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Geophysical and Hydrochemical Investigations Within the Abu Simbel Area, Egypt

تطبيقات الطرق الجيوفيزيقية والهيدروكيميائية على منطقة أبو سمبل، مصر

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Abstract: A geophysical investigation has been conducted in the Abu Simbel region using the D.C. resistivity method. The results have been integrated with geological information in order to determine, where possible, the depth to the basement, any water-table variations, and the delineation of the hydrogeologic conditions. In this study, twenty vertical electric soundings (20 VES-es) were measured in the area. The measured geoelectric data were made utilizing different configurations (Schlumberger and Wenner) using an ABEM-Terrameter SAS300c resistivity meter. The sounding data were interpreted and analyzed by using classical curve matching and modern computer techniques. Interpretation of each curve model provides the equivalent layering in the form of n-layers with different thicknesses and true resistivities. The interpreted results indicated presence of different geoelectric zones with different geographic distribution. The wet zone (50 - 500 Ohm) is lying at a shallow depth with varying thickness (1- 24m) and formed as lenses. Three highly resistive zones can be detected: the first represents the surface and may correspond to dry sands, the second is lying near the surface and is made up of ferruginous sand which is an obstacle to the growing of bushes in the new farming desert lands and the third (deep) may correspond to hard rocks (e.g. basement rocks). Seven surface water samples from Khors of Lake Nasser were analyzed in the years 1999, 2000 and 2001. These samples were taken from different locations around the lake adjacent to Abu Simbel town. The hydrochemical analysis of these samples illustrated that the values of TDS and trace elements are nearly the same. It is observed that the values of TDS and trace elements increase only at the sites near the denser population communities.

Keywords: Kuwait, bioremediation, polluted desert soil, polycyclic aromatic hydrocarbon, bacteria

المستخلص: قام الباحثون بتصميم عدد من التجارب، لدراسة أثر خلط التربة الملوثة بالمركبات الهيدركربونية بتربة طينية غير ملوثة، وذلك كمحسن للتربة، ومثبت للخلايا البكتيرية - على التحلل البيولوجي للمركبات الهيدروكربونية الأروماتية عديدة الحلقات. وقد تم التعرّف على 16 مركبًا من المركبات الأروماتية عديدة الحلقات عن طريق الكروماتوجرام الغازي، وكان أكثر هذه المركبات شيوعًا المركب فلورانثين Flouranthene، والمركب بيرين Pyrene، وهذين المركبين يعدان من المركبات المسرطنة. وقد أمكن عند خلط التربة الصحراوية الملوثة بالمركبات الهيدروكربونية، بتربة طينية غير ملوثة أو بالمستخلص المائي لها، أمكن تنشيط التحلل البيولوجي لهذه المركبات الحلقية إلى ما بين 85.8% - 89.1% من مجموع هذه المركبات الأروماتية الحلقية، وعند مقارنة ذلك بنتائج معالجة تربة ملوثة لم تخلط بالتربة الطينية، وجد أن نسبة تحلل هذه المركبات لا يزيد عن 61.7% - 75.5% وعند استخدام مزرعة بكتيرية مكونة من خليط من ثلاثة أنواع من البكتيريا محملة على حبيبات التربة الطينية (بغرض تثبيتها)، فإن نسبة التحلل إرتفعت إلى 94% من مجموع هذه المركبات. وفي جانب آخر فقد وجد أنه عند حقن التربة الملوثة بهذه المزرعة الخليط غير المثبتة على حبيبات التربة الطينية، أن نسبة تحلل هذه المركبات لم يزد عن 75.5%. وفي أثناء الدراسة أمكن ملاحظة أن المركبات الهيدروكربونية المكونة من 6 حلقات، قد اختفت تمامًا عند خلط التربة الصحراوية الملوثة بالتربة الطينية غير الملوثة. وكان من المميزات الهامة للمزرعة الخليط المثبتة أنها تسببت في تحليل نسبة كبيرة من المركبات الحلقية التي أمكن التعرف عليها، وخاصة المركبات المسرطنة مثل: فلورانثين، بيرين، كريزين، بنزو(a) بيرين، وثنائي البنزين (a,h) أنثراسين، ومن هذه النتائج أمكن الاستدلال على أن معالجة التربة الصحراوية الملوثة بالمركبات الهيدروكربونية بخلطها بتربة طينية غير ملوثة أو بالمستخلص المائي لها، يعتبر من الطرق الفعالة البسيطة وغير المكلفة.

كلمات مدخلية: التحلل البيولوجي، التربة الصحراوية الملوثة، المركبات الهيدروكربونية عديدة الحلقات، بكتيريا، أبو سمبل،مصر.

Introduction

Recently, the government of Egypt has shown great interest in many national projects in the south valley. The Abu-Simbel area is located at the western bank of Lake Nasser, southwestern region of Egypt (Fig.1). It is very attractive for the future of tourism, agricultural and poultry development in the South Western Desert of Egypt.

Different geophysical (gravity, aeromagnetic) and seismological studies have been made by many researchers (e.g. Raid, *et al.* 1978; Raid and Hosny, 1992). Most of these studies (Raid, *et al.* 1978) aimed to study how the different subsurface fractures in different directions affected the Precambrian basement and also the main tectonic forces.

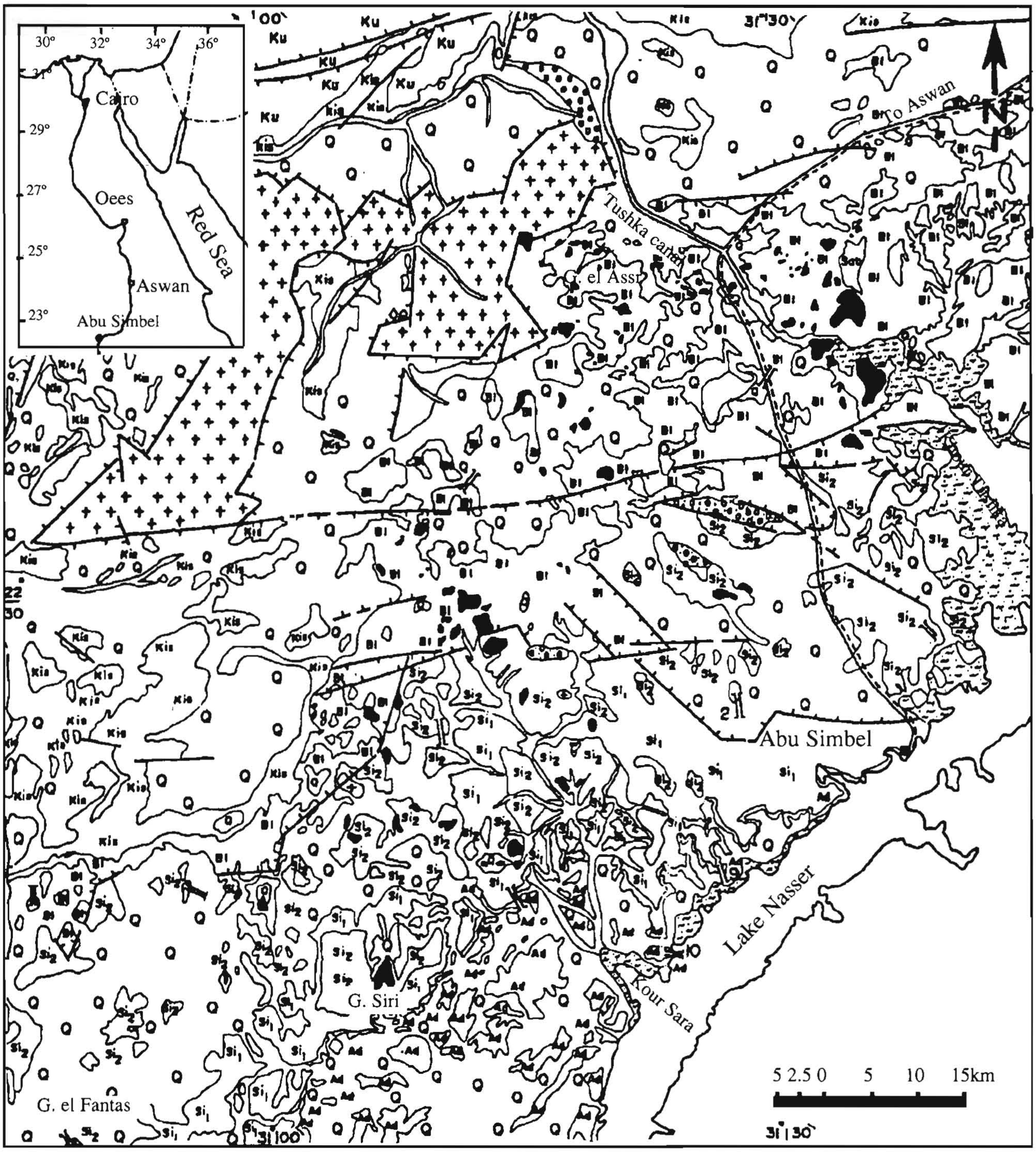


Fig. 1 Geological map of Abu- Simbel area and surrounding parts (after Thabit, 1994).

Geophysical methods are useful in solving most of the subsurface geologic problems. In particular, shallow geophysical techniques (e.g. geoelectric and seismic) are considered the most accurate and effective methods used in engineering, archaeological and environmental investigations. Application of shallow geophysical techniques in engineering and groundwater investigations are of growing interest in Egypt, especially after the rapid growth of existing towns and establishment of new settlements.

The surface geophysical studies applied in this work, were based on the earth resistivity (ER) method. The earth resistivity survey was carried out using the Vertical Electrical Sounding (VES) technique. The method was applied to obtain much subsurface geologic information useful for construction of large buildings and groundwater exploration in the surveyed area of Abu-Simbel. Rainfall in the southern part of Egypt is scarce with rare torrential rains using the drainage lines as channels. The Nubia aquifer system is one of the biggest aquifers in the Western Desert of Egypt. The sediments of this aquifer were deposited in predominantly continental environments. Recharge of the Nubia aquifer is from three possible sources:

1) Seepage of the Nile water,
2) Regional-groundwater influx from areas with modern groundwater recharge, and
3) Local infiltration through precipitation during wet periods in the past (Throrweihe & Heinl, 1998).

Geomorphology and Geological Background

The southwestern region of the Western Desert, in Egypt, is essentially a plateau desert with vast expanses of rock-ground and some deep enclosed depressions. It is of low altitude and attains its maximum height in the southwestern corner. The area is characterized, throughout its recent history, by arid climatic conditions (Butzer, 1959). Due to the arid climate well-marked drainage lines are absent and there are few gullies draining into the Nile Valley.

The area is an extensive plateau having levels ranging from about 150 meters above the sea level (at the Nile Valley side) to about 350 meters above the sea level. Most of the area is composed of rocks belonging to the Nubia Sandstone series. The area extends across four major geologic provinces (Attia, 1955) (Fig.2):

1) Aswan Hills
2) River Nile Valley
3) Nubia Plain
4) Sin El-Kaddab Plateau

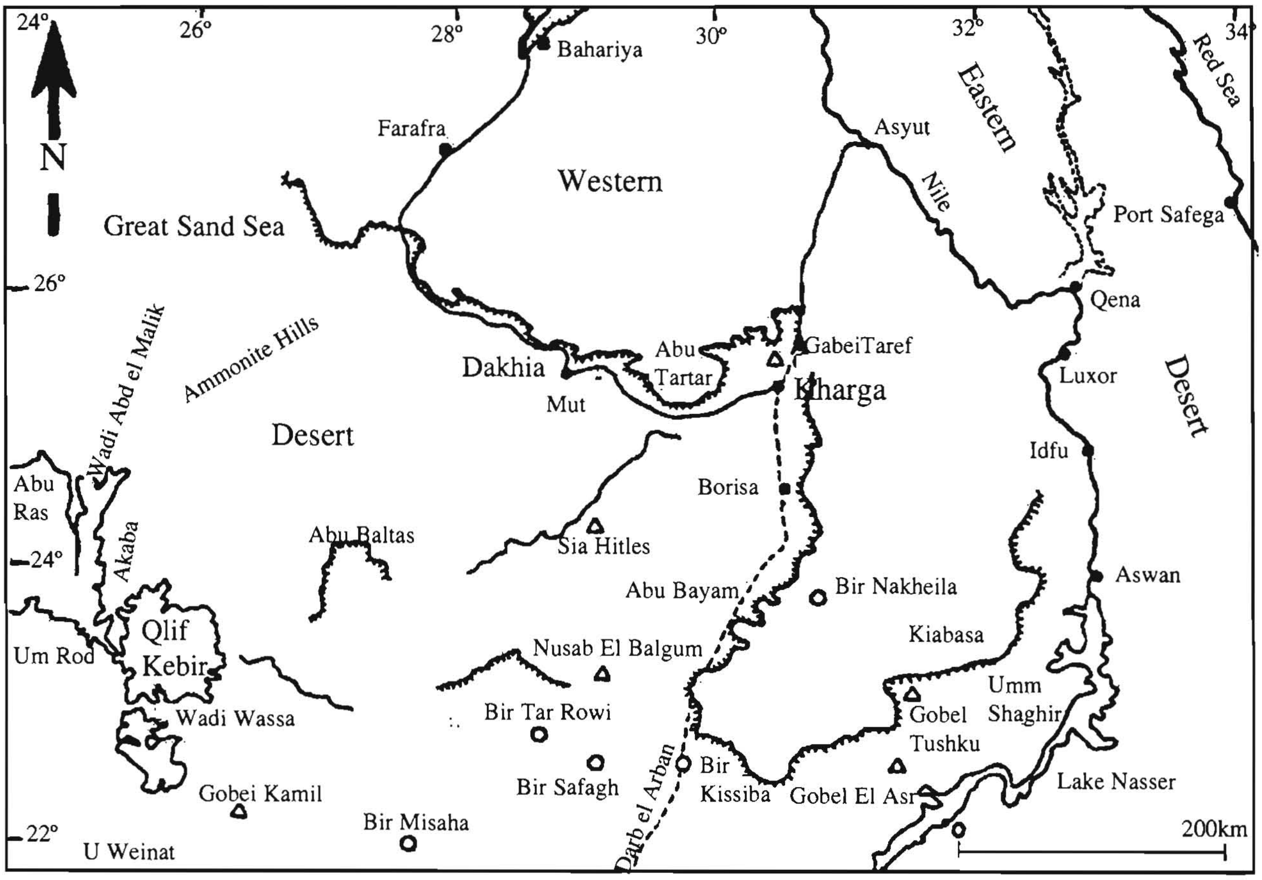


Fig. (**2**): Different geological provinces of Aswan region, southwestern Egypt (after, Mosa, 1978)

The stratigraphy of the area has been investigated by many researchers; e.g. Issawi, 1972 & 1978; Klizsch, 1978 & 1980; Thabit, 1994. According to these studies, the main geologic units (Fig. 3) (from base to top) in the area can be summarized as:

1. *Basement Rocks.* The basement rocks are distributed in the area southeast of Aswan at small localities along the western bank of Lake Nasser. These rocks, on the western bank of Lake Nasser, are mainly represented by coarse-grained granite of Precambrian age.

2. *Nubia Formation.* The Nubia plain, in southern Egypt, west of Lake Nasser is chiefly made up of the Nubia Formation. According to Issawi (1968) the Nubia sandstone (the oldest exposed sedimentary unit) is lying, unconformably, over the Precambrian granitic complex. According to many authors (e.g. Klizsch, 1978 and Thabite, 1994) the Nubia Group, in the southwestern region of the Western Desert, is classified into six formations (from base to top) as follows:

   f) Kurkur Formation

   e) Kiseiba Formation

   d) Sabaya Formation

   c) Abu-Ballas Formation

   b) Abu-Simbile Formation

   a) Adindan Formation

The Nubia formation in the southwestern Egypt is more than 1000m thick. It ranges in age from Jurassic to Late Cretaceous (Fig. 3).

3. *Quaternary Sediments.* The Quaternary sediments are represented by a sporadic discontinuous distribution of sands, silts and gravels, products of the Nile and its tributaries and also by a discontinuous cover of desert pavement veneer and dune sands over the desert surface (tufa deposits, conglomerate sheets and sand dunes). In the majority of the investigated area, these deposits are lying directly over the Nubia Formation (Issawi, 1968).

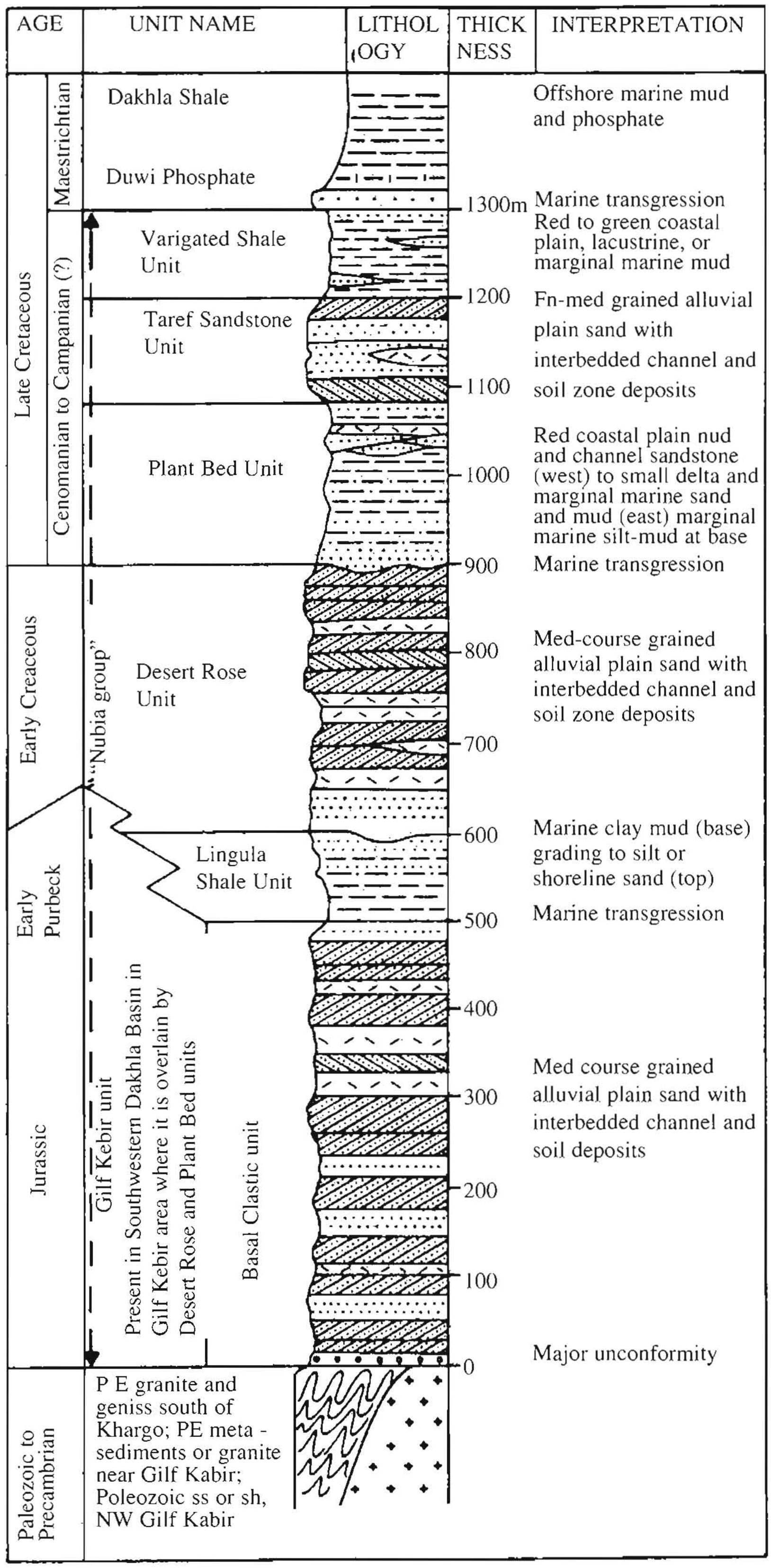


Fig. (3): Generalized stratigraphic column of Nubia strata, southwestern Egypt (after Klizsch *et al.*, 1978).

The surface structural geology of Abu-Simbil and Tushka as a part of the Western Desert has been discussed by many authors (e.g. Youssef, 1968; Issawi, 1978 and Hermina in Said, 1990). The southwestern region of Egypt is affected by many faults in different directions and extensions. The major and important fault trends include East West (Kalabsha fault and Seiyle faults) and North South (Gabel El-Baraqa fault, Kurkur fault, Khor El-Ramla fault, Gazalle fault and Abu-Dirwa faults). The uplifting is very well represented in the area as faulting and interlocking folds with overturned beds.

Surface Geoelectric Method

In the earth resistivity method a committed direct current (DC) or low-frequency alternating current (AC) is introduced into the ground by means of two electrodes (metal stakes or suitably laid out bare wire) connected to the terminals of a portable source of electromotive force (e.m.f.) The resulting potential (V) distribution on the ground mapped by means of two probes (metal stakes or, preferably, non-polarizable electrodes), is capable of yielding information about the distribution of electrical resistivity below the ground surface (Dobrin, 1976).

$$\rho = 2\pi V_{MN}/IK \qquad (1)$$

Where; ρ is the resistivities in unit of Ohm-meters, V is the voltage drop, I is the current strength, K is the geometric factor of electrode configuration.

Equation 1 represents the resistivity of a homogeneous Earth. In an actual case, ρ will vary if we alter the geometrical arrangement of the four electrodes or move them on the ground without altering their geometry. That is, V_{MN}/I will not be directly proportional to K as on a homogeneous Earth. The value of ρ, obtained on substituting the measured V_{MN}/I and the appropriate K in equation 1, is called the apparent resistivity ρ_a (equation 2):

$$\rho_a = \pi L^2 / 2 l . R = K. R \qquad (2)$$

Where; $K = \pi L^2 / 2 l$ and ρ_a is the apparent resistivity.

The value of the apparent resistivity (ρ_a) depends on the geometry of the electrode array used, as defined by the geometric factor K.

Field work and instruments

In the present study the Vertical Electric Sounding (VES) technique involved the measurement of 20 VES-stations during July 2000 (Fig. 4). The measurements were made by the ABEM terrameter SAS 300c, which is powered by a rechargeable 12v (nickel-cadmium) battery. The location of the sounding stations was determined by using the topographic map (scale 1:50000) (Fig.4).

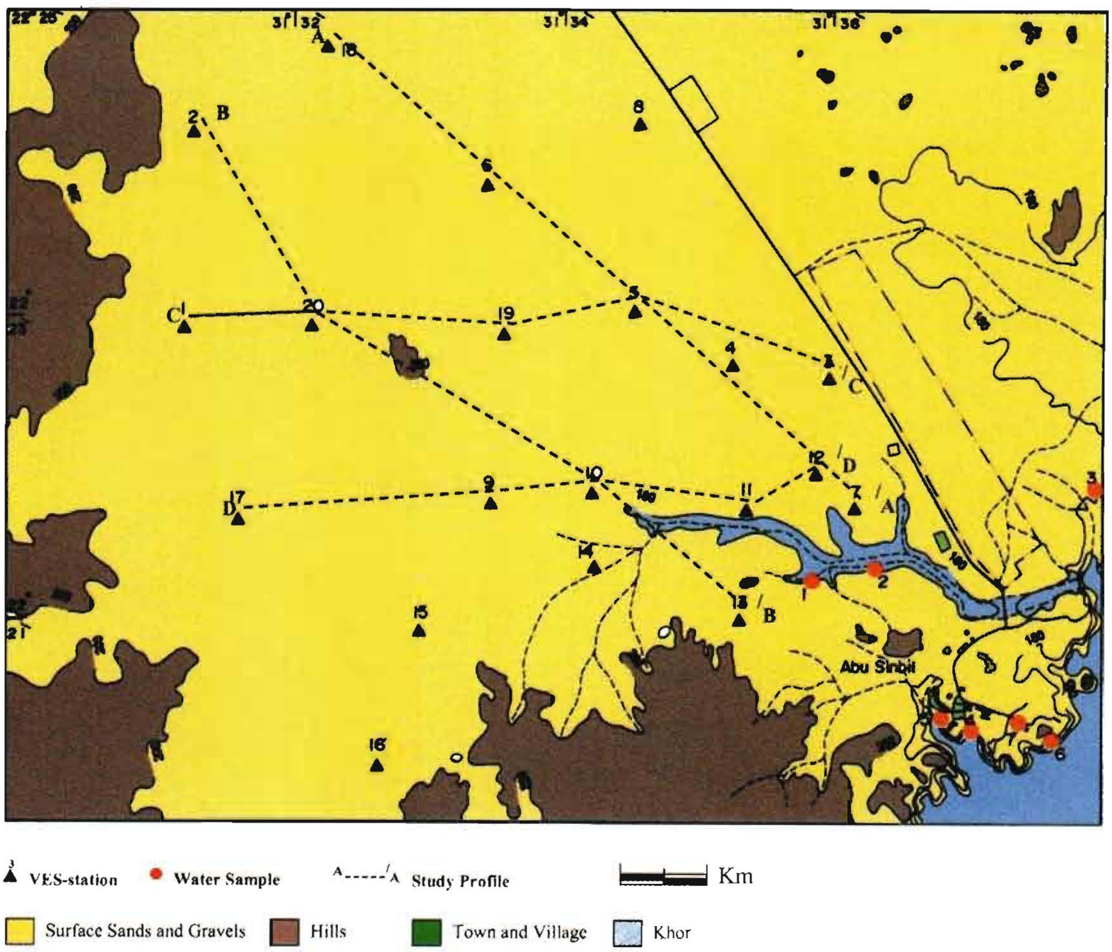


Fig. 4: Locations map showing the VES-stations, studied profiles and collected water samples.

The value of current electrode separation (AB) was varied from 3 to 1200m and from 0.5 to 30m between the potential electrodes (MN), which is sufficient for recognizing all interested geoelectric beds overlying the bed rock. The distribution of VES-stations was not regular due to the presence of much topographic accessibility, e.g. hills and private farms, but the VES-stations were distributed all over the considered area. The apparent resistivity values of each measured sounding curve were plotted on bilogarithmic paper against the half distance between the current electrodes (AB/2) during the field work to correct any odd readings and to make the suitable smoothing for each sounding curve individually.

Before selecting the suitable geometrical array and direction of the spread during carrying out the present geoelectric survey some initial VES-stations were made applying Schlumberger and Wenner arrays along two perpendicular directions (NS and EW) (Fig. 5). The careful interpretation and analysis of all these selected measured VES-curves indicated that the Schlumberger array along the N-S direction gave satisfactory results conformable with the geology of area.

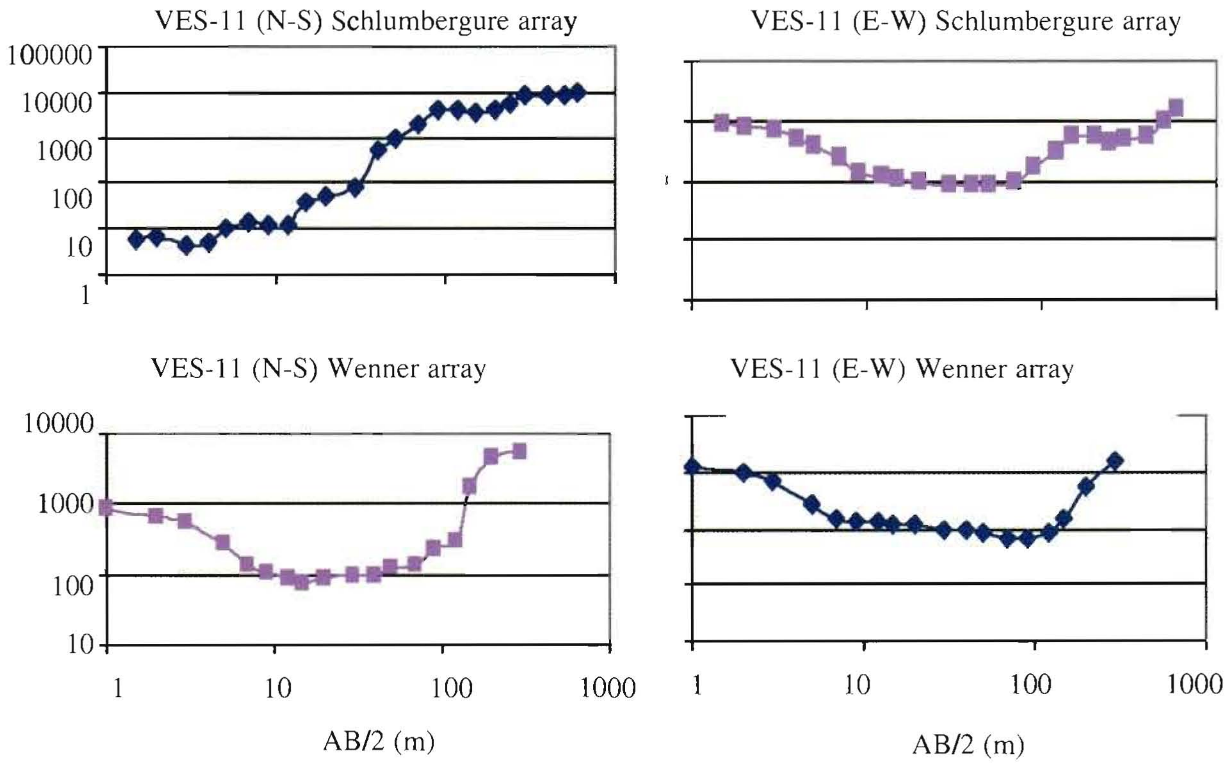


Fig. 5: Different types of VES-curves using; Schlumbergure array (a) and Wenner array (b) measured along the N-S and E-W direction.

Methods of Interpretation

The measured field vertical electric sounding curves (VES-curves) were interpreted by using two approaches, manual and computer modeling, to recognize the subsurface rock sequence in the form of successive geoelectrical layers having definite resistivities, depths and thicknesses. Geologic structures can also be detected by such interpretation. In general, two consecutive steps of interpretation are usually followed, the first is qualitative and the second is quantitative.

Qualitative Interpretation

The qualitative interpretation of geoelectric measurements was applied to illustrate the lateral and vertical irregularities of electric properties, as well as to shed light on the subsurface geological and structural conditions prevailing in the area under investigation.

Zohdy and Bisdorf (1989b) observed many properties of Schlumberger theoretical curves for horizontally stratified, laterally homogeneous, and isotropic media qualitatively, regardless of the number of layers or resistivity distribution with depth. These properties were taken into account during the interpretation process of geoelectric VES-curves measured in Abu-Simbel area.

The most important of these properties are:

a. The form of sounding curves follows the form of the true resistivity depth curve although thin layers may be canceled. As the true resistivities increase (or decrease) with greater depth, the apparent resistivities increase (or decrease) with greater electrode spacing. This is particularly evident for layers whose thickness increases logarithmically with depth.

b. The amplitude of the sounding curve is always less than or equal to the true resistivity- depth curve. The apparent resistivity asymptotically approaches the true resistivity at electrode spacings that are very small with respect to the thickness of the first layer or very large with respect to the depth of an infinitely thick last layer.

c. In a multilayer model, if the true resistivity of a thick layer is changed, the apparent resistivity along a corresponding segment of sounding curve also changes accordingly. Furthermore, the maximum change in true resistivity is approximately equal to the net change in the true resistivity.

In the present study, qualitative interpretation of the sounding data involved:

1) The study of the different types field VES-curves (Fig. 6),
2) Preparation of iso-resistivity contour maps at different electrode spacing (Fig. 7), and
3) The construction of different apparent resistivity-pseudo depth sections along different directions (Fig. 8).

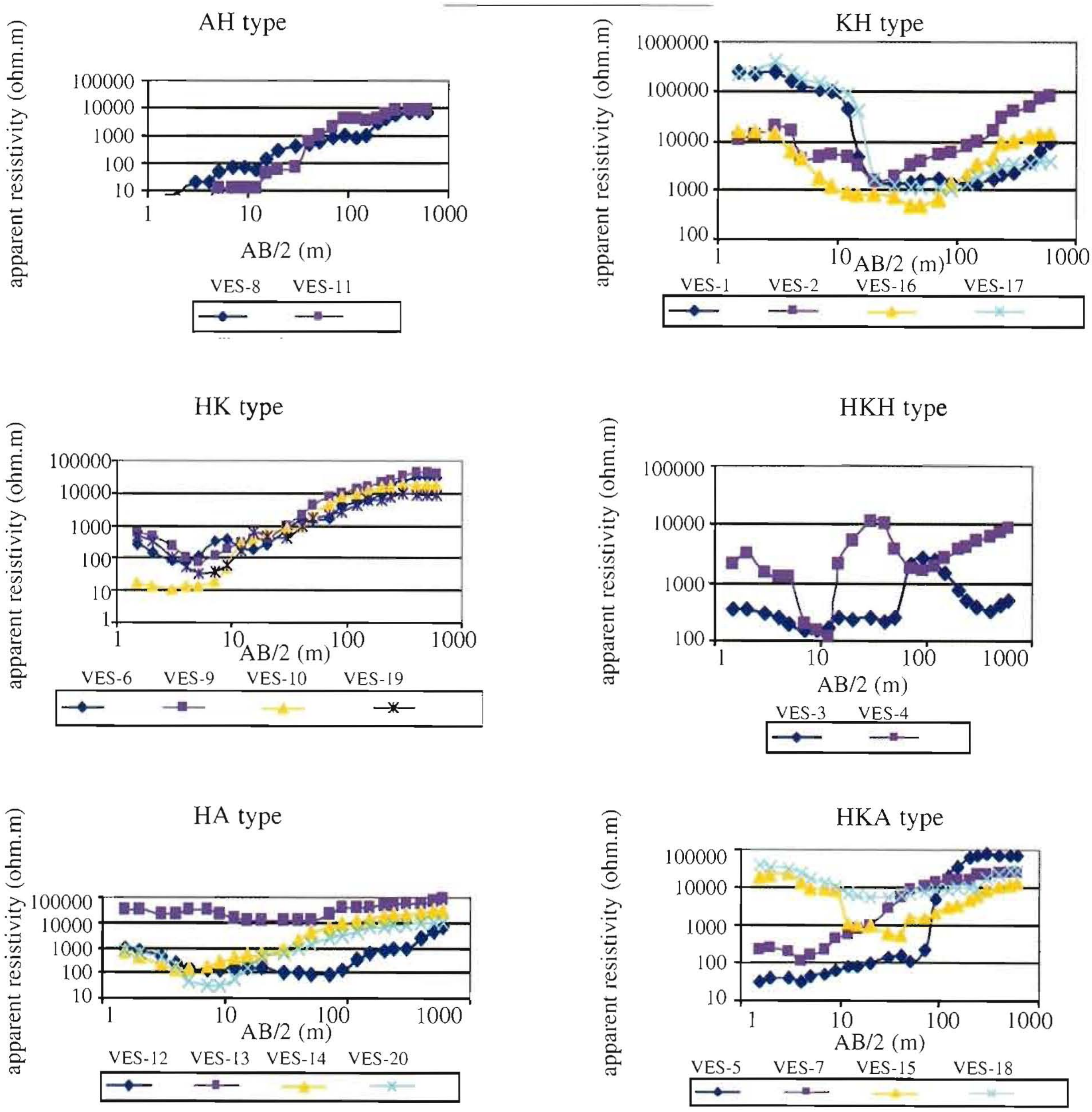


Fig 6: Different types of geoelectric curves measured in the surveyed area.

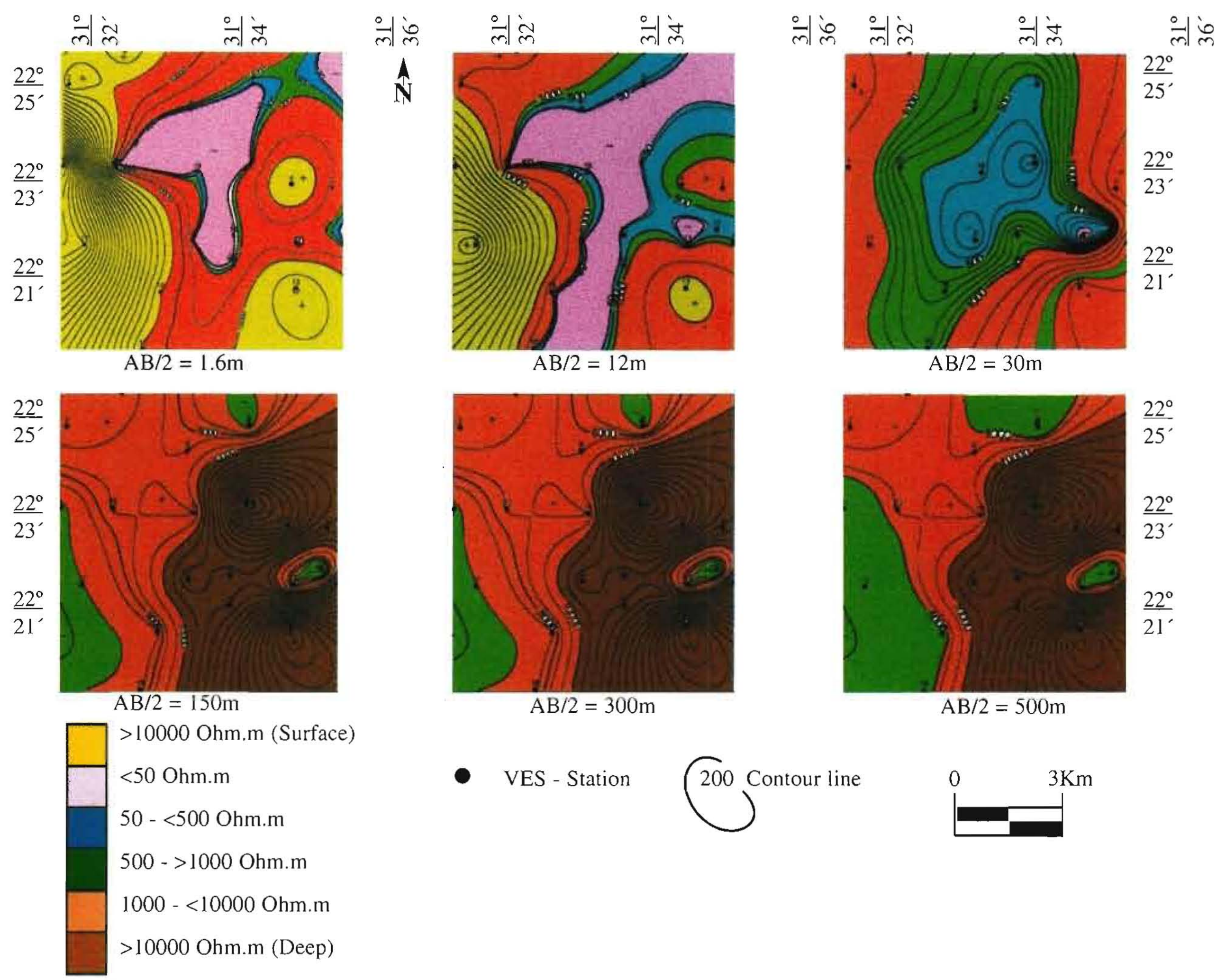


Fig. 7: Iso-resistivity contour maps at different current electrode separation (AB/2)

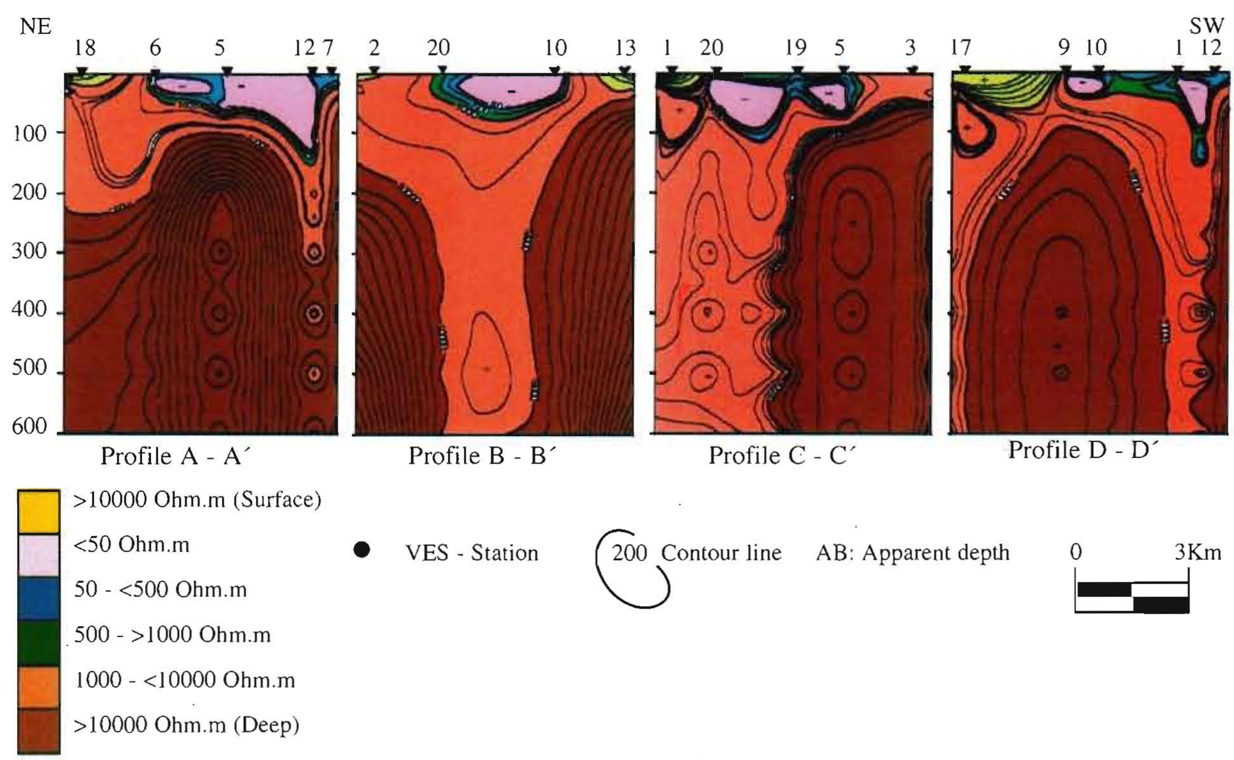


Fig. 8: Apparent resistivity sections along different studied profiles

VES-Curve Types

The measured resistivity sounding curves in the Abu-Simbel area were corrected and smoothed. The resulting smoothed curves were classified into six main different groups (see Fig. 6). The form of these curves is a function of the resistivities and thicknesses of the subsurface geoelectric layers, as well as the type of array employed (Schlumberger) in the examined area. Details of VES-curves characteristics and electrode array have been presented in many papers and literatures (e.g. Bhattacharya and Patra, 1968; Zohdy, 1974). These groups are:

a. KH type: includes four soundings (1, 2, 16 and 17) and has four geoelectrical layers.

b. HK type: includes four soundings (6, 9, 10 and 19) and has four geoelectrical layers.

c. HA type: includes four soundings (12, 13, 14 and 20) characterized by four geoelectrical layers.

d. HKH type: includes two soundings (3 and 4) and has five geoelectrical layers.

e. AH type: includes two soundings (8 and 11) characterize by four geoelectrical layers.

f. HKA type: includes four soundings (5, 7, 15 and 18) and has five geoelectrical layers.

Iso-apparent Resistivity Contour Maps

Different iso-resistivity contour maps were constructed for various electrode spacings (AB/2 of 1.5, 12, 30, 150, 300 and 500m) (Fig. 7) to illustrate the different layers affected by the artificial electric current transmitted through the ground. The careful study of these maps may give a picture about the lateral variations along a certain horizontal plane. The following are the main remarks deduced from the investigation of these maps:

a. An extremely high resistive anomaly (>10000 Ohm.m) is clearly observed on the iso-resistivity contour map AB/2 = 1.5m (Fig. 7a) and also on the map of AB/2 = 12m (Fig. 7b) in most of the western part of the area. This may indicate that the dry zone (dry sands and gravels) continues from the surface until an apparent depth 12m.

b. A conductive zone having low resistivity values lower than 500 Ohm.m is observed in the middle part of the area. It may reflect that this zone (clayey and silty zone) is also continued at AB/2 = 12m (Fig.7b).

c. The linear shape of the low resistivity contours (Fig. 7b) may point to the presence of a buried ancient water channel.

d. Generally, the resistivity at an apparent depth AB/2 = 30m (Fig. 7c) has lower values than those observed at apparent depths 1.5m (Fig. 7a) and 12m (Fig. 7b). This may indicate that the low conductive zone detected at AB/2 = 1.5 and 12m is still continued until AB/2 = 30m, but the conductive zone at AB/2 = 30m may indicate more possibilities for groundwater accumulation than the two overlying zones.

e. Extremely high resistivity values are observed at an apparent depth 150m (Fig. 7d), particularly at the eastern and southern parts of the area, indicating a large dry zone at an apparent depth 150m (Fig.7d), suggesting an absence of any conductive sediments. Similar distribution of resistivity contours with nearly the same values like those at the apparent depth 150m can also be detected at apparent depths 300m (Fig.7e) and 500m (Fig. 7f) respectively, which may indicate that this dry zone is large and beginning from an apparent depth of 150m, having an apparent thickness of more than 350m. This dry zone may be made of Nubia sandstone and/or Basement rocks.

Pseudo-Geoelectrical Cross Sections

Four apparent resistivity-pseudo depth sections were constructed in different directions (see Fig. 8) covering most of the investigated area. Two sections (AA/ and BB/) have N-S direction and the others (CC/ and DD/) have E-W direction. These sections illustrate, qualitatively, 2d-apparent resistivity distribution throughout the area. The study of these sections shows that:

a. In general, the prepared pseudo-sections reflect surface zones of high resistivities, which is characteristic of arid regions like Abu-Simbel.

b. The resistivity values, generally, increase vertically with the increase of the electrode spacing (AB/2) and hence with increase of the corresponding depth.

c. The surface and near-surface layers (dry zone) in all studied sections have a very high resistivity (reaching >1000 Ohm.m). These two layers are made up of dry sands and gravels which are very common sediments covering the area. This dry zone is very common in Abu-Simbel, which represents one of the most arid regions in upper Egypt. Values of apparent resistivities of the dry zone tend to decrease by depth in most locations and then increase again.

d. A general increase of apparent resistivities from southeast to northwest (i.e. towards areas of more arid nature) and/or towards areas of large thickness of overburden.

e. Abrupt lateral and vertical changes in apparent resistivities noticed clearly between VES-stations 7 and 12 (Fig. 8a); between VES-stations 10 and 13 (Fig. 8b); between VES-stations 5 and 19 (Fig. 8c) and between VES-stations 11 and 12 (Fig. 8d). These changes may be related to vertical lithological contacts, e.g. faults or abrupt changes in sedimentary facies due to changes in depositional conditions.

f. Low resistivity anomalous (<300 Ohm.m.) zones at small depths from the ground surface, having nearly lenticular shapes were detected, particularly at the most southeastern part (Figs. 8a and 8b) and at the eastern part (Fig. 8c) of the surveyed area, i.e. near the lake or near the cultivated land. The origin of low resistive values is possibly due to conductive sediments, e.g. silt and clays particularly at the upper most part, or due to water-bearing sediments at the low depths.

g. The presence of high anomalous zones of very high resistivities (>10000 Ohm.m) at an apparent depth of 150m (Fig. 8) in most of the surveyed area may reflect the presence of hard rock materials such as Nubia Sandstone and/or Basement rocks.

Quantitative Interpretation

Quantitative interpretation may be considered as the ultimate stage of the interpretation process. Geoelectrical survey is among the most difficult of all the geophysical methods to interpret quantitatively because of the complex theoretical basis of the technique. For the quantitative interpretation of resistivity data, mathematical analysis is most highly developed for the vertical electrical sounding technique, to lesser degree for constant separation traversing or lateral profiling over two-dimensional structures and least developed for the lateral profiling over three-dimensional structure bodies.

The main purpose of the quantitative interpretation of electrical sounding is to determine the actual resistivities of the subsurface layers beneath each station, as well as the thickness of these layers. The values of the true resistivities of the different subsurface layers can give good information about the location and extension of groundwater accumulation, as well as geoelectrical properties.

Many problems have been faced during the interpretation process of the resistivity data from the present study in the Abu-Simbel area. The most important problems are:

a. Several models may be obtained for the same VES-curve that may lead sometimes to an ambiguity in geoelectric interpretation.

b. The interpretation process of some VES-curves is complicated by the fact that there is generally a considerable drop of the apparent resistivity values (>20000 to 20 Ohm.m), which induces the equivalency of different solutions (principle of equivalency) and the possible disappearance of layers (Plyacv, 1948).

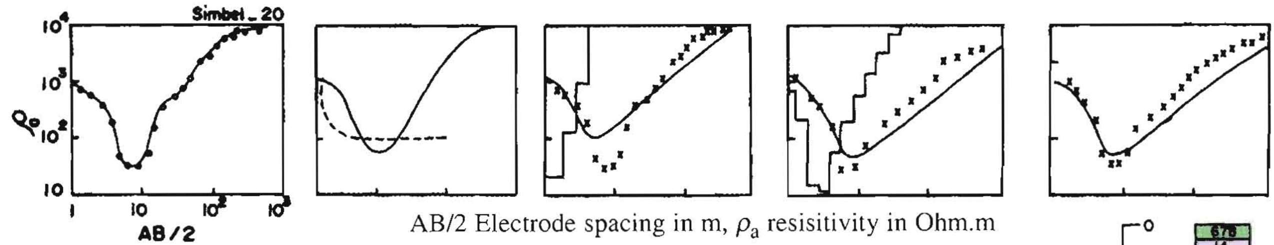
c. The geoelectric measurements have sometimes been obtained with a very low electric current due to the high resistance of the ground throughout the surveyed area.

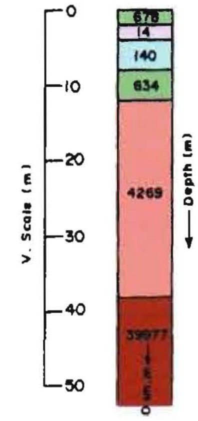
d. The study area around Abu-Simbel town can be considered as a blind area according to the subsurface geological information.

The basic technique for interpreting resistivity-sounding data must consist of four steps:

1) assume a trial earth model,
2) compute the theoretical field curve to be expected from this model,
3) compare with the observed field curve and
4) modify the earth model as necessary to improve the agreement, until the best possible agreement has been achieved.

The quantitative interpretation process in this study is driven by the measurement of twenty VES-curves covering the study area, according to the manual interpretation with congniared master curves to obtain the preliminary model for the number of layers, their thickness and their resistivities. Also, these sounding data are interpreted using software given by Van Der Velpen, *et al.* (1988) Zohdy and Bisdorf (1989b) and Grivel (1989). A correlative stage was then performed among all different techniques to obtain the suitable and logical information about the true resistivities, as well as the depth of the encountered boundaries of the geoelectric subsurface layers which conform with all available geologic information (Fig. 9). The true resistivities and the thickness of the various subsurface layers are recorded in Table 1.





1. Field curve
2. Interpretation by curve matching
3. Interpretation by computer program (Van Der Velpen *et al*, 1988)
4. Interpretation by computer program (Zohdy and Bisdorf, 1989 b)
5. Interpretation by computer program (Grivel, 1989)
6. Resulting geoelectric cross section from VES-20

Fig. 9: Example showing the different stages of geoelectric interpretation followed in the present study

Table 1: Results of the interpretation of the measured VES-curves, in the Abu-Simbel area.

VES	E	No.	Resistivity (Ohm.m)						Thickness (m)					
no.			$\rho 1$	$\rho 2$	$\rho 3$	$\rho 4$	$\rho 5$	$\rho 6$	t1	t2	t3	t4	t5	t6
1	196	3	144525	2043	41499	-	-	-	6	124	∞	-	-	-
2	188	3	19594	4470	91649	-	-	-	2	49	(	-	-	-
3	184	4	18	640	4085	58215	-	-	1	3	120	∞	-	-
4	184	5	25161	4707	742	3844	401896	-	2	1	4	3	∞	-
5	193	5	25	150	745	3124	60215	-	3	24	22	96	∞	-
6	192	4	217	971	4013	79995	-	-	12	6	26	∞	-	-
7	187	4	184	589	4561	51619	-	-	4	2	16	∞	-	-
8	188	5	17	215	687	3881	20465	-	2	6	20	68	∞	-
9	188	4	825	215	4372	115391	-	-	1	7	17	∞	-	-
10	189	5	13	123	525	2610	93466	-	3	4	3	22	∞	-
11	180	5	9	154	666	3307	27010	-	6	12	8	57	∞	-
12	187	4	756	150	6452	45632	-	-	1	16	95	∞	-	-
13	200	3	29150	7114	68349	-	-	-	6	12	∞	-	-	-
14	189	5	1224	195	610	4985	13965		1	4	2	16	∞	-
15	198	4	13447	898	4293	12946	-	-	6	21	96	∞	-	-
16	200	4	13453	747	4707	30041	-	-	3	40	49	∞	-	-
17	194	4	163832	4683	983	2600	-	-	5	6	13	∞	-	-
18	198	3	28143	6587	42918	-	-	-	4	69	∞	-	-	-
19	181	6	116	16	368	723	4735	133381	1	2	3	7	29	∞
20	180	6	678	14	140	634	4269	39977	2	2	4	4	26	∞

E: elevation in meters ρ: resistivity in Ohm.m t: Thickness in meters ; No.: Number of layers.

Four geoelectric cross-sections (Fig. 10) were constructed along specific profiles corresponding to those of the apparent pseudo-geoelectric sections. In the present study all available surface and subsurface geological and hydrogeologic information derived from pervious studies preformed in the area and the surrounding parts has been used to help in the interpretation of the geoelectric subsurface sections.

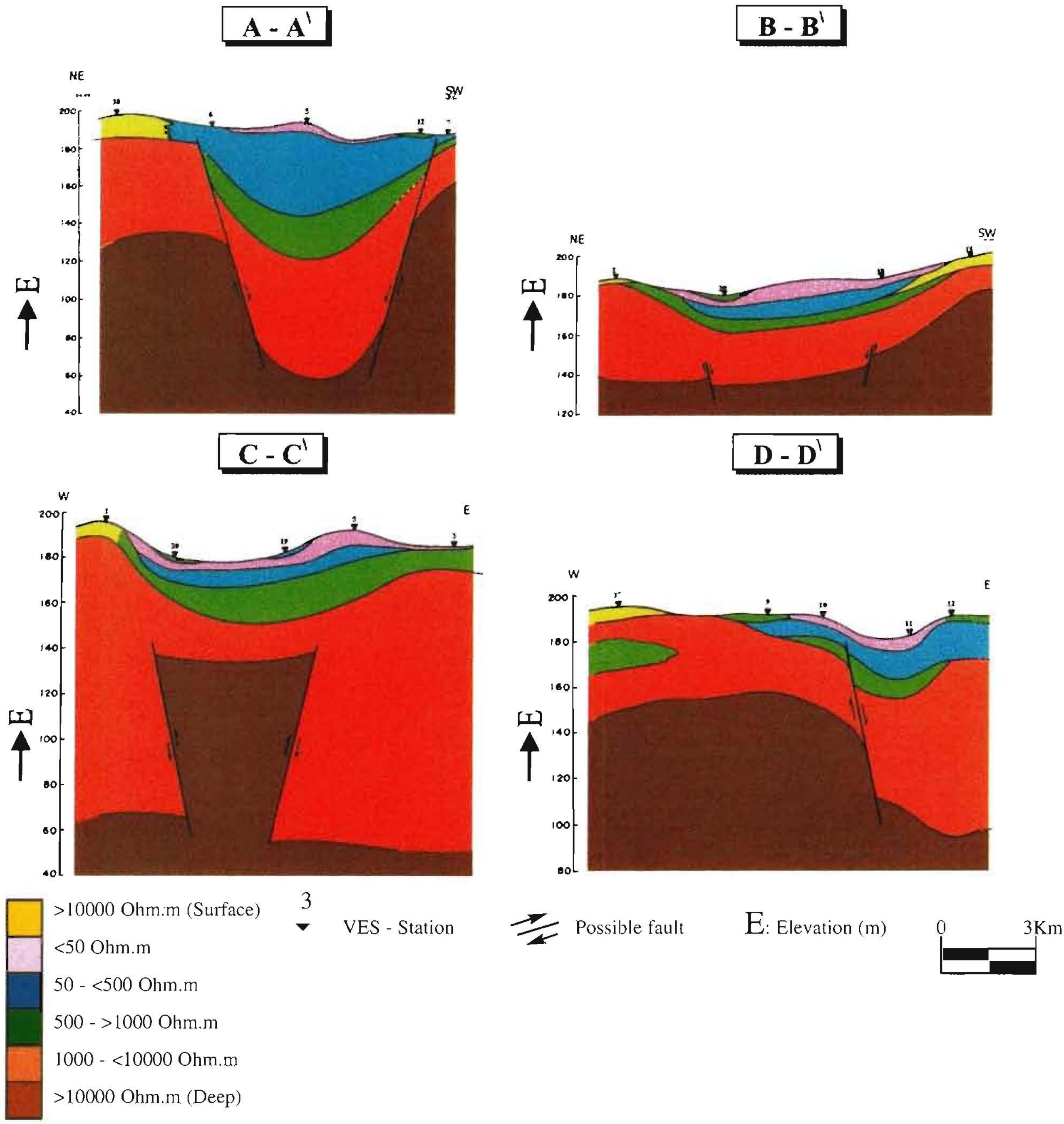


Fig. 10:Subsurface geoelectric cross sections interpreted along different directions.

The careful interpretation of these sections leads to the following:

a. The first geoelectric layer (the surface) has an extremely high resistivity of more than 10000 Ohm.m (Figs. 10a, b, c and d) and its thickness varies from 2 to 6m. It corresponds to a dry zone, which is very common in this part of southern Egypt, and consists of dry sands and gravels.

b. Dissected lenticular sedimentary bodies having various resistivity values from less than 50 to more than 1000 Ohm.m (VES-stations 6, 7, 9, 12, 19 and 20) were found within the surface layer.

c. In certain parts the surface geoelectric layer includes very low conductive sediments (50 Ohm.m) at very shallow depths (from the surface to 2m deep). It is believed that these conductive materials represent clayey and/or silty sediments (1 to 6m thickness), that must be taken into account for engineering purposes.

d. The second layer, in most of the surveyed area, has a general low resistivity (>50 to 500 Ohm.m). It begins from the ground surface to 6m depth with a maximum thickness of 24m (VES-station 5). It may represent conductive sediments, which probably correspond to the water-bearing zone. This zone lies only at the southeastern parts of the surveyed area, i.e. Khor of Abu-Simbel.

e. The third layer has moderate resistivity values (>500 to 1000 Ohm.m). The depth of this zone reaches a maximum value of 27m and its thickness reaches 22m (VES-station 5). This layer may correspond to massive sandstone.

f. The fourth layer has high resistivities (>1000 to 10000 Ohm.m). It begins from the ground surface to a maximum depth 49m (VES-station 5) and maximum thickness of 96m at VES-station 15. It may correspond to massive iron rock, which acts as an obstacle to the growing of bushes in the farming land in Abu-Simbel particularly at locations where it is located near the surface.

g. The deep geoelectric (the fifth) layer is characterized by extremely high resistivities (>10000 Ohm.m.), representing a deeper dry zone in the whole area. Possibly, materials of that dry zone represent a hard rock, which may be Nubia Sandstone and/or Basement rocks.

h. Many lithologic contacts (e.g. faults or abrupt changes in sedimentary facies) can also be detected. These contacts do not affect the surface zone which is in contact with building footings.

Hydrochemical Studies

The River Nile is one of the world's great rivers. It has been the lifeblood of Egypt for thousands of years. For millennia this unique waterway has nourished varied livelihoods, an array of ecosystems and a rich diversity of culture. Just north of the border between Egypt and Sudan lies the Aswan High Dam, a huge rockfill dam that captures the world's longest river, the Nile, in the world's third largest reservoir, Lake Nasser.

Recently, Egypt has been facing multiple pressures such as rapid population growth and increasing industrialization that are creating greater water demand. These multiple pressures threaten Egypt's available water supply, contributing to a deteriorating situation resulting from increasing amounts of pollutants entering the Nile from industrial, agricultural and domestic sources.

The picturesque Nile River, the lifeblood of Egypt, is becoming a serious hazard to people. Its water contains a chemical stew of heavy metals, dioxins, PCBs, DDT and other pesticides, untreated human and animal waste and disease carrying bacteria. The source of these are local industry and farm runoff, as well as industry upstream and untreated waste from villages, towns and cities near its banks. Some of the pollutants exceed allowable levels. For many chemicals, safe, permissible levels of exposure are not known.

Presentation of Chemical Analyses

In the present study all collected water samples were hydrochemically analyzed for determining; pH, electric conductivity (EC), major ions and cations and also trace elements in three successive years 1999 (Tables 2, 3 & 4), 2000 (Tables 5 & 6) and 2001 (Tables 7 & 8). The data in this study have been expressed in milligrams per liter (mg/l), milliequavilents per liter (meq/l), or millimoles per liter. Both the trilinar diagram (Piper, 1953) and the semilogarithmic diagram (Schoeller, 1962) were used to correlate the chemical composition of the collected water samples in the surveyed area. The GWW program facilities were used for plotting the data.

Table 2: Results of the hydrochemical analysis of the collected surface water samples in the Abu-Simbel area (1999).

No.	PH	EC µS/*cm*	TDS (ppm)	Units	Cations				Anions		
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{3-}	Cl^{-}	SO^{4-}
1	8.28	316	220	Ppm	20	16	25	6	135	22	32
				Epm	0.9	1.3	1.08	0.15	2.2	0.62	0.33
2	7.99	406	320	Ppm	18.5	17.7	30	5.6	133	25	31
				Epm	0.9	1.5	1.3	0.14	2.18	0.70	0.64
3	8.43	448	271	Ppm	23	18.8	40	6.3	148	30	39
				Epm	1.1	1.5	1.73	0.16	2.42	0.84	0.81
4	8.23	447	286	Ppm	30	20	12	4.1	143	23	23.43
				Epm	1.5	1.6	0.52	0.1	2.34	0.64	0.48
5	8.14	232	87	Ppm	30.1	12	26.5	5.5	177.8	17.33	16
				Epm	1.5	0.98	1.15	0.14	2.9	0.48	0.33
6	8.28	498	260	Ppm	24.1	14.6	32	5.5	154.5	14.85	12.5
				Epm	1.2	1.2	1.39	0.14	2.53	0.41	0.26
7*	8.54	344	145	Ppm	26.7	4.24	36.5	5.7	180	17.3	12.3
				Epm	1.3	0.36	1.58	0.14	2.94	0.48	0.25

* Drinking water E.C: Electrical conductivity TDS: Total dissolved salt

Table 3: Chemical analysis for trace elements (Ppm) of surface water samples in the surveyed area (1999).

No	.N	Fe^{2+}	Mn^{2+}	Cu^{2+}	Ni^{+}
1	0.00	0.15	0.12	0.00	0.001
2	0.00	0.08	0.08	0.00	0.002
3	0.02	0.1	0.11	0.00	0.003
4	0.00	0.09	0.16	0.001	0.005
5	0.03	0.06	0.04	0.002	0.001
6	0.00	0.12	0.12	0.001	0.009
7	0.00	0.02	0.008	0.00	0.002

Table 4: Results of the hydrochemical analysis of the collected surface water samples in the area (2000).

No.	PH	EC µS/cm	TDS (ppm)	Units	Cations				Anions		
					Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{3-}	Cl^{-}	SO^{4-}
1	8.26	313	220	Ppm	21	15	24	7	132	23	32
				Epm	0.9	1.1	1.10	0.18	2.15	0.64	0.33
2	7.95	407	320	Ppm	20	17.7	31.5	5.6	135	22	31
				Epm	0.9	1.5	1.34	0.14	2.2	0.62	0.64
3	8.41	450	271	Ppm	23	18	40.5	6.3	148	30	39
				Epm	1.1	1.4	1.83	0.16	2.42	0.84	0.81
4	8.21	445	286	Ppm	32	18	12	4	145	21	23.43
				Epm	1.5	1.4	0.52	0.1	2.34	0.60	0.48
5	8.2	420	287	Ppm	30	12	26	6	177	17.33	16
				Epm	1.5	0.98	1.15	0.14	2.9	0.48	0.33
6	8.26	495	260	Ppm	24	14.7	31.5	6	152.5	15.85	13.5
				Epm	1.2	1.2	1.34	0.14	2.53	0.41	0.28
7*	8.52	346	145	Ppm	26.8	4.23	36.5	5.7	180	17.3	12.3
				Epm	1.3	0.36	1.58	0.14	2.94	0.48	0.25

* Drinking water EC: Electrical conductivity TDS : Total dissolved salt

Table 5: Chemical analysis for trace elements (ppm) of surface water samples in the studied area (2000).

No.	N	Fe^{2+}	Mn^{2+}	Cu^{2+}	Ni^{+}
1	0.001	0.13	0.15	0.001	0.001
2	0.001	0.08	0.081	0.001	0.002
3	0.02	0.12	0.12	0.002	0.003
4	0.001	0.08	0.15	0.001	0.005
5	0.03	0.07	0.02	0.002	0.001
6	0.00	0.13	0.14	0.001	0.008
7	0.001	0.03	0.009	0.001	0.003

Table 6: Results of the hydrochemical analysis of the collected surface water samples in the area (2001).

No.	PH	E.C.	TDS	Units	Cations				Anions		
		µ*S/cm*	(ppm)		Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	HCO^{3-}	Cl^{-}	SO^{4--}
1	8.29	314	220	Ppm	19	17	26	5	130	25	31
				Epm	0.9	1.4	1.08	0.13	2.12	0.70	0.64
2	7.96	405	320	Ppm	18	17.7	30.5	5.6	135	22	31
				Epm	0.8	1.5	1.3	0.14	2.2	0.62	0.64
3	8.41	448	271	Ppm	24	17.8	40	6.3	148	30	39
				Epm	1.2	1.5	1.73	0.16	2.42	0.84	0.81
4	8.20	445	286	Ppm	32	18	13	3.1	145	21	23.43
				Epm	1.5	1.6	0.52	0.1	2.40	0.62	0.48
5	8.3	425	287	Ppm	30.14	13	25.5	5.5	175.8	16.33	15
				Epm	1.5	0.98	1.15	0.14	2.9	0.48	0.33
6	8.25	500	260	Ppm	25.1	13.6	32	5.5	152.5	16.85	12.5
				Epm	1.2	1.2	1.39	0.14	2.53	0.48	0.26
7*	8.51	342	145	Ppm	27.5	4.24	36.5	5.7	180	17.3	12.3
				Epm	1.31	0.36	1.58	0.14	2.94	0.48	0.25

* Drinking water EC: Electrical conductivity TDS: Total dissolved salt

Table 7: Chemical analysis for trace elements (ppm) of surface water samples in the investigated area (2001).

No.	N	Fe^{2+}	Mn^{2+}	Cu^{2+}	Ni^{+}
1	0.00	0.15	0.12	0.003	0.001
2	0.001	0.09	0.08	0.002	0.002
3	0.02	0.10	0.14	0.003	0.003
4	0.00	0.09	0.17	0.001	0.005
5	0.03	0.06	0.041	0.002	0.001
6	0.00	0.12	0.120	0.001	0.009
7	0.001	0.03	0.008	0.00	0.002

The trilinear diagram is one of the most widely used graphical methods used for classification of natural water. It constitutes a useful tool for water analysis interpretation. This type of classification is based on the percentage equivalent per million of cations and anions. There are two triangular diagrams, one at the left for plotting the cations and the other at the right for plotting the anions with a diamond-shaped field.

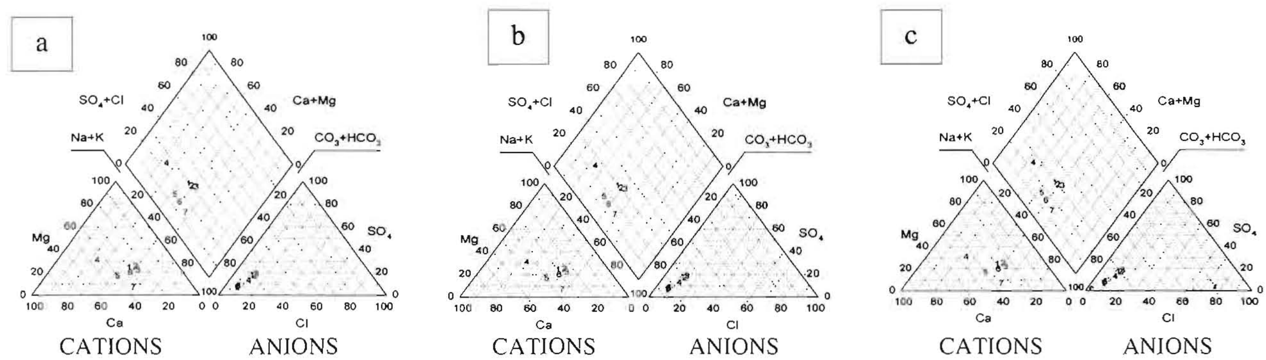
Hydrochemical Classifications

The diamond-shaped field of a Piper diagram (Fig. 11) consists of two equal triangular fields. Generally, water samples, which appear in the upper triangle, have secondary salinity properties, where sulfate and chloride exceed sodium and potassium. On the other hand, the other samples, which appear in the lower triangular, are considered to have primary alkalinity properties, where carbonates and bicarbonates exceed calcium and magnesium.

In the study area the data of the chemical analysis of water samples showed that it is presented close to each other and couldn't be distinguished into groups, indicating that the water is in good connection and having close relation. It is clear that the sodium ions represent the dominating cations, while bicarbonate ions are the dominating anions. On the other hand, the majority of the water samples are sodium-bicarbonate facies.

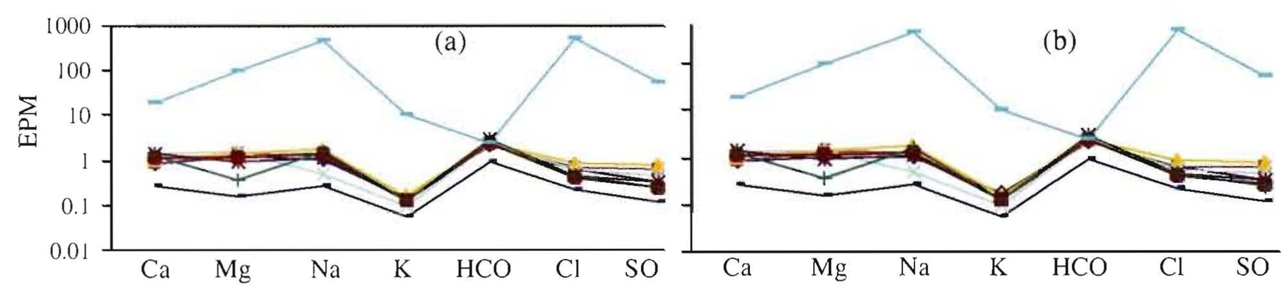
The results of the analysis are also plotted on the Schoeller diagram (Fig. 12) which is a linear diagram based on a system developed in part by the French investigator Schoeller (1962). A line representing analyses may be drawn on this diagram by connecting points representing gravimeteric concentrations of ions. Concentration values of data on a diagram of this type may be helpful in comparing analyses for major ions especially for water samples of high salinity.

Piper diagram .. Demo of GWW software



1 N-1, 2 N-2, 3 N-3, 4 N-4, 5 N-5, 6 N-6, 7 N-7

Fig. 11: Piper-Trilinear diagram for classification of the water samples in the years 1999 (a), 2000 (b) and 2001 (c) in the studied area.



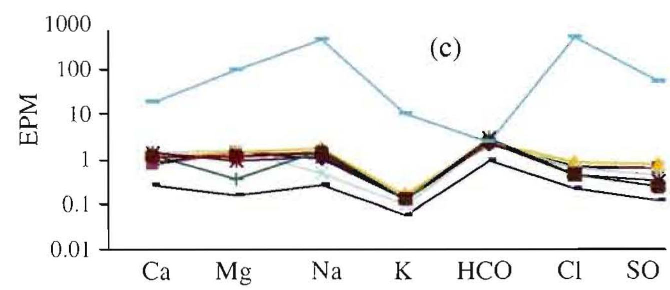


Fig. 12: Schoeller-semi-logarithmic nomogram for the water samples representation in the years 1999 (a), 2000 (b) and 2001 (c) in the Abu-Simbel area.

In this diagram (Fig. 12) it is clear that

$Na^{+} > Ca^{++} > Mg^{++}$ and HCO^{3} - > SO^{4}— > Cl^{-}

in all water samples. The parallelism observed between the zigzag lines refers to the closeness in the ionic ratio, which in turn ensures the strong relationship between the water samples in the studied area.

Water Quality

The quality of water, as determined by its chemical and biological constituents, its sediment content, and also its temperature, is one of the important factors in determining its suitability for a particular use. In the present study, the chemical constituents of water determine the evaluation of the water quality.

Water Quality for Drinking and Domestic Purposes

In general, water for drinking and domestic uses should be colorless, free of turbidity, excessive amount of dissolved mineral matter and unpleasant odor or taste. The standards of quality cannot be met in many places. Climate, weight and age of persons, individual eating, and drinking habits are important factors that modify the health requirements. Generally, for water of good quality (potable), the total dissolved solids shouldn't exceed 500ppm.

According to the international standards set for drinking water suggested by the World Health Organization (WHO, 1973 & 1984) the water quality in the investigated area, can be classified as an excellent water (TDS < 500ppm) for drinking, domestic, livestock and poultry uses.

The surveyed area represents one of the most important suitable locations for a tourism project. Accordingly, extensive needs for the water as a supplement for domestic use attracted more attention.

Relative Proportion of Sodium to Other Cations

Wilocx (1948) suggested the definition of the percentage of Na^{+} relative to the percentage of common cations in the following equation:

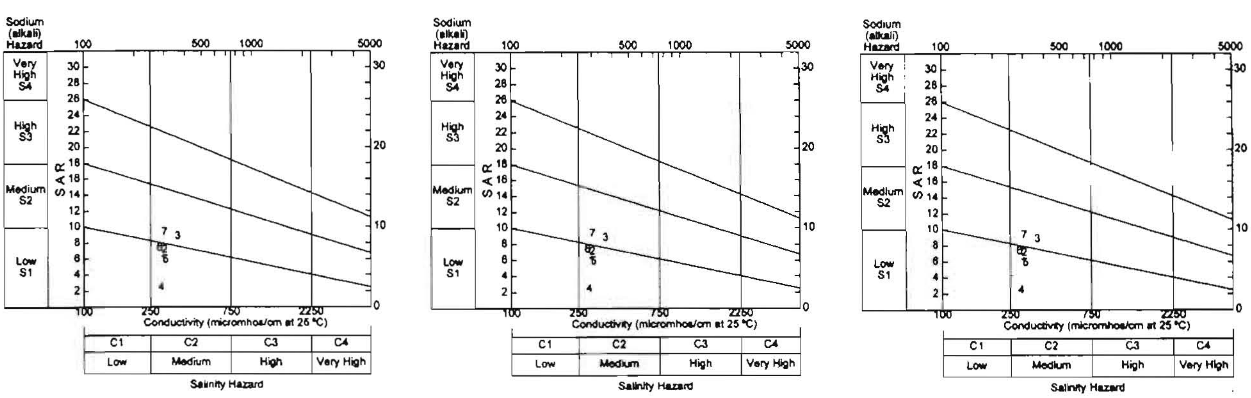
$$Na^{+}\% = \frac{Na^{+} + K^{+}}{Ca^{++} + Mg^{++} + Na^{+} + K^{+}} \times 100$$

The U.S. salinity laboratory staff (1954) had used a special nomogram for evaluation of the water for irrigation purposes. According to this diagram (Fig.13), the water is distinguished into four classes C1, C2, C3 and C4 which denote the electrical conductance and S1, S2, S3 and S4 which denote sodium adsorption ration (SAR). Generally, irrigation water with low SAR is much more desirable. The sodium adsorption ratio is calculated according to the following equation:

$$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{++} + Mg^{++}}{2}}} \text{ epm}$$

Where Na^{+}, Ca^{2+} and Mg^{2+} are in meq/L

Wilcox diagram .. Demo of GWW software



1 N-1, 2 N-2, 3 N-3, 4 N-4, 5 N-5, 6 N-6, 7 N-7

Fig. 13: Water quality evaluation according to U.S. salinity laboratory staff diagram (1954) in the years 1999 (a), 2000 (b) and 2001 (c) in the Abu-Simbel area.

The U.S. salinity laboratory staff diagram depends on the two factors of sodium and salinity hazards. Regarding the sodium hazard, four classes were distinguished:

a. S1: Low sodium water can be used for irrigation of almost all soils.

b. S2: Medium sodium water represents an appreciable sodium hazard in fine textured soils having high cation exchange capacity.

c. ·S3: High sodium water may produce harmful levels of exchangeable sodium in most soils.

d. S4: Very high sodium water is generally unsatisfactory for irrigation purposes.

Regarding the salinity hazard, four classes were also distinguished:

a. C1: Low salinity water can be used for irrigation of most crops in most soil, some leaching is required, but this occurs under normal irrigation practices.

b. C2: Medium salinity can be used if a moderate amount of leaching occurs.

c. C3: High salinity water content can be used in soil with restricted drainage, but special management for salinity control may be required and tolerant plants should be selected.

d. C4: Very high salinity water isn't suitable for irrigation under ordinary conditions, but may used, occasionally, under special conditions.

According to this classification most of water samples in the area are excellent (2, 4, 5 and 6) for irrigation purposes, some others are good (1 and 3) for irrigation.

Conclusions

The results obtained from the correlation and integration of the present geoelectric and hydrochemical studies, together with information available from geology and hydrogeology in the Abu Simbel part of southern Egypt allow the evaluation of the subsurface geologic conditions throughout the area which are useful for their groundwater potential and for civil engineering purposes. The conclusions obtained can be summarized as:

1. Very low conductive sediments (< 50 Ohm.m) at very shallow depths may represent clays and/or silts, which must be taken into account for engineering purposes.

2. A water-bearing zone of resistivity (50 to 500 Ohm.m) is lying at shallow depth with a maximum thickness of 24m.

3. A high resistivity geoelectric layer (Fourth layer) (>1000 to 10000 Ohm.m) begins from the ground surface to maximum depth 49m and maximum thickness 96m. It may correspond to massive iron rock, which is an obstacle to the growing of bushes in farming land especially at locations where it is near the surface in Abu-Simbel.

4. A deep geoelectric layer is characterized by extremely high resistivities (>10000 Ohm.m.), representing a deeper dry zone in the whole area. Materials of that dry zone may represent hard rocks (Nubia Sandstone and/or Basement rocks).

5. Many lithologic contacts (e.g. faults or abrupt changes in sedimentary facies) can also be detected. These contacts have not affected the surface zone which is in contact with building footings.

6. The hydrochemical analysis of collected water samples in the years 1999, 2000 and 2001 respectively at different locations around Abu-Simbel Town illustrated that the measured values of TDS, major anions and cations and trace elements are nearly the same. These values increase only at locations near the denser population comities.

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