Sci. J. Fac., Sci., Minufiya Univ., Vol. XVIII (2004 : 109 - 122)

ELECTRICAL RESISTIVITY EXPLORATION FOR GROUNDWATER AT EL-AGRAMIA PLAIN, SOUTHERN SINAI – EGYPT.

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Received : 24/1/2004

Abstract

El-Agramiya plain is one of the most important physiographic features of Saint Catherine area, south Sinai. It is located about 30 km to the northeast of Saint Catherine Monastery and covers an area of about 25 km2. It is located within a dominantly granitic basement. Some basic dykes trending in a NNE – SSW direction disturb the area. The prevailing fault trend has a nearly perpendicular trend to that of the dykes.

Thirty nine vertical electric sounding (VES) were measured to determine the thickness of the alluvium and its potentiality for a groundwater resource to be used in any development project. Their sites were selected to prospect the low land within El-wet-El Agramiya area where the low land is considered to be the most favourable site for the accumulation of groundwater.

The results showed that, the groundwater in studied area exists in both the alluvium deposits and lower horizon of fractured granite. The Thickness of the alluvium varies from few meters to about thirty meters. It is supposed that such alluvium is favourable to preserve groundwater at some places. The thickness of the lower part of fractured granite accesses to reach about fifty meters. The quantity of expected water is poor as the local drainage is thin, but the quality is expected to be fresh as it is directly related to the annual precipitation of rainfall.

Introduction

The investigated area is bounded approximately by the latitudes 28o 50' 00" N and longitudes 33o 45' 00" and 34o 00' 00" E (Fig. (1)). The main wadis included in the area wadi Hurkus and wadi El-Akhdar to the north, entrance of wadi sa'al, wadi El-Rayana and wadi El-Sheikh fringa to the east, wadi Barah to the west and wadi Muslem and wadi Sahab to the southwest as shown in Fig. (1).

The area forms a rugged mountainous region dissected by many principal wadis and their tributaries, trending mostly in NNE – SSW, N – S and nearly E – W directions. The mountains have high altitude and rise to considerable heights greater than any of those in Egypt.

The heights of the mountains depend on the exposed rock types and the structures such as the younger granites, especially the alkali feldspar granites form conspicuous landmarks with high altitudes and rough slopes. The area is dissected by a great number of dyke's swarms of different composition.

Electrical resistivity of a rock formation varies over a wide range, depending upon the material, density, pore size and shape, water content and quality and temperature. In a relatively porous formation resistivity is controlled more by the water content and its quality than by the rock material. Accordingly, electrical resistivity measurements, when assisted by relevant geological information, may permit evaluation of subsurface water potential.

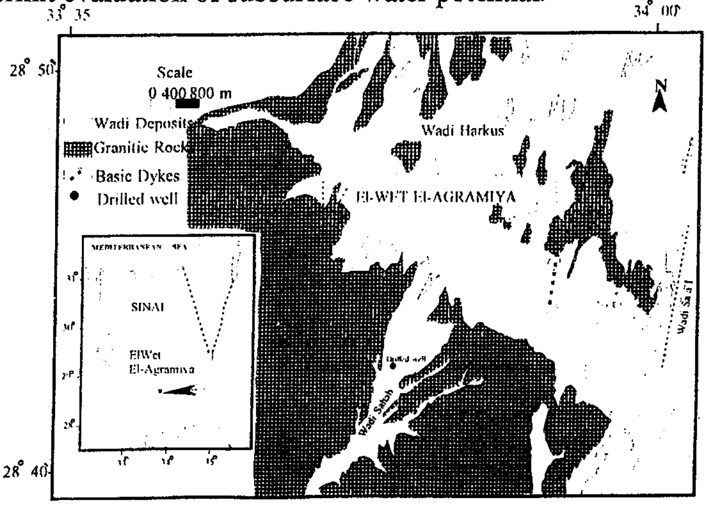

Fig. (1): Location and geological map of the studied area.

Geological Setting

The area was studied by several geological and geophysical authors, e.g. ***Hume (1939), El-Shazly, et al. (1974), Hussein (1982), El-Ghawaby and Abu El-Einen. M. (1982), Awad (1985), Shendi (1992), Mohamed (1995) and Khalaf, et al. (1999).***

The exposed rocks in the studied area are granitoids with some basic to intermediate dykes which attain NNE – SSW direction. Separate granitic outcrops are sporadically sloping in the studied area towards the entrance of wadi Harkus. The area is characterized by thick vegetation, which indicates a fertile and moist soil.

The following is a brief description of the different rock units in the area ***(khalaf, et al. 1999)*** (Fig. (1).

1- **Hammamat Sediments:-** Are represented by a coarsely bedded succession of siltstone and greywacke which may be locally thermally metamorphosed to biotite-quartz sericite schist, biotite gneiss and metagreywacke. The Hammamat sediments lie unconformable above the G-1 granite and are intruded by G-2 granite. The Hammamat sediments are folded into a syncline trending NE-SW.

2- **Gabbro:** Occurs as a limited outcrop of coarse to medium grained greenish grey rock. It is intruded by G-1 older granite and overlain by Hammamat sediments. The Gabbro is composed of plagioclase and hornblende.

3- **G-1 Granite:** Belongs to the syntectonic to late tectonic plutonits. The granite occupies extensive outcrops in the central part of the mapped area (Fig. 1). G-1 granite is intruded by the G-2 and G-3 granites. It ranges in composition from diorite to granodiorite, and is composed mainly of plagioclase, quartz, hornblende and /or biotite.

4- Younger Granite: Belongs to late to post orogenic plutonic rocks. Petrologic and field investigations reveal that, it includes two separate groups corresponding to the second and the third granite phases of ***Sabet, 197*** or to G-2 and G-3 of ***Hussein et al., 1982.***

A- Younger Granite of G-2: Is intruded by G-3 granite, alkaline syenite and dykes. The G-2 granite is coarse-grained, pink or pinkish grey and is composed of alkali feldspar, quartz, plagioclases and biotite. The contact between G-2 and G-1 is sometimes gradational.

B- Younger Granite of G-3: Is the youngest rock unit in the area. It is coarse to medium-grained, massive red and is composed of alkali feldspar, quartz and biotite.

5- Alkaline Syenite:- Is intruded by G-3 granite, while it intrvedes G-2. It is fine grained, massive, and grey to light grey and is composed of alkali feldspar and little quartz.

Electrical Resistivity Exploration

Electrical resistivity survey with schlumberger configuration was used in El-wet El-Agramiya plain to evaluate the groundwater potentiality where El-Agramiya plain is one of the most important physiographic features of Saint-Catherine area.

Thirty nine vertical electrical soundings (VESes) were measured in the studied area along five profiles extending in E-W direction nearly perpendicular to the main trend of faults in the area (NW-SE) and NW-SE direction which make an acute angle with the main trend of surface structural geology. VES's spacing ranges between 500 m to about 1000 m according to the topographic features.

The half spacing of the current electrodes (AB/2) reached to 500 m to obtain the optimum depth (about 150 m) Fig. (2).

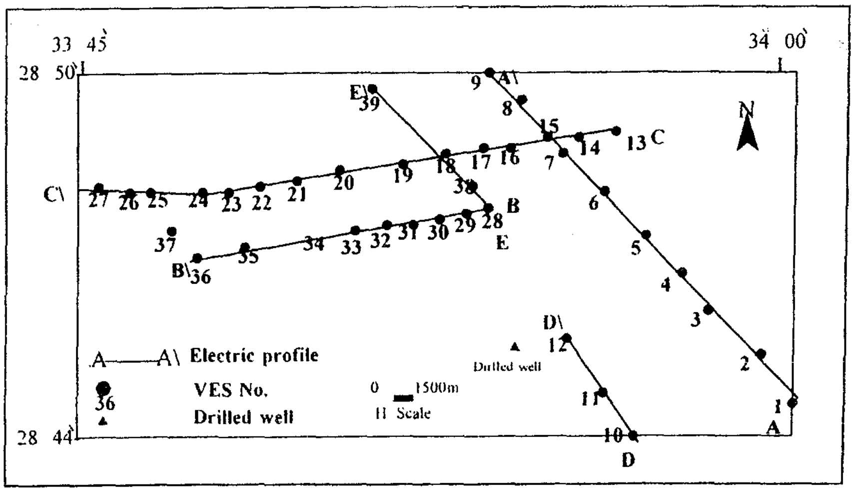

Fig. (2): Location map of profiles and distribution of the VESes.

Processing and interpretation of the data of the electrical survey were made by using software of the applied program (Resix-Ip, 1993). The interpreted data are represented as iso-resistivity and iso-pach contour maps Fig. (3a, b, c and d), accompanied with pseudo-sections of apparent electrical resistivity (Figs. 4 a, and b). In addition to geoelectrical cross-sections as shown in Figs. 5a, b, c, d and e

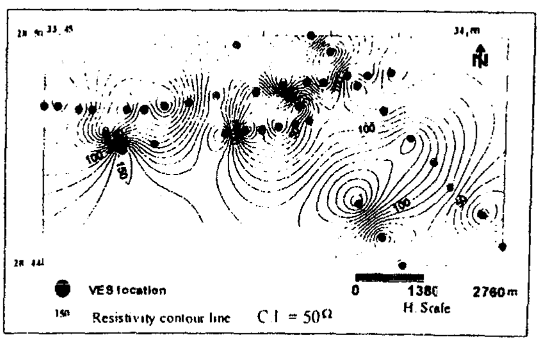

Fig. (3a): Iso-resistivity contour map of the surface alluvium deposits.

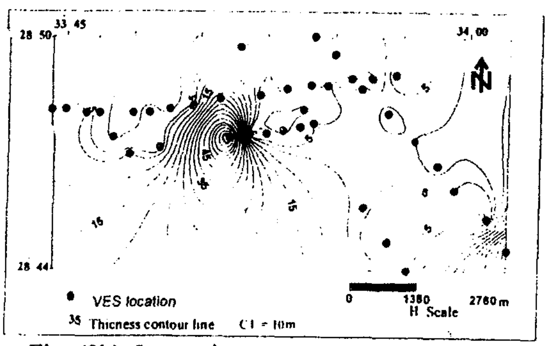

Fig. (3b): Iso-pach contour map of the surface alluvium deposits.

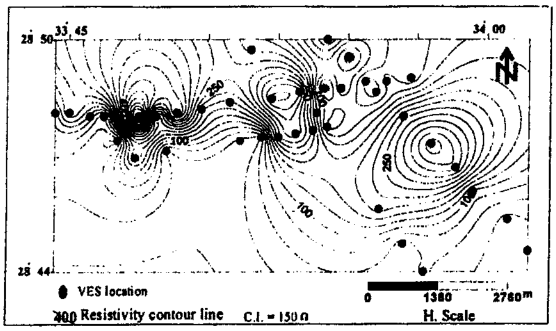

Fig. (3c): Iso-resistivity contour map of the water bearing fractured granite horizon.

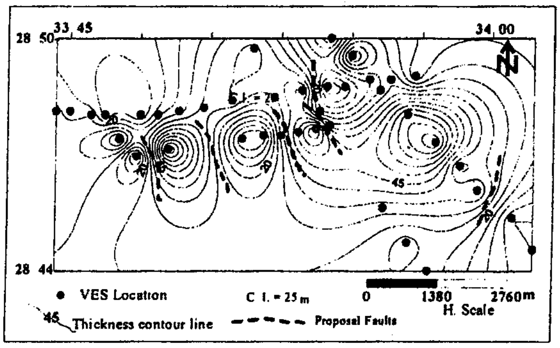

Fig. (3d): Iso-pach contour map of the water bearing fractured granite horizon.

The geoelectrical cross-sections define the electrical resistivity values and thicknesses of the different geoelectrical units in the area. Iso-resistivity and iso-pach contour maps show the changes of resistivity and thicknesses values of the layers, which may preserve groundwater and its quality for irrigation and drinking purposes. Also, the pseudo-sections reflect the lateral and vertical changes of the electrical resistivity values and help to construct the geoelectrical cross-sections. Such presentations, when are correlated with available geological information, can provide a clear hydrogeological picture.

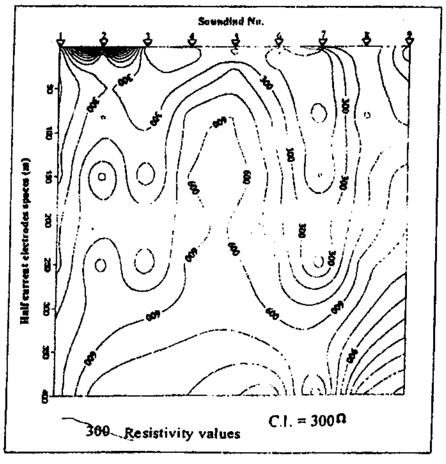

Fig. (4a): Pseudo-section for the VESes at profile AA\

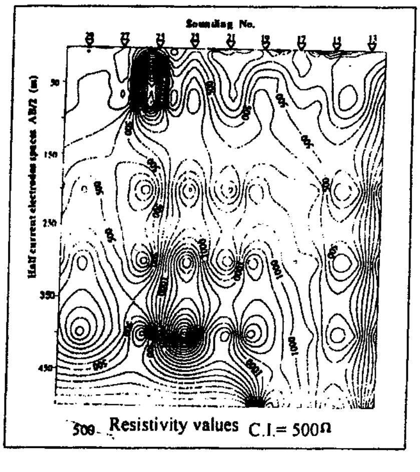

Fig. (4b): Pseudo-section for the VESes at profile CC\

Interpretation and Discussion

The obtained VES's curves of electrical survey in the studied area are mainly consisting of five segments representing five geoelectrical layers and their resistivity values are related to each other as $\rho 1>\rho 2<\rho 3>\rho 4<\rho 5$ Fig. (6) and Fig. (7).

Five geoelectrical cross-sections were constructed along five profiles (AA\, BB\, CC\, DD\ and EE\). These profiles were chosen at low land within El-wet El-Agramiya area. Profiles (AA\, BB\ and DD\) were extending in nearly NW-SE direction and profiles (DD\ and EE\) were extending nearly in E-W direction. The cross-sections and the pseudo-section are in good agreement and it is possible to conclude the following layers (Figs. 4 a, and b) and (Figs. 5a, b, c, d and e).

1- Solid soil: This layer is characterized by high interpreted resistivity values ranging between 200 and 350 Ohm.m and its thicknesses are ranging from 0.5 m to 2.5 m. The solid thin layer is represented by the upper-most of alluvium fall. This soil was formed as a result of weathering of the granitic country rocks Quartz and Orthoclase.

2- Surface alluvium (water bearing alluvium): This layer relatively has low resistivity values ranging between 75 and 180 Ohm.m, its thicknesses are ranging between 2.5 m and 38m and it could be consisting of sand, gravel and silt.

3- Fractured Granite: Fractured granite is considered as the upper-most of the bed rock unit and it is covered by the surface alluvium. It may be outcropped or absented or replaced by solid granite in some localities. This layer is relatively characterized by high resistivity values ranging between 300 and 900 Ohm.m and its thicknesses are ranging between 20 and 60m. Comparatively, the resistivity values of this layer are lower than the expected values of non-weathered granite may be due to the existence of fresh groundwater which is accumulated from seasonal rainfall water.

The lower horizon of the fractured granite is represented in the interpreted curve as clearly geoelectrical segment with relatively low resistivity value. In fact this segment may represent the water bearing lower horizon of the fractured granite layer where the resistivity values for the same layer are decreased from about 900 Ohm.m to reach about 250 Ohm.m and it reflects also the quality of groundwater. The thicknesses of this horizon are reaching in some localities 50 m and disappear in other rare localities.

4- Massive granite: This layer is represented by non-weathered granite or solid granite. The average resistivity values of massive granite exceed 2000 Ohm.m and the depth to the upper surface of it reaches in some localities 150m and it is uplifted in other localities as a natural result of subsurface structure represented by sets of faults extending NW-SE direction.

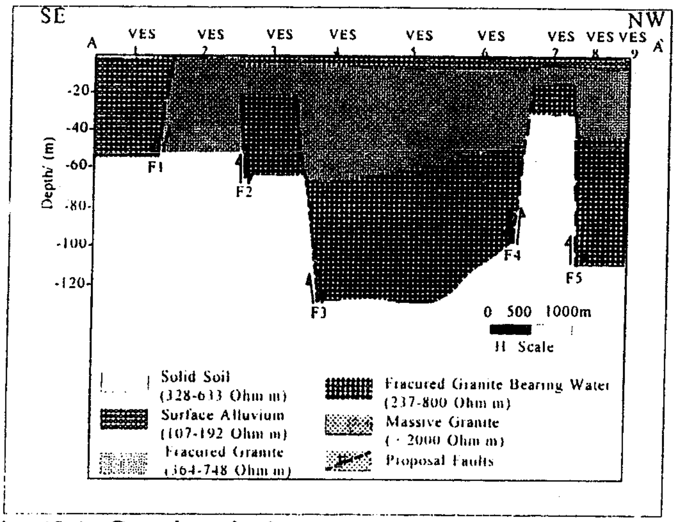

Fig. (5a): Geoelectrical cross-section at profile AA .

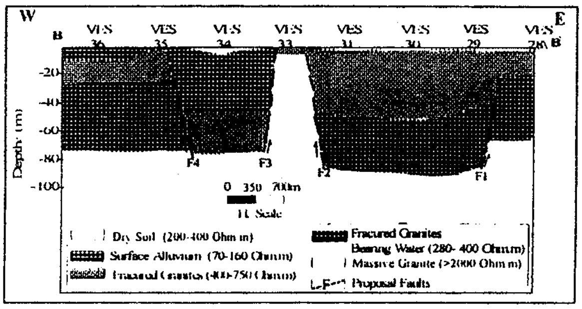

Fig. (5b): Geoelectrical cross-section at profile BB.

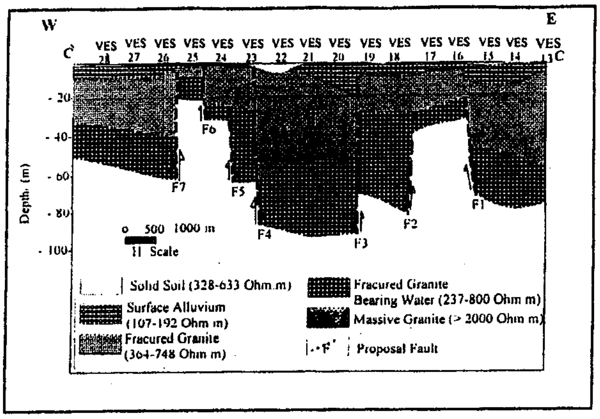

Fig. (5c): Geoelectrical cross-section at profile CC.

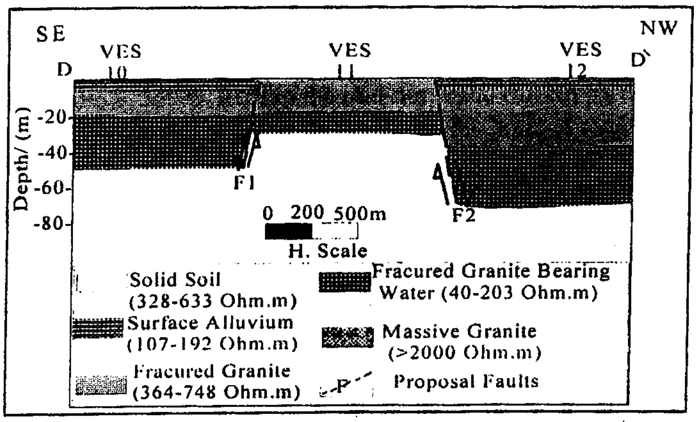

Fig. (5d): Geoelectrical cross-section at profile DD`,

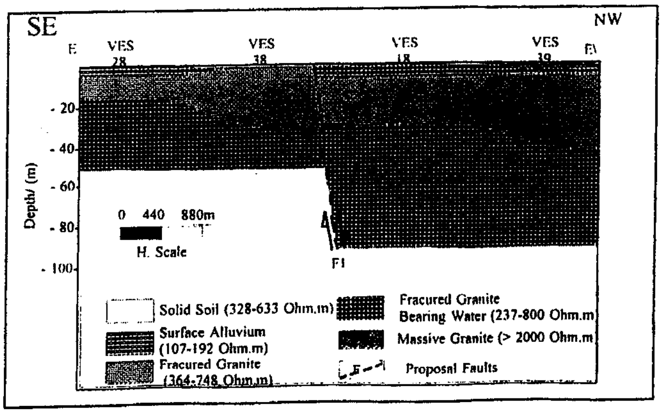

Fig. (5e): Geoelectrical cross-section at profile EE`.

The Results

Mathematical physical inversion of sounding curves and correlation of the deduced geoelectrical horizons to existing geological units are a good method to obtain useful knowledge about the subsurface layers and their resistivity values, which reflect the possibility of existing groundwater potentiality and the thicknesses of the water bearing layer.

The interpretation of electrical resistivity data in El-wet El-Agramiya area proved that, geo-electrically the area is represented by five layers, that are related to the geological units (solid soil, alluvium deposits, fractured granite, water bearing horizon of fractured granite and massive granite). The groundwater potentialities could be located in the alluvium deposits, where the resistivity values ranging between 75 Ohm.m in easternsouth, easternnorth and middle parts and 180 Ohm.m in the mid-north and south parts as shown in Fig. (3a). The thickness of this sediments ranging between 10 m in the most parts of the studied area and about 40 m in the mid-north and easternsouth parts at VESes 1 and 2 on profile AA\ and VES 34 on profile BB\ as shown in Fig.(3b). The lower horizon of fractured granite also could be considered the water bearing layer, where the resistivity values decreased to reach 150 Ohm.m nearly in the most parts of the area, 250 Ohm.m in the mid-north and eastern parts and 400 Ohm.m in the westernnorth parts Fig. (3c). The thickness of this horizon ranging between 20m in the most parts of the studied area and accedes 45 m in the eastern parts on VESes 5 and 6 and western part on VES 34 on profile BB\. This opinion is confirmed by well which has been drilled in wadi Sahab to the southwest of the studied area and different works in the area (Mina, et al. 1992, Shindi, 1992, Awad, et al., 1985 and El-Shamy, et al., 1989).

The bed rock (fractured granite and massive granite) is affected by sets of faults which led to uplift or outcrop of this unit to act on the thicknesses of overlaying alluvium deposits and this is confirmed with the pseudo-sections, which are executed for VESes along the profiles AA\ and CC\ Fig. (4a and 4b).The common trend of these faults is taking the same trend of profiles CC\ where extending in the NW-SE direction. The best proposal sites for drilling wells to product groundwater are located at VES-1 and VES-8 on profile AA\, VES-34 on profile BB\ and VES-27, VES-20, and VES-14 on profile CC\ where the thicknesses of alluvium deposits in these localities are ranging between 10m and about 40m.

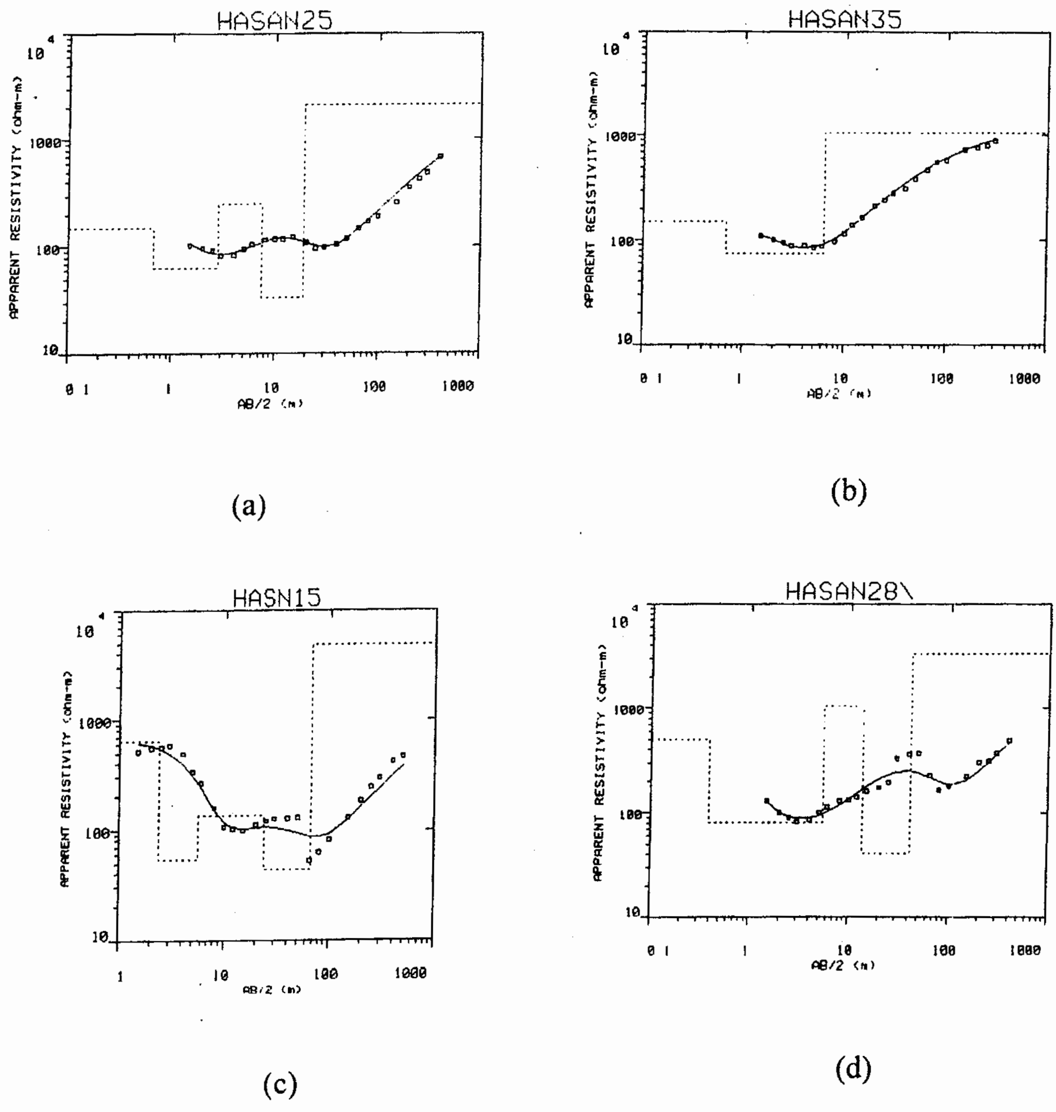

Fig. (7a, b, c and d) : Interpreted field curves for some VESes represented at different profiles

Conclusion

According to the previous discussion it may be concluded that, the geoelectrical layers which are related to geological rock units are solid soil, alluvium deposits, fractured granite, lower horizon of fractured granite and massive granite. The groundwater potentialities could be occurred in the surface alluvium deposits and the lower horizon of the fractured granite. The thickness of the surface alluvium ranging between 2.5 m and 38 m and the thickness of lower horizon of fractured granite reaches about 50 m. The lower part of the surface alluvium deposits may be contain a thin layer of silt, which can prevent the direct vertical recharge of groundwater to the fractured granite layer or this may be due to existence of the impermeable fractured granite layer itself. The bed rock is affected by sets of faults, which led to uplift or outcrop this unit to act on the thicknesses of the overlaying surface alluvium deposits.

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اكتشاف للمياه الجوفية باستخدام طريقة المقاومة الكهربية بعلوية العجرامية – جنوب سيناء – مصر

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ملخص البحث :

تقع منطقة الدراسة شمال شرق دير سان كاترين جنوب سيناء وهى عبارة عن سهل مساحته حوالى ٢٥ كم٢ يقع ضمن صخور الجرانيت ، ولقد إستخدمت طريقة المقاومة الكهربية للبحث عن أماكن تواجد المياه الجوفية بهذة المنطقة حيث تم عمل ٥ بروفيلات تمتد من الشرق الى الغرب ومن الجنوب الشرقى الى الشمال الغربى حيث تراوحت المسافات البينية بين الجسات المتتالية من ٥٠٠م الى ١٠٠٠م حسب التداريس السطحية بالمنطقة وبذلك يصل العمق المخترق الى ما يزيد عن ١٠٠ م كما تم تفسير المنحنياتىالحقلية تفسيرا كميا ونوعيا بإستخدام أحدث البرامج التطبيقية والمتخصصة فى هذا المجال مثل برنامج RESIX IP .

ودلت النتائج النهائية للبحث عن وجود طبقة من الرواسب الوديانية تلى الطبقة السطحية الصلبة ويتراوح سمكها من ٢ متر الى حوالى ٣٨ متر ويتوقع وجود تجمعات من المياه بهذة الطبقة حيث إنخفضت قيم المقاومة من ٤٠٠ أوم.متر للطبقة السطحية الصلبة والتى لا يتعدى سمكها ٥ أمتارلتصل الى ١٦٠ أوم . متر ، كما دلت نتائج تفسير ألأعمال الكهربية على إمكانية وجود المياه الجوفية بالجزء الأسفل من طبقة الجرانيت المشققة حيث إنخفضت قيم المقاومة الكهربية من ٧٠٠ أوم. متر والتى تمثل طبقة الجرانيت المشقق لتصل الى ٢٥٠أوم . متر ، وقد يعزى عدم تسرب المياه الموجودة بطبقة الرواسب الوديانية ال طبقة الجرانيت المشقق لوجود طبقة غير منفذة من السلت وربما جاء هذا نتيجة لوجود الجزء العلوى من الجرانيت المشقق ، تم تحديد انسب الأماكن التى يمكن أن تتواجد فيها المياه الجوفية عند الجسات ١ ، ٨ على البروفيل أ أ" والجسه ٣٤ على البروفيل ب ب" والجسات ١٤، ٢٠، ٢٧ على البروفيل ث ث" حيث تتراوح سمك طبقة الرواسب الوديانية ما بين ١٠ أمتار الى ٤٠ متر.