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CONTRIBUTIONS TO THE HYDROGEOELECTRICAL AND HYDROGEOCHEMICAL CHARACTERISTICS OF THE MIOCENE AND FRACTURED BASEMENT AQUIFERS AT HALAIB, SOUTH-EASTERN DESERT OF EGYPT

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إضافة لخصائص الهيدروجيوكهربية والهيدروجيوكيميائية لخزانات المياه الجوفية فى صخور الميوسين والقاعدة المتشققة بمنطقة حلايب بجنوب الصحراء الشرقية.

الخلاصــة: يوضح العمل الحالى ولأول مرة الخصائص الهيدروجيوكهربية والهيدروجيوكيميائية للمياه الجوفية لكل من خزانى الميوسين وصخور القاعدة المتشققة بوادى إيكوان والمناطق المجاورة له. ويمثل هذا البحث جزءاً من الأعمال الحقلية المستفيضة التى تم تخطيطها وتنفيذها بواسطة الهيئة العامة لمشروعات التعمير والتنمية الزراعية منذ عام ١٩٩٤. وتهدف الدراسة إلى تقييم إمكانيات المياه الجوفية لمنطقة حلايب . أبو رماد . شلاتين بهدف التنمية المتكاملة لها ، وقد أجريت بالمنطقة ثمانى جسات جيوكهربية عمودية مثلت نتائجها فى قطاعات هيدروجيوكهربية حيث أظهرت الدراسة وجود خزانين هما خزان الميوسين وخزان صخور القاعدة المتشققة وسبعة صدوع تحتسطحية حصرت فيما بينها ثلاثة صدوع بارزة وثلاثة صدوع خسف. وقد تم جمع عينات مياه من الآبار (أربع آبار) وتحليلها كيميائياً وأظهر التحليل لبئر أيكون –١ أن مياهه تحوى كلوريد صوديوم من أصل مطيرى واستقر بأعماق ضحلة، بينما ترجع المياه فى الآبار الأخرى إلى أصل مطيرى سطحي.

ABSTACT: *The present work throws light, for the first time, on the hydrogeoelectrical and hydrogeochemical characteristics of the groundwater encountered in both of the Miocene and the fractured Basement aquifers, located at wadi Ei Kwan and its vicinities. This work represents a part of the extensive field program, that was planned and executed by GARPAD, since 1994.The objective of the work was to achieve an integrated development for the area of Halaib-Abu-Ramad-Shalatein on an agricultural basis, hence the groundwater potentiality should be investigated. The present area is very close to the Egyptian-Sudaneese borders. Four hand-dug wells (Birs) exist in this locality. Eight vertical Electrical Soundings (VESes) are carried-out, using the Schlumberger Four Symmetrical Electrodes. These VESes are interpreted by different methods. Hydrogeoelectrical cross-sections were constructed. Four geoelectrical layers were encountered in VESes 110, 111,112,113, 115 and 116, while five ones are encountered in both VESes 109 and 114.This work revealed the existence of two aquifers. The first one is the Miocene aquifer, while the second is the fractured Basement aquifer. Seven concealed faults are located. They constitute three horsts and three grabens. Water samples were collected from the Birs and chemically analyzed. The water type is sodium chloride and the origin is shallow meteoric for Ei Kwan 1,while it is of meteoric origin for the rest of the Birs.*

INTRODUCTION

The area of study lies between longs. 36° 36′ and 36° 41′ E, and lats. 22° 00′ and 22° 08′ N (Fig. 1). Four hand-dug wells (Birs) exist. These Birs are: Frukit 1,Frukit 2, Sarari Ei Kwan 1, and Sarari Ei Kwan 2. The Political borders between Egypt and Sudan lies at very few kilometers from them. The natives suffer from the lack of water that should satisfy their needs. They are complaining from the bad quality of water, especially during summer times. The Schlumberger Four Symmetrical Electrodes Configuration was used to conduct eight VESes in the field. Fig. (1) shows the locations of the observed VESes.

The methodology and the bases of the quantitative interpretation of VESes were discussed by many authors; among them, Koefoed (1965 and 1979), Kunetz (1968), Kunetz and Rocroi (1970), Bhattacharya and Patra (1968), Gosh (1971), Zohdy, et al, 1974. The Pylaev Catalogue (1948) was initially used for the quantitative followed by interpretation of the present observed VESes, then then followed by the software of Resist (Van Der Velpen, 1988) to get the final interpretation. Water samples are collected from the existing Birs and chemically analyzed to compute the hydrogeochemical parameters.

GEOLOGICAL SETTINGS

There are many hydrographic basins in and near-by the area of study. The most important of them are the following wadis: Ei Kwan, Aklahook, Hero, Shallal, Olia, Akhook and Mirkwan. The first two wadis lie in the area of study. These wadis drain their seasonal surface water into Red Sea. They are structurally built and controlled.

According to the geological map of the area of study (CONOCO, 1987) (Fig.2), the exposed geological units are as follows:

1- Quaternary units: These units are Sabkha, Qb, Wadi deposits, Qw, and undifferentiated Quaternary deposits, Q.
2- Tertiary: It is Miocene, undifferentiated, Tm.
3- Tertiary volcanics, Vb, and basement rocks

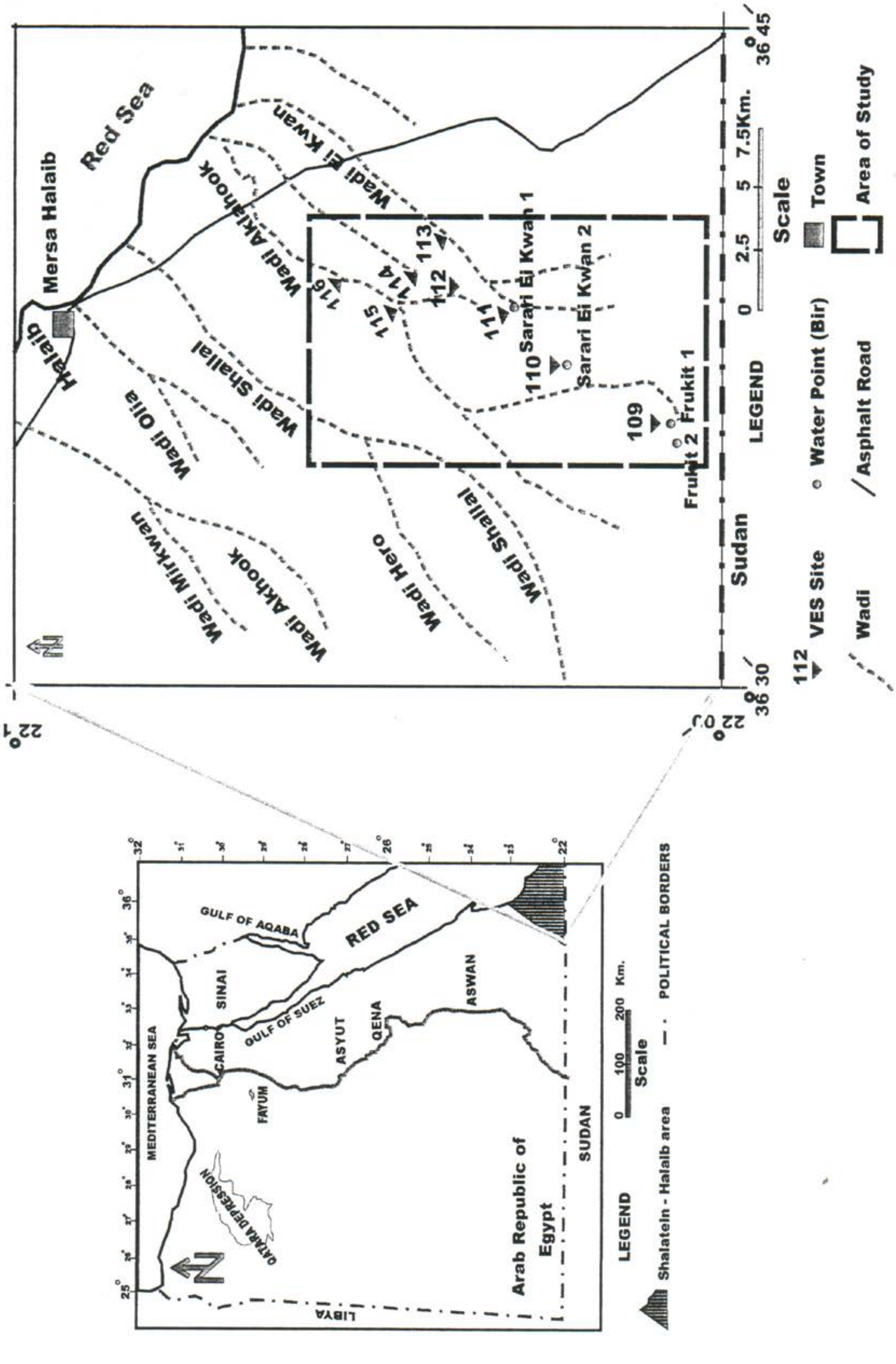

Fig.(1)Location Map and the Hydrographic System of the Area of Study

The Tertiary Miocene rocks are exposed in the area at many scattered locations. This geological unit is concentrated near Halaib town and also at both wadis of Ei Kwan and Aklahook, that are located in the area of study, near-by the exposed basement rocks.

The most dominant basement rocks in the area are the g β rocks, which consist of chalk-alkaline, weakly recognized granitic rocks. This goes well with both maps of structural elements (Fig.10) and fracture intensity contour map (Fig.17) constructed for this area by Elewa. (2000). This shows, that these rocks are less affected by deformation, and so they are poor in groundwater resources. The present area is dissected by many faults with different trends; the most frequent of them are the NE and NW ones. According to EGSMA (1987 a, b) the area that lies between longs.29^o and 33^o E is related structurally to the Red Sea and south Western Desert regions. The tensional stresses led to a great number of faults of different trends. Moreover, vertical and diagonal uplifting of the basement rocks let to generate horsts and grabens of various sizes and displacements. From the above discussion, the only possible aquifers in this area are the Miocene and the fractured basement ones, as the Quaternary deposits are very thin. As the present area lies between Red Sea and the area mentioned above, the fore – mentioned geological structures, are highly expected.

RESULTS AND DISCUSSION

Eight VESes are conducted in the area. Three out of them were observed near to three Birs. These Birs are: Frukit 1(VES 109), Ei Kwan 2(VES 110), and Ei Kwan 1(VES 111). The rest are located along wadi Ei Kwan (Fig.1). The observed measurements are used to construct the psuedo sections, while the interpreted values of these VESes (Figs.3 and 4) were used in constructing two hydrogeoelectrical cross- sections.

Qualitative Interpretation

This kind of interpretation is expressed in constructing the psuedo-geoelectric sections A – A$^/$ and B – B$^/$ (Fig.5). The first one is oriented NE, while the other trends NW-SE. Both sections have the same following description:

There are high resistive geoelectric layers at the shallow depths. This is followed by a relatively huge geoelectric layer that is characterized by its low apparent resistivity. It is followed by geoelectric layers that have high apparent resistivity values.

Quantitative Interpretation

The quantitative interpretation of the measured VESes (Figs.3 and 4) revealed that there are five geoelectric layers for these VESes 109 and 114, while there are four geoelectric layers for VESes 110, 111, 112, 113,115,and 116. Two hydrogeoelectrical cross-sections, C – C$^/$ and D – D$^/$, were constructed (Figs.5 and 6). The first one is oriented NE, while the other is NW.

Description of the Hydrogeoelectrical Cross-Section C – C$^/$:

This cross-section comprises the VESes 109, 110, 111, 112, 114, and 116. It runs for about 17 kilometers. The very shallow geoelectric layers represent wadi deposits. These layers are comprised in one main geoelectric layer that has true resistivity values between 28.8 and 262.6-ohm.m. The maximum thickness of the layer is 9.9 m. at VES 114. These wadi deposits are followed by the Miocene rocks at both sites of VESes 109 and 116. The upper part of this geoelectric layer is water bearing. The true resistivity of this part varies between 19.9. and 32.9 ohmm. It has a true thickness of 18.1 m. at VES 109 (Frukit 1) and 30.2 m. at VES 116.The deeper parts of these rocks generally, have higher resistivity values.

At the middle part of this cross-section, the wadi deposits are followed by two geoelectrical layers. The first one represents the fractured basement aquifer, which is water bearing. Its true resistivity values vary between 3.9 and 22-ohm .m. Its maximum thickness is 130.5 m. at VES 111. This water-bearing layer is followed by the basement rocks that have true resistivity value of ∞ ohm. m.

Concealed Geological Structures

Five concealed faults are encountered in this cross-section. Most probably they trend N-S and NW-SE. These tensional stresses had been accompanied by vertical and diagonal uplifting of the basement rocks that led to the generation of a huge horst that is located between F1 and F2. This major horst was later on subjected to another forces that let to generate two minor horsts and two minor grabens. Both of F3 and F4 have the same throw of 90 m., while that of F5 is 30m.

Description of the Hydrogeoelectrical Cross-Section D – D$^/$:

There are only three VESes encountered in this section. These VESes are 115, 114, and 113.It runs NW – SE for a distance of about 5 Km. The very shallow geoelectric layers constitutes the wadi deposits. Their true resistivity values range between 28.8 and 148.6-ohm.m, with a maximum thickness of 9.9 m at VES 114 This is followed by the Miocene rocks at VES 113. The upper part of these rocks is water bearing. It has true resistivity value of 11.3ohm.m. and a thickness of 10.8m, then followed by non-water bearing Miocene rocks, with true resistivity value of 66-ohm.m. On the other hand, the wadi deposits are followed by the fractured basement rocks at VESes 114 and 115. These rocks are water bearing. Their true resistivities are 3.9 and 19.4 ohm.m respectively. The maximum thickness of this unit is 102.8m at VES 115. It is followed by the basement rocks that have true resistivity of ∞ ohm. m.

Concealed Geological Structures:

There is one major horst that was later divided into one minor horst and one minor graben. The major horst is located between veses 113 and 114, and between veses 115 and 116. Consequently, only two faults are delineated in this cross-section. They are f6 and f7. The fault f7 has a throw of 30m.

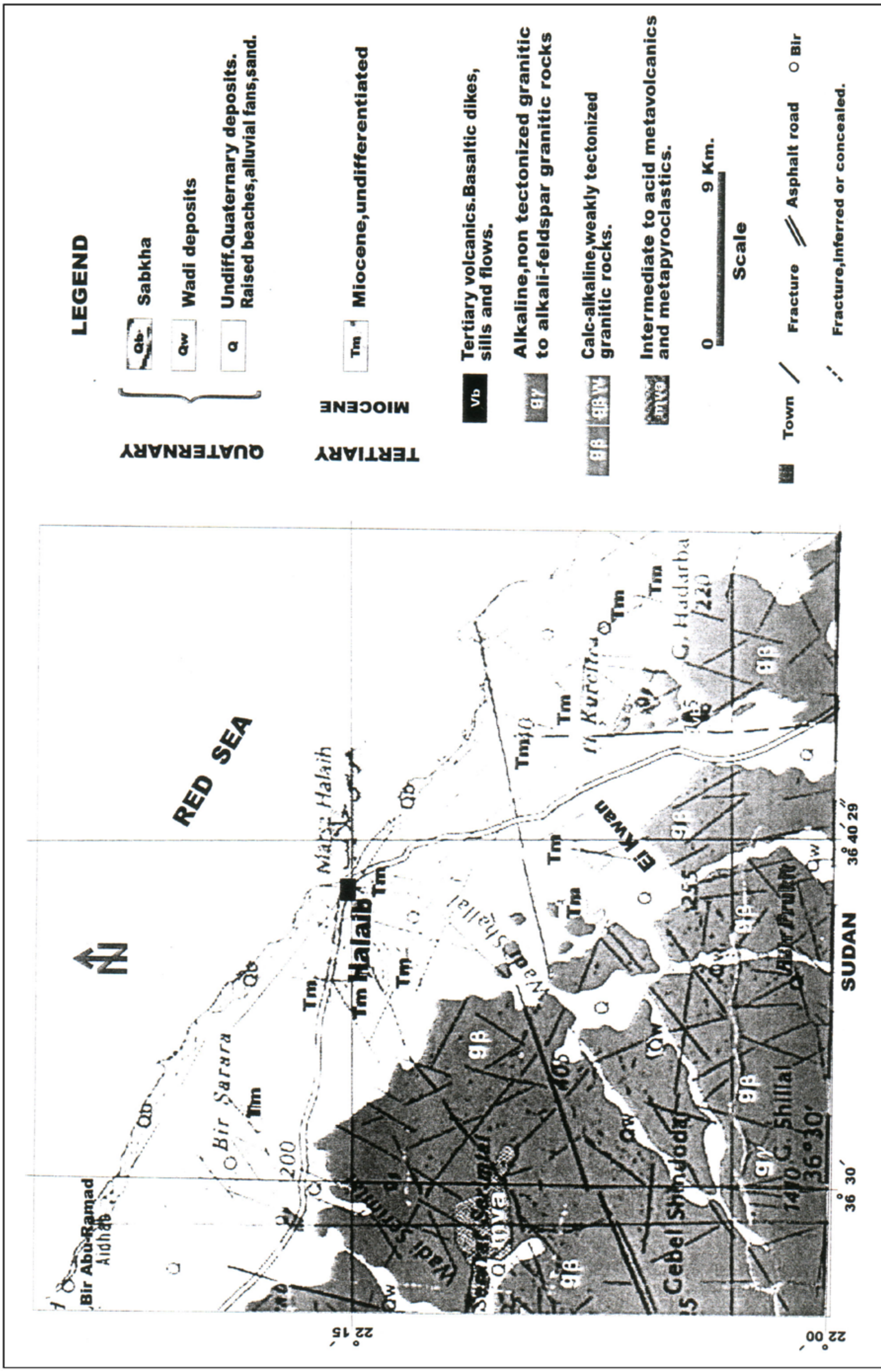

Fig. (2) Geological Map Of The Area Of Study
(After CONOCO, NF 36 NE BERNICE , 1987)

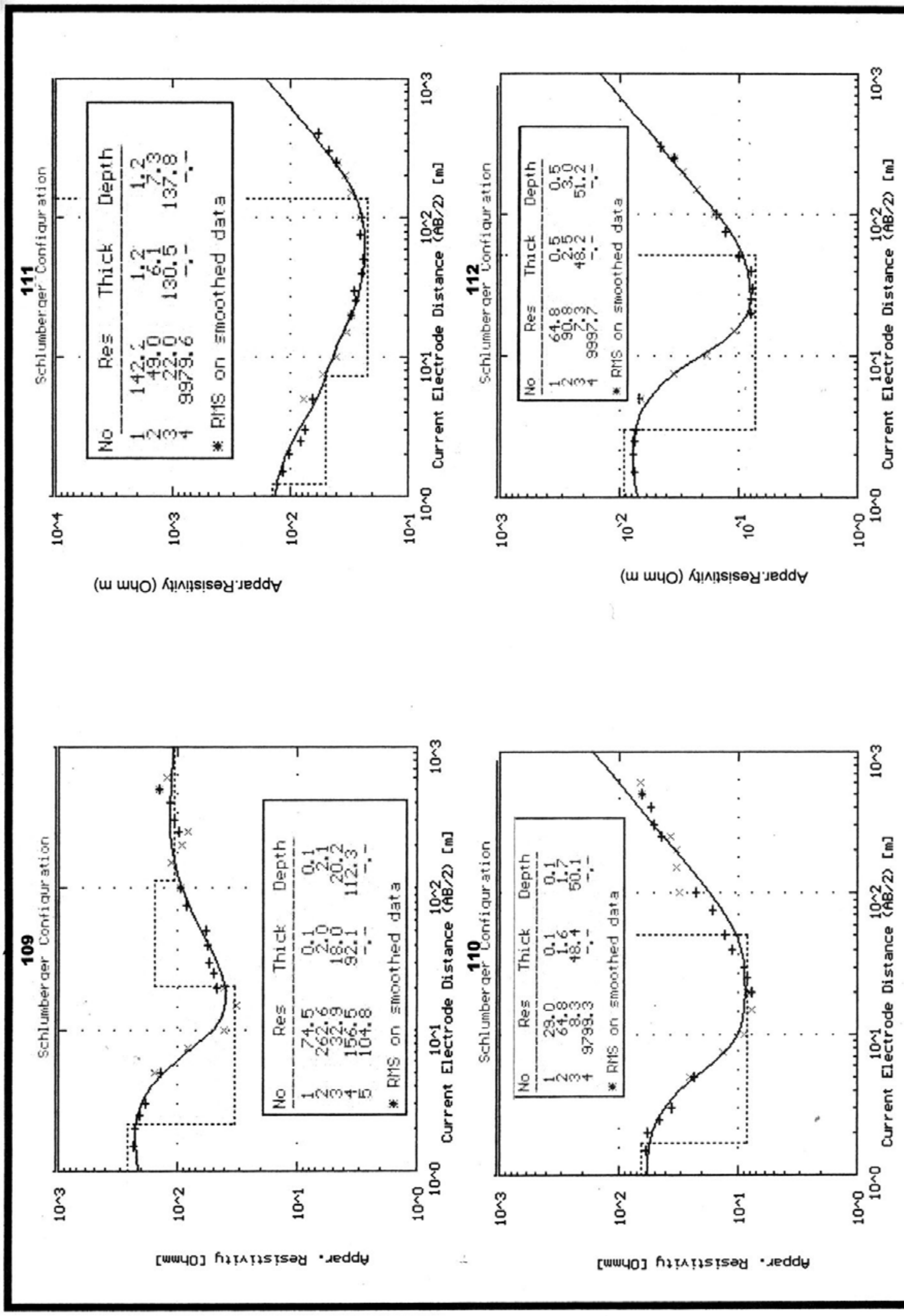

Fig. (3) VESes Conducted at the Area of Study

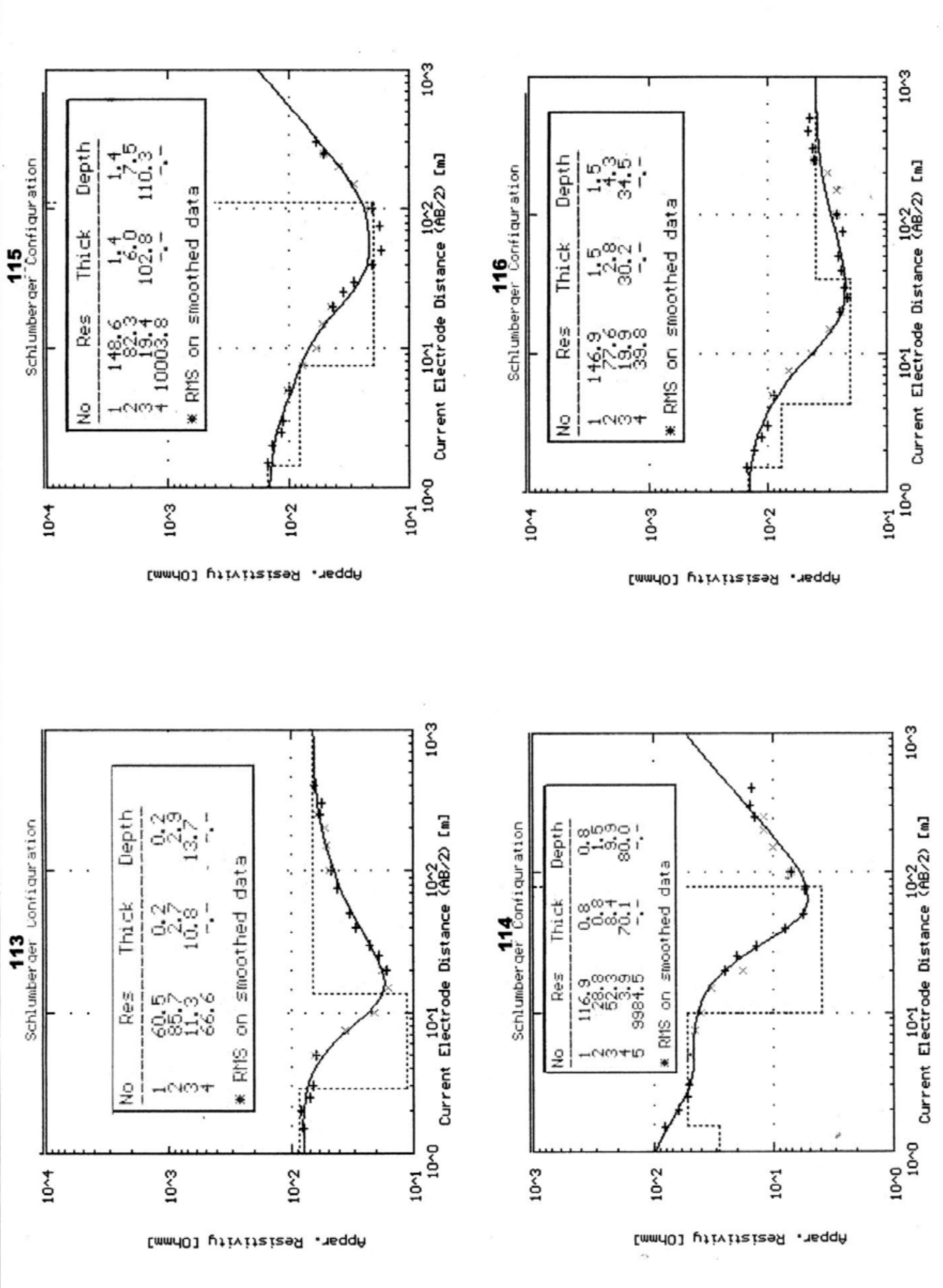

Fig.(4) VESes Conducted at the Area of Study

By comparing the final results of both cross-sections, C-C/ and D-D/, it is obvious that:

1- A fault should exist between VESes 115 and 116.

2- Both cross-sections are very similar in their content.

3- The area located between both wadis of Ei Kwan and Aklahook is subjected to the uparching of the basement rocks through the Miocene rocks, at the sites of VESes 110, 111, 112, 114, and 115 (Figs 1and 6).

The Hydrochemical Characteristics of the Groundwater

The hydrochemical characteristics of the groundwater of the fractured basement and Miocene aquifers in the area of study are defined through the results of chemical analyses of four water samples collected from the Birs, during Sept. 1997 and chemically analyzed by GARPAD (Tables 1 and 2). These water samples were collected from both aquifers. Samples from Birs Ei Kwan 1 and Ei Kwan 2 are of the fractured basement aquifer, while samples from Birs Frukit 1 and Frukit 2 are of the Miocene aquifer. For comparison, the groundwater of the Miocene aquifer located in the area of study is compared with the Miocene aquifer located outside the area of study by a water sample that was collected from Bir Abu- Ramad 2. Accordingly, the following characteristics are obtained:

1- The total salinity of the groundwater in the Miocene aquifer is 1360 ppm for Bir Frukit 1, 3798 ppm for Bir Frukit 2 and 14818 ppm for Bir Abu- Ramad 2 (Table 1).

2- The total salinity of the groundwater in the fractured basement aquifer varies from 1855 ppm (Bir Ei Kwan 1) to 3442 ppm (Bir Ei Kwan 2) (Table 1)

3- The pH value varies from 7.6 (Bir Frukit 2) to 8.3 (Bir Ei Kwan 1) (Table 1), reflecting an alkaline water. The pH value of water is controlled by the amount of dissolved CO_2, carbonates and bicarbonates concentrations.

5- For the groundwater Birs in the fractured basement and Miocene aquifers located at the area of study, the sequence of abundant ions indicates the presence of one anionic and two cationic order of abundance:-

$Na^+ > Ca^{++} > Mg^{++}$ / $Cl^- > SO_4^{--} > HCO_3^-$ (Birs Ei Kwan 1 and Abu- Ramad 2)

Na+ >Mg++ > Ca++ / Cl- > SO4 $^{--}$>HCO3$^-$ (Birs Ei Kwan 2, Frukit 1 and Frukit 2)

6- The ion sequence reflects sodium as major cation, and chloride is the major anion for all Birs, the chemical water type, is **sodium chloride** for both aquifers (Schoeller, 1995).

7- The combinations between cations and anions reflect the following four groups of salt assemblages in the groundwater of both aquifers: -

Group (1): (K+Na) Cl, Na_2SO_4, $NaHCO_3$, Ca $(HCO3)_2$, and Mg $(HCO3)_2$ (Bir Ei Kwan 1).

Group (2): (K+Na) Cl, Na_2SO_4, Ca $(HCO3)_2$, MgSO4, and Mg $(HCO3)_2$. (Bir Ei Kwan 2).

Group (3): (K+Na) Cl, $MgSO_4$, Ca $(HCO3)_2$, $CaSO_4$, and. Na_2SO_4 (Bir Frukit 1).

Group (4): (K+Na) Cl, MgSO4, $CaSO_4$, Ca $(HCO3)_2$ and Na_2SO_4. (Bir Frukit 2).

Group (5): (K+Na) Cl, $CaSO_4$, $MgCl_2$, $MgSO_4$, and Ca $(HCO3)_2$. (Bir Abu- Ramad 2).

It is clear that, the fractured basement groundwater in Bir Ei Kwan 1 is rich in Na_2SO_4, $NaHCO_3$ and Ca $(HCO3)_2$ salts, which reveal the **meteoric origin of groundwater,** while, in Bir Ei Kwan 2 and Birs Frukit 1 and Frukit 2 (Miocene aquifer) they are rich in Na_2SO_4 and Ca $(HCO3)_2$ salts, which reveal the **deep meteoric origin of groundwater**. The Miocene aquifer groundwater in Bir Abu- Ramad 2 is rich in MgCl2 salt, which reveal the **marine origin of groundwater**. This could be attributed to the fact that this Bir is very near to the sea shore.

8- Ovitchinikov (1955), demonstrated the significance of the hydrochemical parameters namely: rK^+/rCl^-; Na^+/K^+, rNa^+/rCl^-; rMg^{++}/rCl^-; rCa^{++}/rCl^- and $rSO4^{--}/rCl^-$ for comparison and investigation in the hydrogeochemical variations. The letter (r) expresses, that the relation is calculated in epm for those elements or components, which differ either in valency or in chemical affinity. If they are similar in both valency and chemical affinity, the relation is given in ppm. The values of these parameters in the normal sea water, which are taken as standard values for correlation, are 0.0181; 40, 0.08537; 0.1986; 0.0385 and 0.103, respectively.

The hydrochemical parameters for the groundwater birs in both aquifers are calculated (table 2). Only two hydrochemical parameters, namely Na^+/K^+ and rNa^+/rCl^- are discussed as follows:-

$NA^{\pm}/K^{\pm}$

The calculated values in the area of study are varying from 49.04 (Bir Frukit 1) to 456.43 (Bir Ei Kwan 2). It is more than the normal value of sea water (40). The increase in value is due to the increase of Na^+ content, which could be attributed to the leaching of the continental clay and shale deposits.

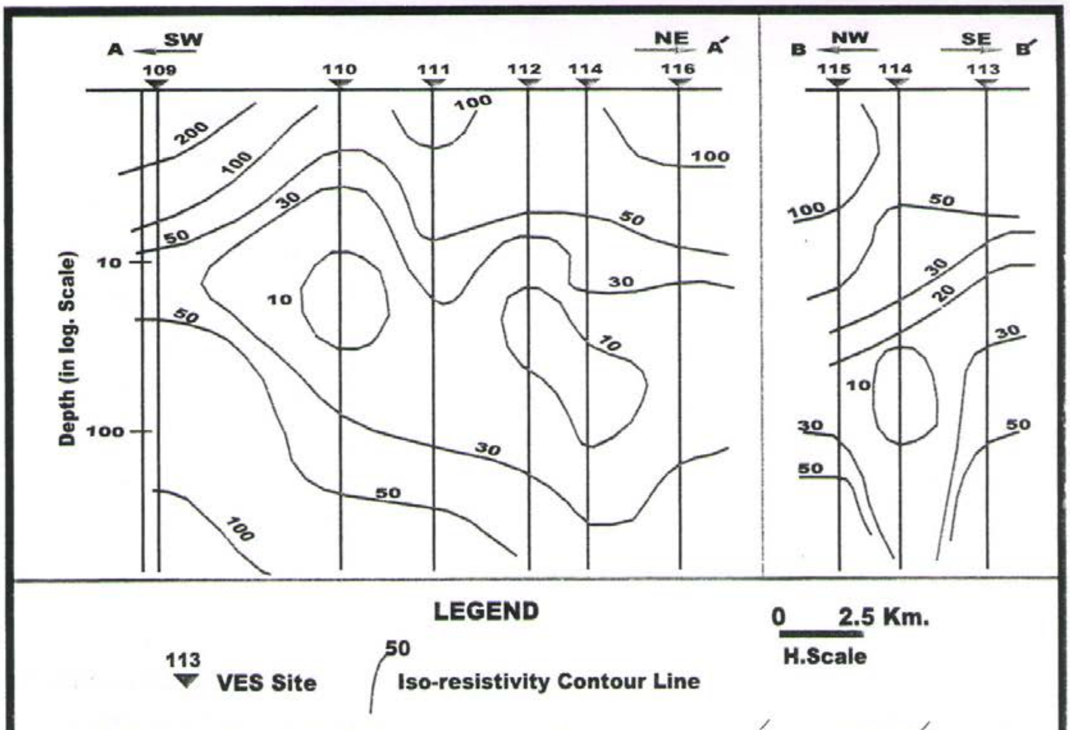

Fig.(5) Psuedo-Geoelectric Sections A - A' and B - B'

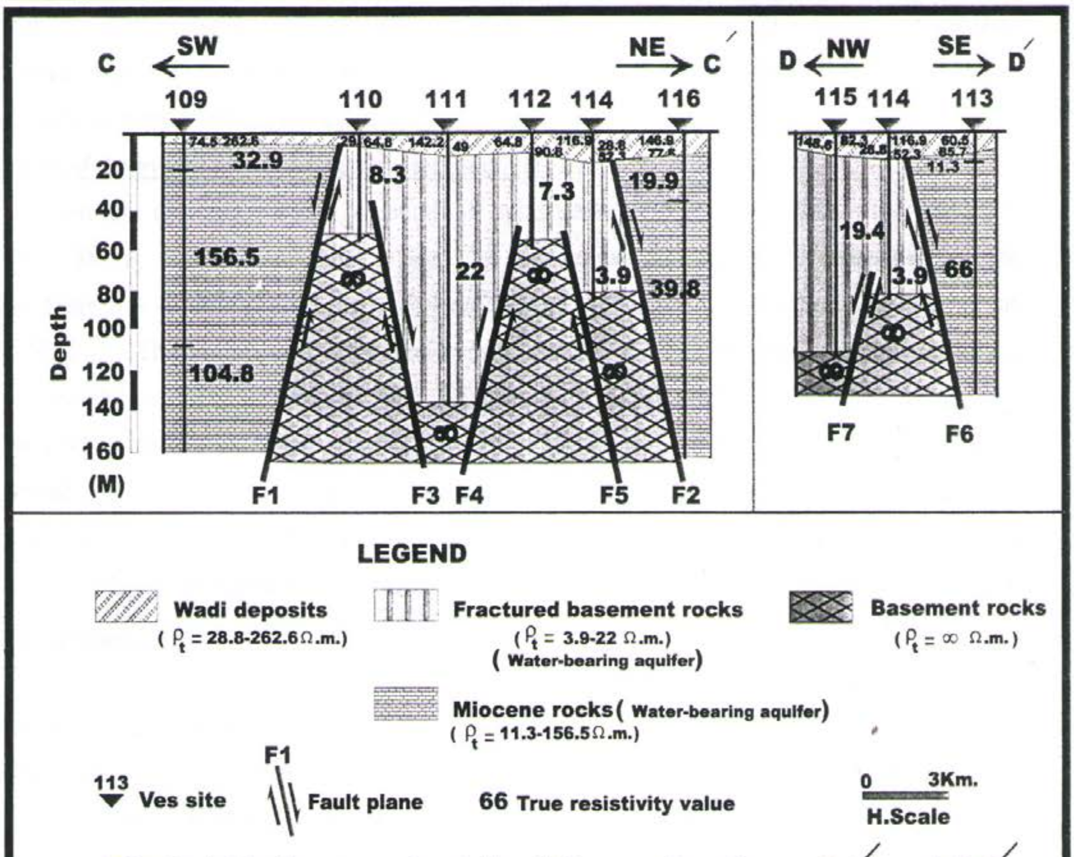

Fig.(6) Hydrogeoelectrical Cross-Sections C-C' and D-D'

Table (1) Chemical Analyses of Selected water Birs at and near the area of study

Well NO.	Unit	CATIONS				Total (epm)	Anions			Total (epm)	E.C. μ.mhos	T.D.S (ppm).	pH	S.A.R	R.S.C	Fe (mg/l)	General Formula
		K	Na	Ca	Mg		CL	SO4	HCO3								
Ei Kwan 1	ppm	2.5	700	38.4	11.6		580	500	480								CL 47 SO_4 30 HCO_3 23
	epm	0.06	30.5	1.92	0.95	33.38	16.4	10.4	7.872	34.63	3000	1855	8.3	25.44	5.01	2.50	------------------------------
	%	0.19	91.2	5.74	2.84		47.2	30	22.73								(Na+K) 91 Mg 3 Ca 6
Ei Kwan 2	ppm	2.41	1100	128	87.5		1350	850	485								CL 60 SO_4 28 HCO_3 12
	epm	0.06	47.9	6.39	7.19	61.49	38.1	17.7	7.954	63.70	4920	3442	7.75	18.36	-5.63	2.25	------------------------------
	%	0.1	77.8	10.4	11.7		59.8	27.8	12.49								(Na+K) 78 Mg 12 Ca 10
Frukit 1	ppm	5.2	250	122	80		390	420	245								CL 46 SO_4 37 HCO_3 17
	epm	0.13	10.9	6.09	6.58	23.67	11	8.74	4.018	23.75	2010	1360	8.2	4.32	-8.65	1.65	------------------------------
	%	0.56	45.9	25.7	27.8		46.3	36.8	16.92								(Na+K) 47 Mg 28 Ca 26
Frukit 2	ppm	3.5	730	180	190		1100	1160	60								CL 55 SO_4 43 HCO_3 2
	epm	0.09	31.8	8.98	15.6	56.44	31	24.1	0.984	56.13	5130	3798	7.6	9.05	-23.62	1.50	------------------------------
	%	0.16	56.3	15.9	27.7		55.3	43	1.753								(Na+K) 56 Mg 28 Ca 16
Abu-Ramad 2	ppm	12	2530	1010	480		4750	3150	40								CL 67 SO_4 33 HCO_3 0
	epm	0.31	110	50.4	39.5	200.22	134	65.5	0.656	200.13	15330	14818	7	16.42	-89.20	1.50	------------------------------
	%	0.15	55	25.2	19.7		66.9	32.7	0.328								(Na+K) 55 Mg 20 Ca 25

Fig. (7) Hydrochemical cross- section

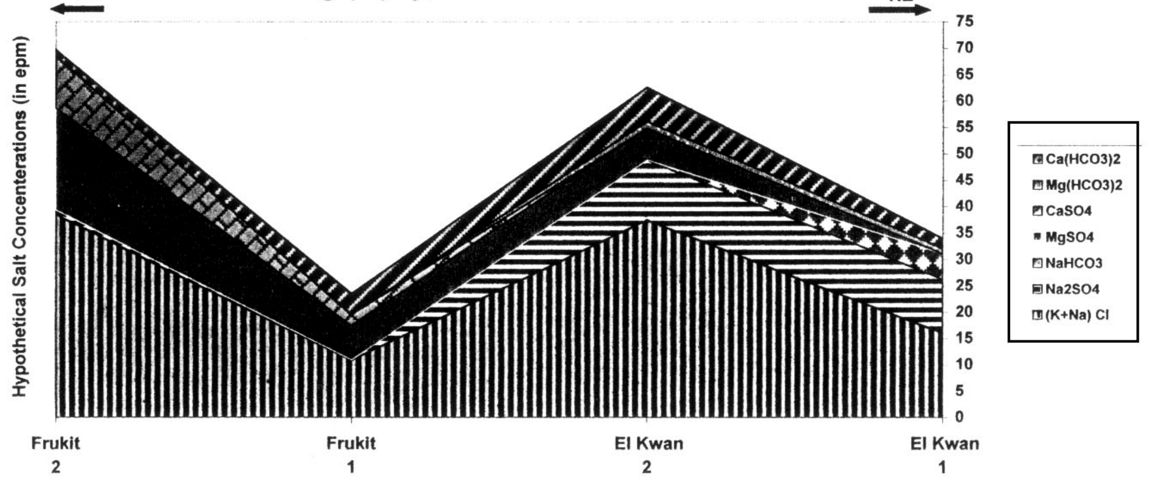

Table (2) Hypothetical Salt Combination and Hydrochemical Parameters of Selected water Birs at and near the area of study

Well NO.	Hypothetical Salt Combination										Hydrochemical Parameters						
	KCl	NaCl	Na2SO4	NaHCO3	MgCl2	MgSO4	Mg(HCO3)2	CaCl2	CaSO4	Ca(HCO3)2	rK^+/rcl^-	rNa^+/rcl^-	Na^+/K^+	rMg^{+2}/rcl^-	$rSO4^{-2}/rcl^-$	$(rcl^- - r(Na^+))/rCl^-$	$r(K^++Na^+)-rcl^-/rSO4^{-2}$
Ei Kwan 1	0.19	47.04	30.03	14.15	0	0.00	2.84	0	0	5.74	0.00	1.86	280.00	0.06	0.64	-0.86	1.47
Ei Kwan 2	0.10	59.66	18.16	0	0	9.60	2.10	0	0	10.39	0.00	1.26	456.43	0.19	0.46	-0.26	0.65
Frukit 1	0.56	45.94	0.00	0	0	27.78	0	0	9.00	16.92	0.01	0.99	48.08	0.60	0.79	0.01	0.01
Frukit 2	0.16	55.10	1.15	0	0	27.67	0	0	14.16	1.75	0.00	1.02	208.57	0.50	0.78	-0.02	0.03
Abu-Ramad 2	0.15	54.97	0.00	0	12	7.90	0	0	24.84	0.33	0.00	0.82	210.83	0.29	0.49	0.18	

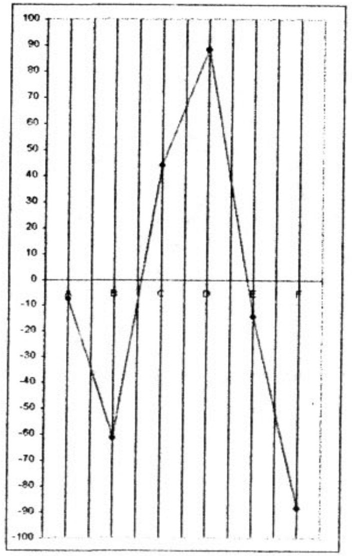

Fig. (8a) D' Amore Diagram for Bir El Kwan 1

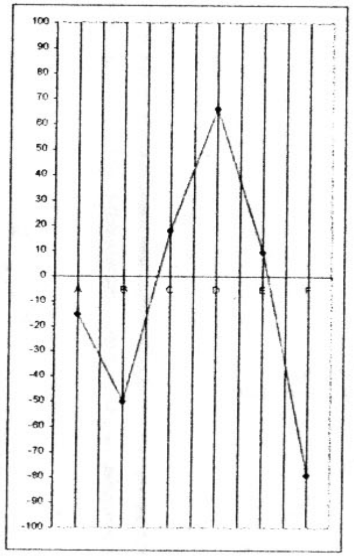

Fig. (8b) D' Amore Diagram for Bir El Kwan 2

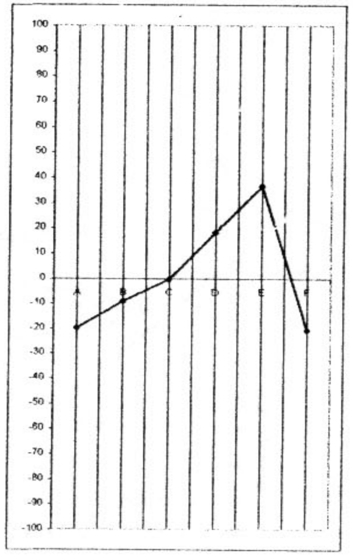

Fig. (8c) D' Amore Diagram for Bir Frukit 1

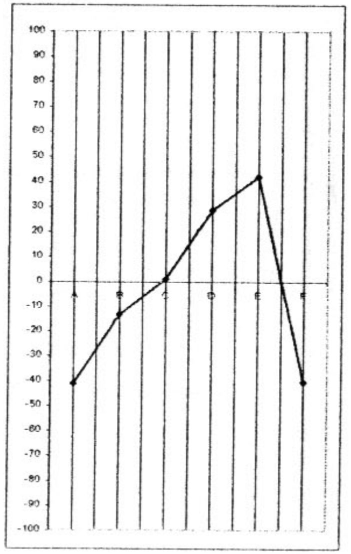

Fig. (8d) D' Amore Diagram for Bir Frukit 2

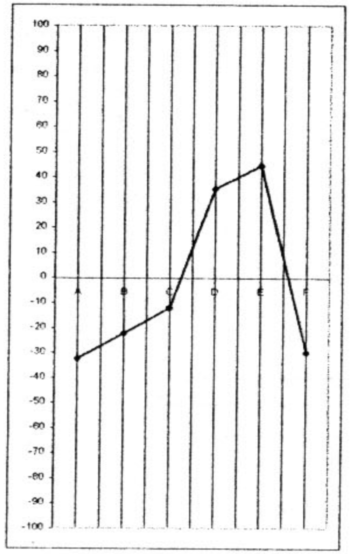

Fig. (8e) D' Amore Diagram for Bir Abu- Ramad 2

rNa^{+}/rCl^{-}

The calculated values are ranging between .082 (Bir Abu- Ramad 2) and 1.86 (Bir Ei Kwan 1), which are more than unity. The increase in value reflects an active leaching of Na salt by meteoric water during rainfall or due to flow of groundwater in the subsurface.

In order to compare between, the chemical compositions of groundwater of the fractured basement and Miocene aquifers in the area of study, one cross section is constructed (Fig. 7). It reflects the following results: -

1- The salts of (K+Na) Cl, Na_2SO_4 and $MgSO_4$ represent the main bulk of concentration in the groundwater of the both aquifers in the area of study with lateral variations.

2- A general increase of salts in the groundwater of the both aquifers generally is due south. While, the concentrations of Ca $(HCO_3)_2$ has an opposite direction of increase.

To differentiate between both aquifers hydrochemically, D' Amore's diagram (F. D' Amore's, et. al, 1983) was used (Figs. 8 a, b, c, d and e). It resulted that:-

i- The groundwater in Birs Ei Kwan 1 and Ei Kwan 2 **are from the basement rocks**.

ii- The groundwater in Birs Frukit 1, Frukit 2 and Abu- Ramad 2 **are from sandstone rocks.**

The hydrochemical classification of the groundwater of the fractured basement and Miocene aquifers in the area of study could be achieved by applying Piper's diagram (1944) (Fig. 9), and Sulin´s diagram (1946) (Fig. 10) that reveals the following results: -

1- The alkalis (Na + K) exceed the alkaline earth's (Ca + Mg).

2- The strong acids (Cl+ SO4) exceed the weak acids (CO3 + HCO3). This indicates that the groundwater of these aquifers has non-carbonated alkalies exceeding 50 %, and indicating secondary salinity properties.

3- The **Na_2SO4 salt**, type of **deep meteoric geneses**, ((rNa /rCl) > 1), ((rK + rNa - rCl) /rSO_4 < 1). (Table 2), reflect the hydrochemical composition of the water samples, which are collected from the Birs Ei Kwan 2, Frukit 1 and Frukit 2, lie in the upper triangle of the lower left square in the Sulin´s diagram. While, The **Na_2SO_4 and $NaHCO_3$ salts**, type of **meteoric geneses**, ((rNa /rCl) > 1), ((rK + rNa - rCl) /rSO_4 >1) (Table 2), reflect the hydrochemical composition of the water samples, which are collected from Bir Ei Kwan 1, lie in the lower triangle of the lower left square.

4- The water samples, which are collected from the Bir Abu- Ramad 2, lie in the lower triangle of the upper right square, this means **$MgCl_2$** type of **marine origin** ((rNa /rCl) < 1), (rCl -(rK + rNa) /rMg < 1) (Table 2). The salt combination that have been discussed before are similar to the normal composition of sea and ocean water (Sulin´s, 1946).

Quality Evaluation

The groundwater of the fractured basement and Miocene aquifers in the area of study is evaluated for drinking, domestic, livestock and irrigation purposes by using the following methods: -

1- According to the International Standards by World Health Organization (WHO, 1971), the groundwater has two classes of quality evaluation for drinking, as follows:

a- Permissible water (T.D.S.500 – 1500 ppm) is detected in Bir Frukit 1

b- Unsuitable water for drinking (T.D.S.> 1500 ppm) includes the groundwater of the other Birs.

2- According to the American National Academy of Science and National Academy of Engineering (1972), the groundwater has three classes of quality evaluation for livestock and poultry purposes as follows :

i- The groundwater for Birs Ei Kwan 1 and Frukit 1 are very satisfactory water (T.D.S.1000 - 3000 ppm)

ii- The groundwater for Birs Ei Kwan 2 and Frukit 2 are satisfactory water (T.D.S.3000 – 5000 ppm) but may cause temporary diarrhea or be refused at the first by animals that are not accustomed to it.

iii- The groundwater for Bir Abu- Ramad 2 is risky with this highly saline water (T.D.S.> 10000 ppm). It cannot be recommended for use under any condition.

3- The groundwater in the area of study has three classes of quality evaluation for irrigation purposes regarding the U.S. Salinity Laboratory Staff's Classification (1954), which is based on the relationship between the water salinity and sodium adsorption ratio (S.A.R.) as shown in Fig. (11):

a- C_3S_2 class: The groundwater of Bir Frukit 1.

b- C_4S_4 class: Water of this class can't be used for irrigation (The groundwater of Birs Ei Kwan 1 and Ei Kwan 2).

c- The groundwater of Birs Frukit 2 and Abu- Ramad 2 are located outside the figure.

CONCLUSIONS

1- The groundwater in the study area is available from the fractured basement and Miocene aquifers.

2- There are seven concealed faults and one expected fault. These faults are constituting two major horsts.

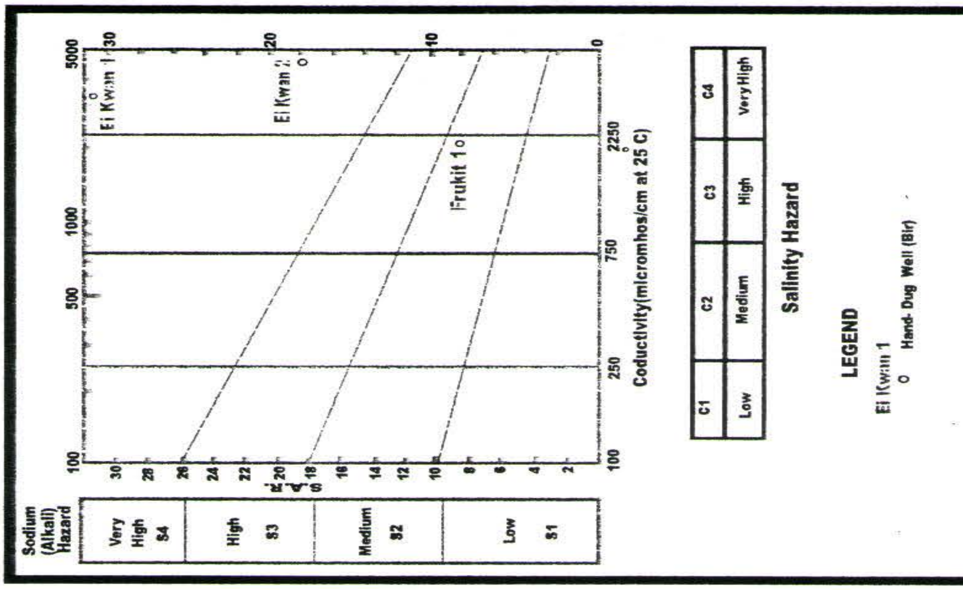

Fig.(11)Diagram for The Classification of Groundwater for Irrigation (ACCORDING TO U.S. SALINITY LABORATORY STAFF,1954)

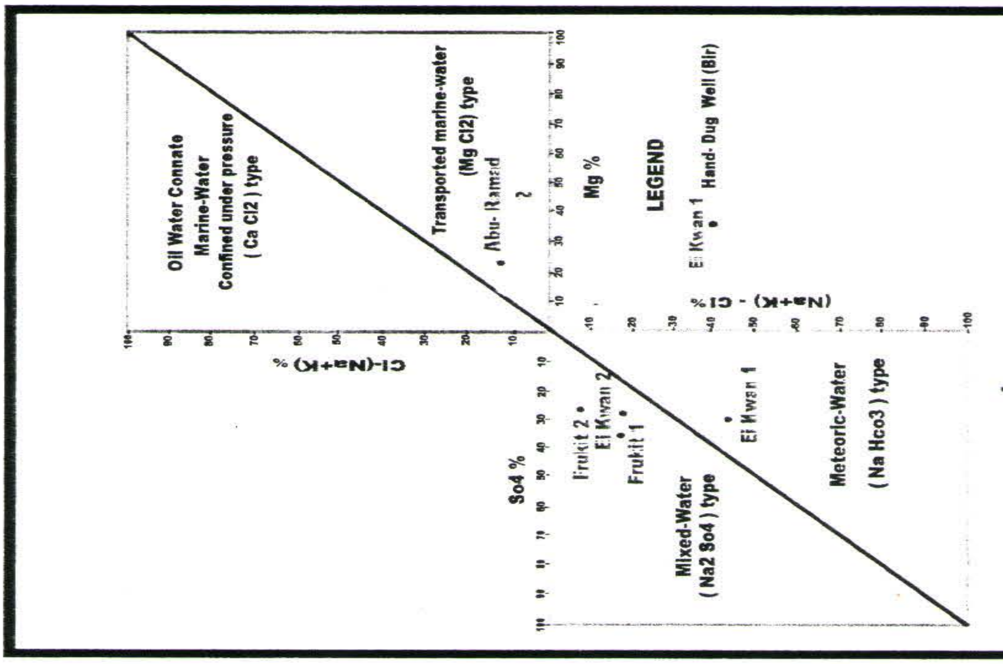

Fig.(10) Sulin's Graph for Water Classification, for the Area of Study

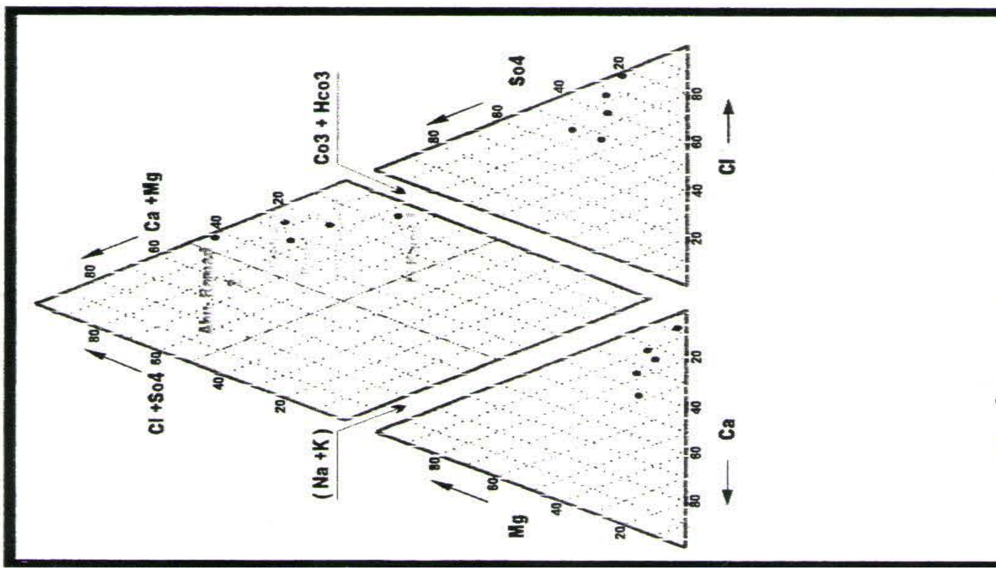

Fig.(9) Piper's Diagram For Water Classification, for the Area of Study

3- The Miocene rocks have true resistivity values that range between 11.3- 156.5 ohm.m.

4- The fractured basement rocks have true resistivity values that range between 3.9- 22 ohm.m.

5- The total salinity ranges between 1360 ppm and 3798 ppm. The distribution of the total dissolved salts reflects a general increase of salinity due south for each aquifer.

6- The sodium represents the dominant major cation and chloride represents the dominant major anion and the water has a sodium chloride type.

7- The groundwater of Bir Ei Kwan 1 is of **meteoric origin**, while that of the Birs Ei Kwan 2, Frukit 1 and Frukit 2 are of deep **meteoric origin**. The groundwater of Bir Abu- Ramad 2 is of **deep marine origin**. The water has a secondary salinity.

8- The groundwater of the both aquifers is permissible to unsuitable for drinking before treatment. It is very satisfactory to satisfactory for all kinds of livestock and poultry except Bir Abu- Ramad 2.

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