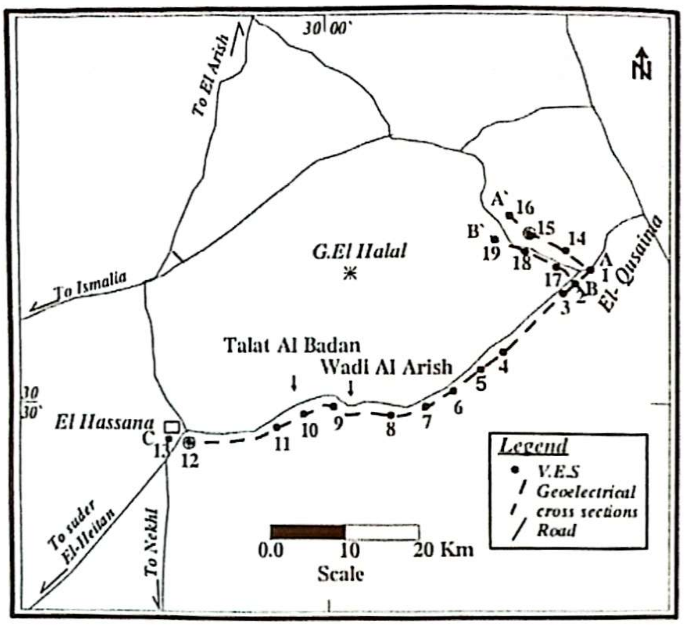

Figure (2) Location map of the study area, sounding stations and geoelectrical cross sections

GEOLOGICAL BACKGROUND

The study area, having a part of central Sinai is characterized by an arid climatic condition. The major geomorphological units present those are elongated anticlinal ridges, elevated structural plateaux and low synclinal plains (Hassanin, 1997).

According to the previous geological works, the stratigraphy of the investigated area can be differentiated from base to top into the following:

Lower Cretaceous Rocks

These rocks represent the oldest exposed rocks in the northeastern part of central Sinai. They are composed of sandstone, exposed only in the core of Gebel El Halal anticline. In the subsurface, these rocks are mainly sandstone with shale bands interbeded by sandy limestone and dolomite. This formation constitutes one of the main deep groundwater aquifers in Central Sinai (Hassanin, 1997).

Upper Cretaceous Rocks

In west central Sinai, the upper cretaceous succession (Cenomanin, Turonian and Senonian rocks) are differentiated into Raha, Wata and Matulla-Sudr formations respectively (Ghorab. 1961). In central Sinai, these formations were encountered in several drilled wells with variable thickness at different depths. The Turonian rocks are similar in lithology to the underlying Cenomanian rocks. They are composed of limestone, dolomitic limestone, marl, shale and sandstone beds. The Senonian rocks are subdivided from older to younger into Matulla and Suder formations. In view of the lithologic data of the drilled wells in central Sinai and El Hassana, these rocks are composed of dolomitic limestone, white chalky limestone with shale, marl interbeds and massive snow-white chalk respectively. These rocks constitute the main aquifers.

Tertiary

Paleocene

The Paleocene deposits are represented by Esna shale formation overlying the Senonian rocks which is exposed over wide areas in central Sinai. It is unconformably overlying the Turonian rocks in some areas between El Qusaima and El Hassana. Paleocene shale is encountered in Wadi El Amr well northwest of El Qusaima area at a depth of about 169m from the ground surface (Shabana, 1993).

Eocene rocks

The Eocene rocks are represented by the Thebes formation (Lower Eocene), which is composed of a thick bedded fractured limestone and dolomite with chert bands and shale. It is exposed in El Qusaima and its vicinities. The Lower Eocene fractured limestone forms the most important shallow aquifer in El Qusaima area.

Quaternary deposits

In El Qusaima area, the Quaternary alluvial and eolian deposits are found to be unconformably overlying the Eocene deposits. These deposits are distributed in the lowland areas. The alluvial deposits cover the course of the wadis and constitute their terraces. These deposits are composed of clayey loam converted in some places into sandy loam and gravel. The alluvial deposits forms one of the Aquifers in El Qusaima area. The aeolian deposits are composed of drift sand accumulations and are developed into sand sheets or scattered dunes. Along El Qusaima- El Hassana direction, these deposits are unconformably underlain by the Paleocene shale or Upper Cretaceous rocks in some different areas.

Structurally, the study area is affected by strong anticlines separated by synclines forming an elongated belt extending in the NE-SW direction. The anticlines are mostly built up of Upper Cretaceous carbonate rocks while the surface of the synclinal areas is dominated by Eocene, Paleocene and Quaternary deposits. These folds are associated with faults. The plains and wadis were developed along the strike direction of the existing faults, which are trending in the NE-SW and NW-SE directions.

FIELD WORK AND INTERPRETATION OF THE RESISTIVITY FIELD CURVES

A total of 19 vertical electrical soundings were carried out in the study area distributed along three profiles; two parallel profiles (AA`) and (BB`) run in NW-SE direction in El Qusaima area and the third one (AC) runs in NE-SW direction between El Qusaima and El Hassana (Fig.2).

The Schlumberger 4-electrode array was applied in the geoelectrical measurements with current electrode separation (AB) ranges from 1000m. to 2000m. This electrode separation proved to be sufficient to reach the required depth that fulfills the aim of the study in view of the geologic and hydrogeologic information.

Use was made of the digital earth resistivity meter (Terrameter model SAS 300m) that directly measures the resistance (R) at each electrode separation with high accuracy.

In order to parameterize the geoelectrical result, VES No.15 was measured near to Regwa well in El-Qusaima. Figure(3) illustrates the lithologic log of El Qusaima and the interpreted geoelectrical curve of VES, 15.

The computer program RESIXP-PLUS, ver. 2.39 (Interpex Limited, 1996) was used for the quantitative interpretation of the geoelectrical sounding curves. It is an interactive, graphically oriented, forward and inverse modeling program for interpreting the resistivity sounding data in terms of a layered earth model as in figure (3) which shows the detailed interpretation results of the geoelectrical resistivity sounding measurement (VES 15) at El Qusaima well (Fig. 3).

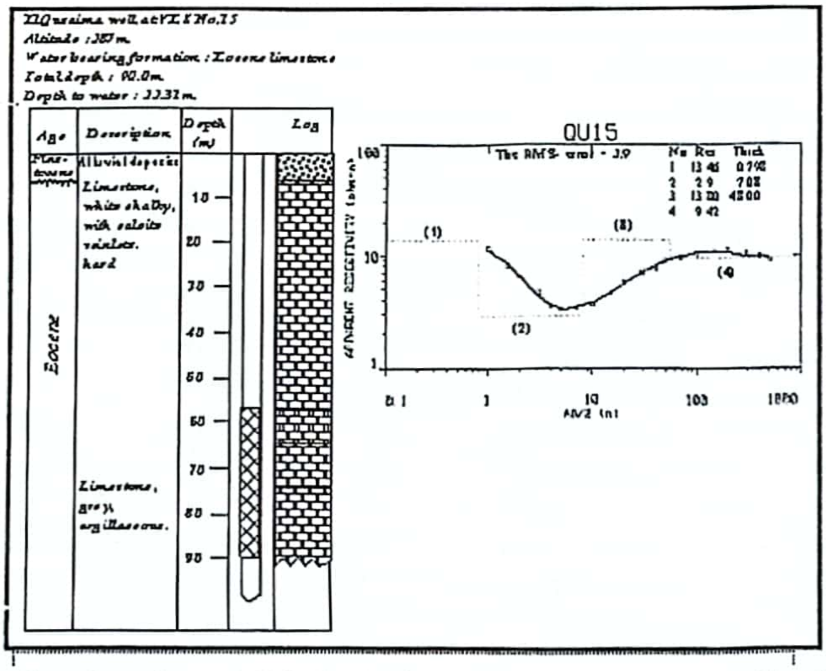

Fig. (3). Geoelectric and lithologic data at sounding station No. 15 In El Qusaima area.

RESULTS AND DISCUSSION

The obtained field curves were qualitatively and quantitatively interpreted. The qualitative interpretation revealed that the HK and HKH are the dominant curves types allover the area. However, the thickness of the geoelectrical layers may differ from one locality to another. Figure (4) depicts some examples of the apparent resistivity curves in El Qusaima area.

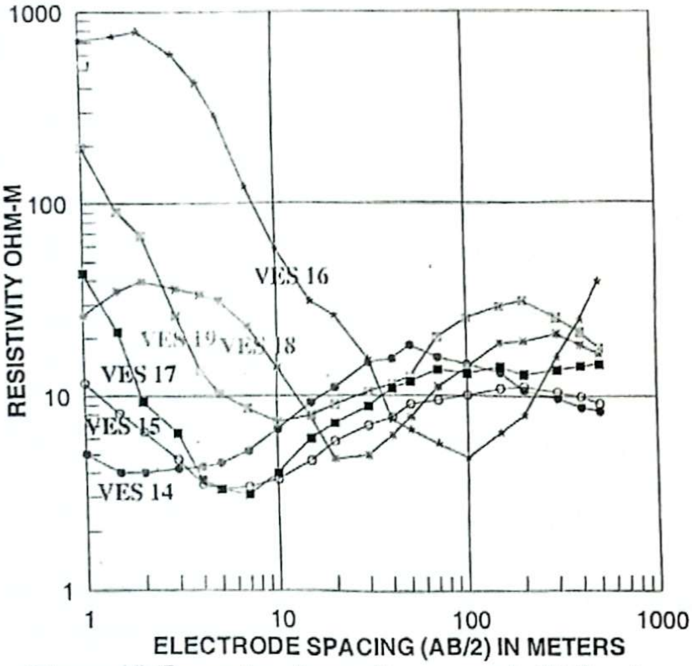

Figure (4) Examples of sounding curves in El Qusaima aera

The details of the findings from the quantitative interpretation of the field sounding data are given in table (1).

TABLE (1). A summary of the geoelectrical layering in the study area.

Layer No.		Layer thickness	Layer resistivity	Geologic unit	Lithology
1		2 to 20 m.	>2 – 1200 Ohmm	Alluvial	Sand, gravel & Clay
2		6 to 35 m.	90 – 200 Ohmm	Limestone	Limestone (dry)
3		----------------	8 – 26 Ohmm	Argillaceous limestone	Argillaceous limestone
4	Upper	20 to 30m.	>5 - 10 Ohmm	Limestone with marl	Limestone with marl
	Lower	-----------------	25 – 60 Ohm.m.	Limestone	Limestone (water bearing)

The results of interpretation of the geoelectrical measurements were constructed along three geoelectrical cross sections to illustrate the vertical sequence of the different geoelectrical layers. The quantitative interpretation of the resistivity measurements revealed that the geoelectrical succession consists of four geoelectrical layers in El Qusaima area and along El Qusaima – El Hassana road from East to West direction. In the following a detailed description of each of these layer, from top to base; is given:-

The uppermost geoelectrical layer consists of two thin layers having different resistivities, which are grouped together in one layer. The upper part of this layer represents alluvial deposits, which consists of sand and gravel showing a wide resistivity values, ranging from 100 to 1200 Ohm.m. Whereas its lower part is characterized by low resistivity ranging from 1.0 to 20 Ohm.m. The low resistivity value within this layer is explained as due to the increase of clay content downward. The maximum thickness of this layer was 20m, at VES 19 in El Qusaima area and 15m. at VES 6 while its minimum found to be dose not exceeded 2m at VES stations 10 and 1.

The second geoelectrical layer shows a higher resistivity ranging from 96 to 200 Ohm.m. Based on geological criteria this geoelectrical layer represents dry limestone. The maximum thickness of this layer is 35m, detected at VES station 18 and its minimum thickness is 6m, detected at VES stations 14 and 17. This layer was recorded only at El Qusaima area and belongs to the Eocene rocks.

The third geoelectrical layer exhibits resistivity values ranging from 2 to 25 Ohm.m. This layer has its minimum resistivity values (2 - 8 Ohm-m) at VES stations 16, 18 and 19. The low resistivity value, characterizing this geoelectrical layer, is indicative of an increase of the clay content within this layer in the northwest direction and increase of saline groundwater downward in the same direction. Correlation with geologic succession from borehole data at El Qusaima revealed that this zone is formed of the Eocene argillaceous limestone with marl intercalation. The base of this layer has not been reached in any of the measured soundings in the aera.

The fourth geoelectrical layer is the last one detected in the geoelectrical succession. This layer consists of two parts and exhibits a wide resistivity range of 6 to 100 Ohm.m. The upper part has been detected at soundings 9, 10 and 11 with a relatively low resistivity value ranging between 6 and 10 Ohm-m. Lithologically, this layer is similar to the third geoelectrical layer (argillaceous limestone). Its thickness was found to be 30m. The lower geoelectrical part of this layer exhibits resistivity values ranging from 25 to 60 Ohm.m and is interpreted to be as water bearing limestone. This was detected at the sounding stations exist along El Qusaima - El Hassana direction. According to the available geological data, this layer represents the lower part of the limestone and dolomitic limestone layer of the Senonian (Upper Cretaceous). The base of this layer has not been reached in any of the measured soundings in the area.

A better visualization of the vertical and horizontal distribution of the obtained geoelectrical layering has been reached through the construction of the geoelectrical cross sections AA`, BB` and AC illustrated in Figs (5 a, 5 b and 6, respectively). The cross sections AA` and BB` extend in NW-SE direction at El Qusaima area. The section AC extends E –W direction from El Qusaima to El Hassana area. The cross sections AA` and BB` show the second and third layers are present at the down thrown side of the fault F1. At the up thrown side, this layer is missed possibly by erosion, while along the cross section (A-C) the layers are present at the upthrown side of fault F1. At the down thrown side these layers also disappear. The structural elements in the area are represented by seven normal faults affecting the geologic succession in different directions. The strike and throw direction of each fault is illustrated on the map of Figure 7. The faults F1, F4, F5 and F6 shown strike in NE-SW direction. The fault F1 and F6 throw down towards the NW direction, whereas the faults F4 and F5 throw down to the SE direction. The faults F2, F3 and F7 shown strike in NW-SE direction. The fault F2 throws down toward the NE direction, whereas the faults F3 and F7 throw down towards SW direction.

GROUNDWATER POTENTIAL

The geoelectrical results revealed that groundwater occurs in the fractured zones of the carbonate rocks (anisotropic aquifers). The results revealed that the limestone layers with resistivity values less than 50 Ohm.m are water bearing. The groundwater potentiality increases in layers having more fracture density. The resistivity of the water bearing formation decreases with the increase of water salinity and /or the increase of the fine materials content as clay and silt.

However, the present study revealed that the study area includes two aquifers. The first aquifer has been detected only at El Qusaima area. This aquifer is represented by the third geoelectrical layer that is characterized by low resistivity values ranging from 2 to 24 Ohm-m which indicate groundwater with dominated increase of salinity. According to geological information this aquifer consists of the Eocene argillaceous limestone. The second aquifer has been detected only along El Qusaima - El Hassana section. The fourth geoelectrical layer that is characterized by resistivity values ranging from 25- 60 Ohm-m represents this aquifer. Based on the geological data, this aquifer is composed of limestone of Senonian (Upper Cretaceous). Moreover, the Eocene aquifer shows resistivity values less than that of the Senonian aquifer. This phenomenon may be explained by the possibility that of the Eocene aquifer is more saline.

It is clear that on the prevailing faults in the investigated area have developed karstic caves, fissures and fractures in the different types of carbonate rocks creating highly permeable zones that are favorable for groundwater accumulation.

CONCLUSION

A geoelectrical resistivity survey has been carried out in El Qusaima area which lies northeast of central Sinai, with the purpose of evaluating the factors affecting the groundwater potentiality in this area and its vicinities.

The quantitative interpretation of the field measurements revealed that the subsurface sequence consists of four geoelectrical layers. The third geoelectrical layer has been defined as water-bearing formation characterized by low resistivity values. This layer is composed of the Eocene argillaceous limestone has been detected only at El Qusaima area, while along El Qusaima – El Hassana sector this layer is missed due to erosion process. The fourth geoelectrical layer is the Senonian limestone (Upper Cretaceous) which is proved to be a water bearing layer characterized by resistivity values higher than that of the third layer, this phenomenon indicates that the Senonian aquifer is less saline than the Eocene aquifer. The geoelectrical survey showed also that the area is affected by a number of normal faults that control the groundwater accumulation in the area.

Fig. (5). Geoelectrical cross sections AA` and BB` In El Qusaima aera.

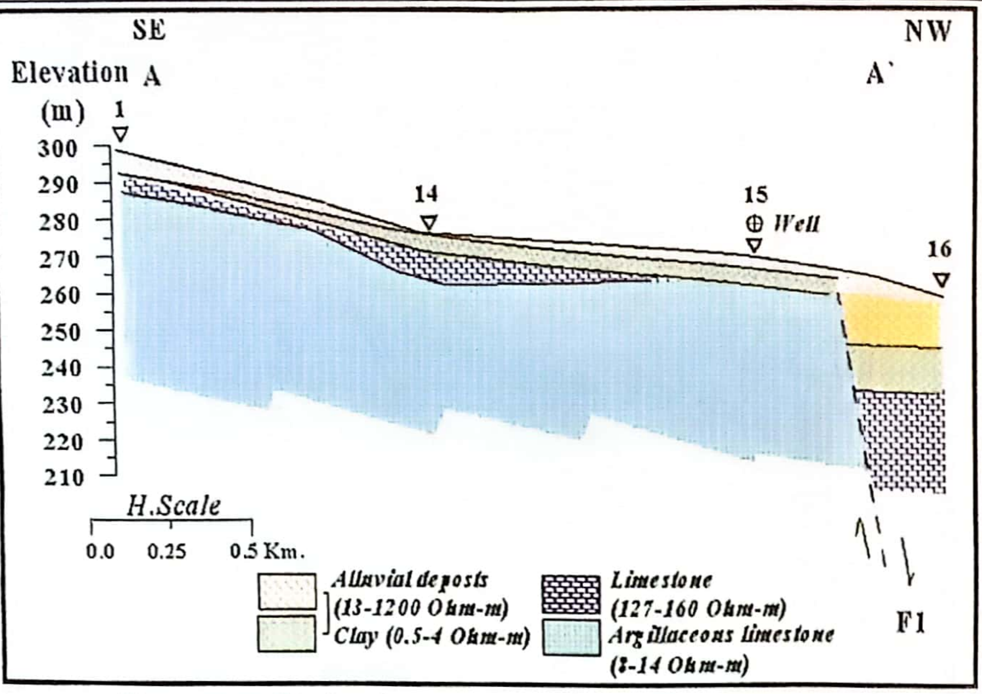

Figure (5-a) Geoelectrical cross section A- A `(El Qusaima area)

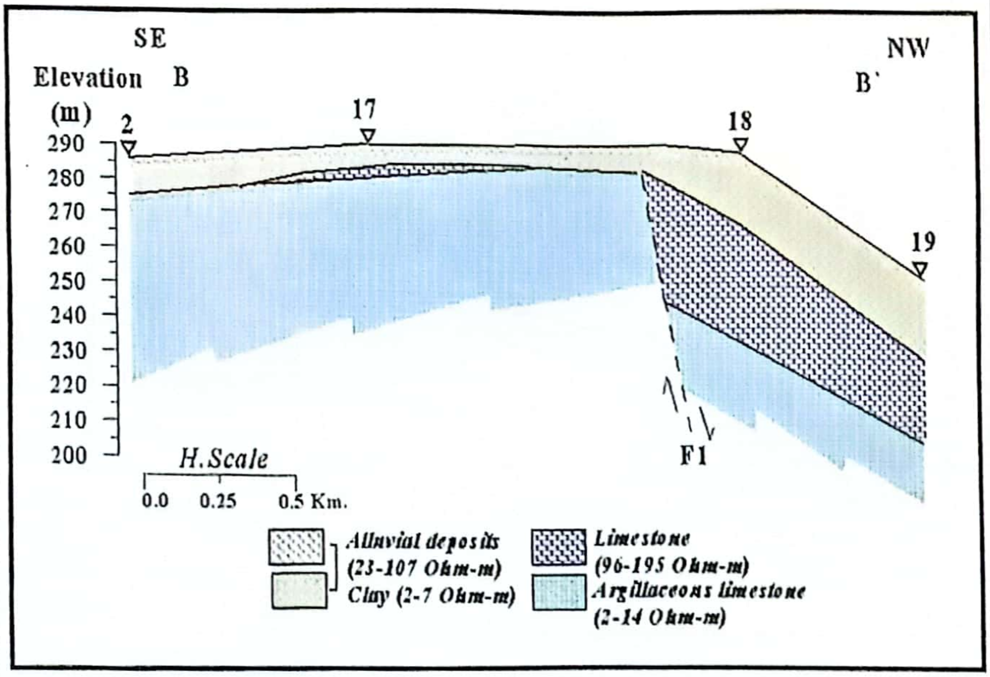

Figure (5-b) Geoelectrical cross section B-B ` (El Qusaima area)

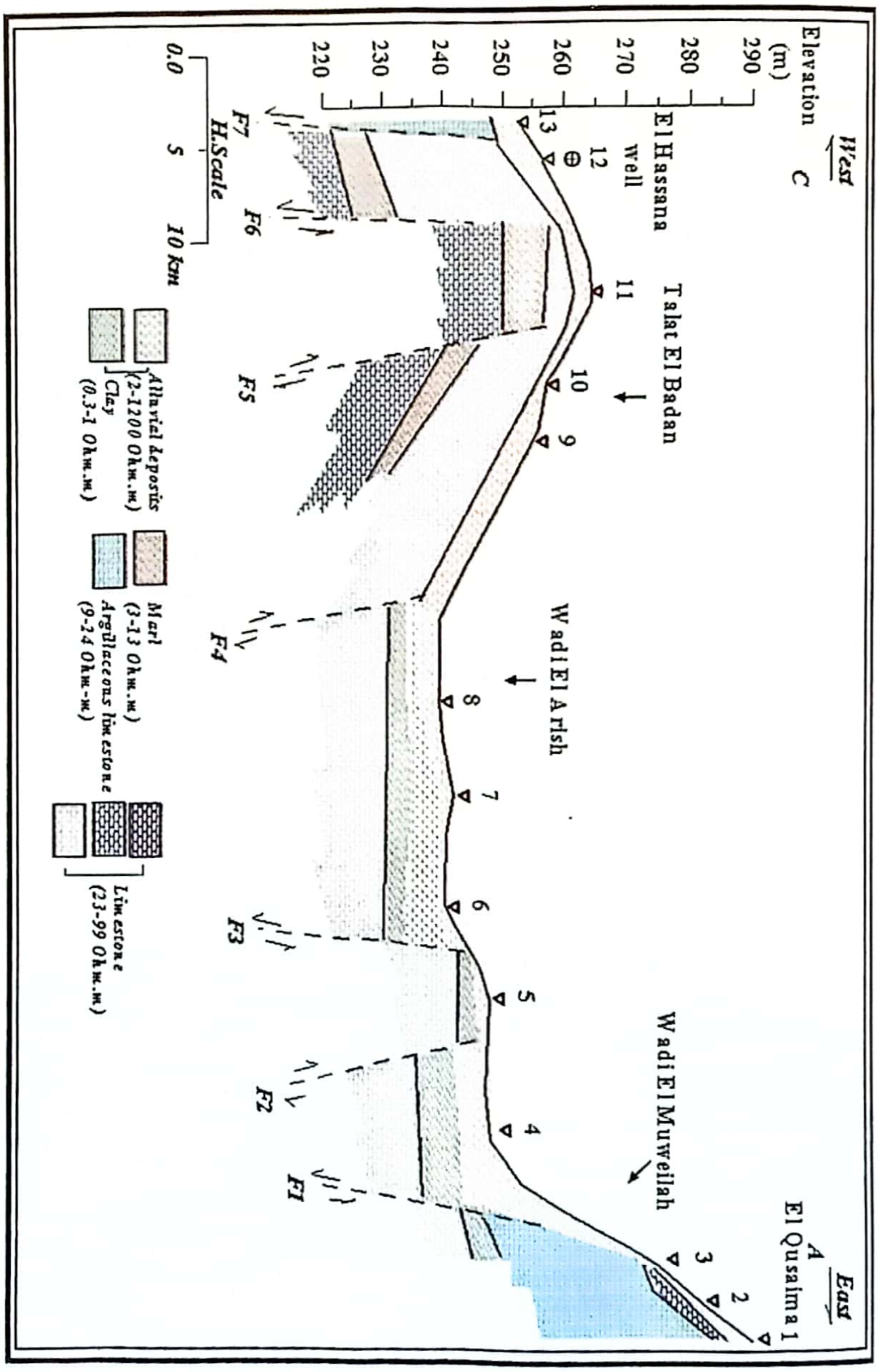

Figure (6) Geoelectrical cross sections (A-C) along El qusaima El Hassana Road

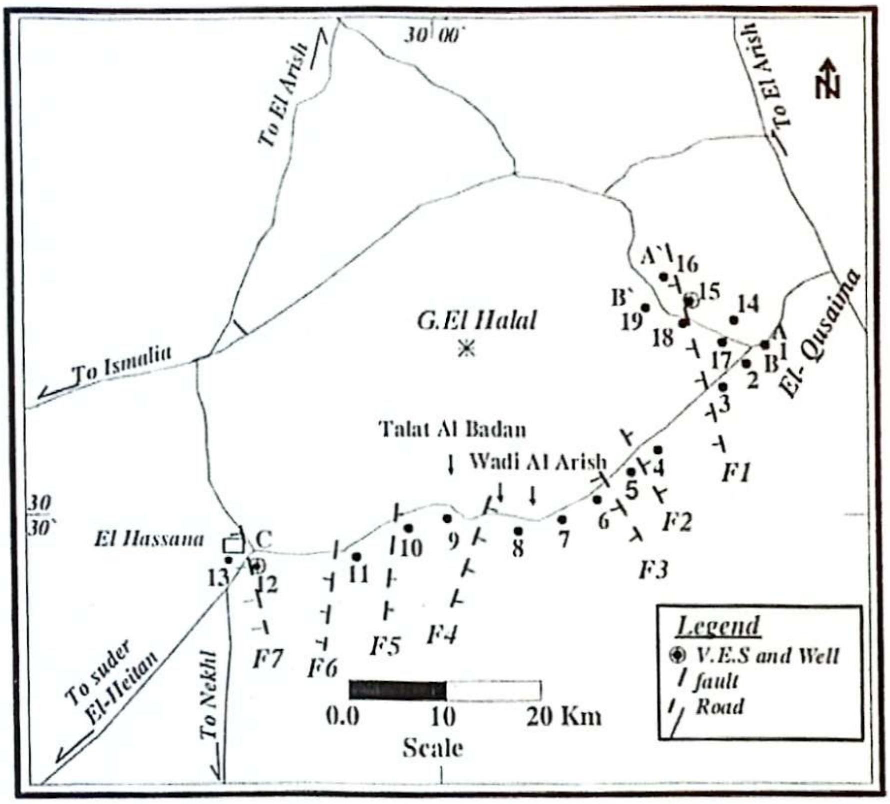

Figure (7). Inferred faults in the study area

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دراسة جيوكهربية لتقييم العوامل المؤثرة على امكانيات تواجد المياه الجوفية بمنطقة القصيمة شمال شرق سيناء

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الغرض من هذا البحث هو تقييم العوامل المؤثرة على امكانيات تواجد المياه الجوفية بمنطقة القصيمة شمال شرق سيناء. تم اجراء عدد ١٩ جسة جيوكهربية موزعة على ثلاث بروفيلات، أثنين بالقصيمة والثالث على الطريق بين القصيمة والحسنة. ومن خلال نتائج التحليل الكمى للجسات الجيوكهربية تم تحديد تتابع طبقى مكون من اربع طبقات. من خلال عمل مضاهاه بين مقاومات هذه الطبقات على شكل قطاعات جيوكهربية وجد أن هذه الطبقات متأثرة بعدد من الفوالق التى تؤثر تأثيراً مباشراً على هذه الطبقات من حيث تشققها ودرجة تشبعها بالمياه .

لقد وجد أن المقاومات الكهربية للطبقة الثالثة والرابعة منخفضة نتيجة تشبعها بالمياه خلال التشققات المنتشرة داخل هذه الطبقات والتى تتشبع بالمياه بدرجات متفاوتة، ووجد ان الطبقة الثالثة ذات مقاومة كهربية منخفضة عن الطبقة الرابعة مما يدل على انها أكثر ملوحة من الطبقة الرابعة كما تم تحديد التركيب الصخرى لهذه الطبقات بناءاً على مضاهاة النتائج الجيوكهربية بمعلومات الأبار والمعلومات الجيولوجية للمنطقة وجد أن التتابع الطبقى يتكون من الصخور الجيرية المختلفة.

وقد أوضحت نتائج الدراسة أن العناصر التركيبية مثل الفوالق لها تأثير مباشراً على الطبقات الجيرية، من حيث تشققها وجعلها تتميز بخصائص المسامية والنفاذية العالية التى تجعلها مناسبة لتخزين وأمرار المياه. وتوصى هذه الدراسة باستخدام طرق الأستكشاف الجيوفيزيائى المختلفة بالتفصيل قبل أجراء أى أعمال حفر أبار للمياه الجوفية وبالأخص فى الصخور الجيرية حيث تتواجد التشققات ودرجة تشبعها بالمياه بصورة متفاوتة من مكان الى أخر.