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Hydrogeophysical Exploration for Groundwater Potentials in Titin Basin, South Jordan

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Abstract

Titin basin locates to the most southern part of Jordan in an arid region with annual precipitation amounts less than 37 mm and more than 90% rates of evaporation. Analyses on historical records of rainfall show that some thunder storms frequently take place in the one decade and can form good recharge opportunities for the aquifer. Many side wadis with good catchment areas drain their water after these storms to the basin. Qualitative interpretation of gravity measurements revealed that the grabin of the basin is filled with more than 70 m thick clastic deposits from granite origin, where the southern part of the basin was found to show deeper basement, and accordingly good possibilities for groundwater reservoir. Vertical geoelectrical profiles conducted in the basin in the promising areas defined depending on the interpretation of the gravity measurements revealed to the southern part of the basin a water bearing zone with a thickness of 20 meters at depths of about 60 meters.

The quality of the groundwater found in some shallow perched aquifers in the area was found to be of fresh type with TDS less than 620 mg/l.

The defined water amounts and quantity may meet local and small scale demands of the dwellers for their livestock husbandry activities, and can develop the Titin small community economically.

Key words: Hydrogeophysics, water quality, Titin basin, arid lands.

1 Introduction

Jordan is considered as one of the most ten poor countries respecting water resources on the world water poverty scale (Lawrence, 2002). This is attributed to the low rain amounts which were averaged as less than 200 mm/year, and to the elevated

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evaporation rates because of its location in an arid to semi arid zone. On the other, hand pollution processes resulted from human and industrial activities stress the water equation in the country between available and demanded (Salameh, 1996).

Going to the most southern part of Jordan nearer to the boarders of Saudi Arabia, rain amounts are more less than the mentioned value and range around 37mm/year, while actual evaporation rates are over 90% (Al Farajat 2002).

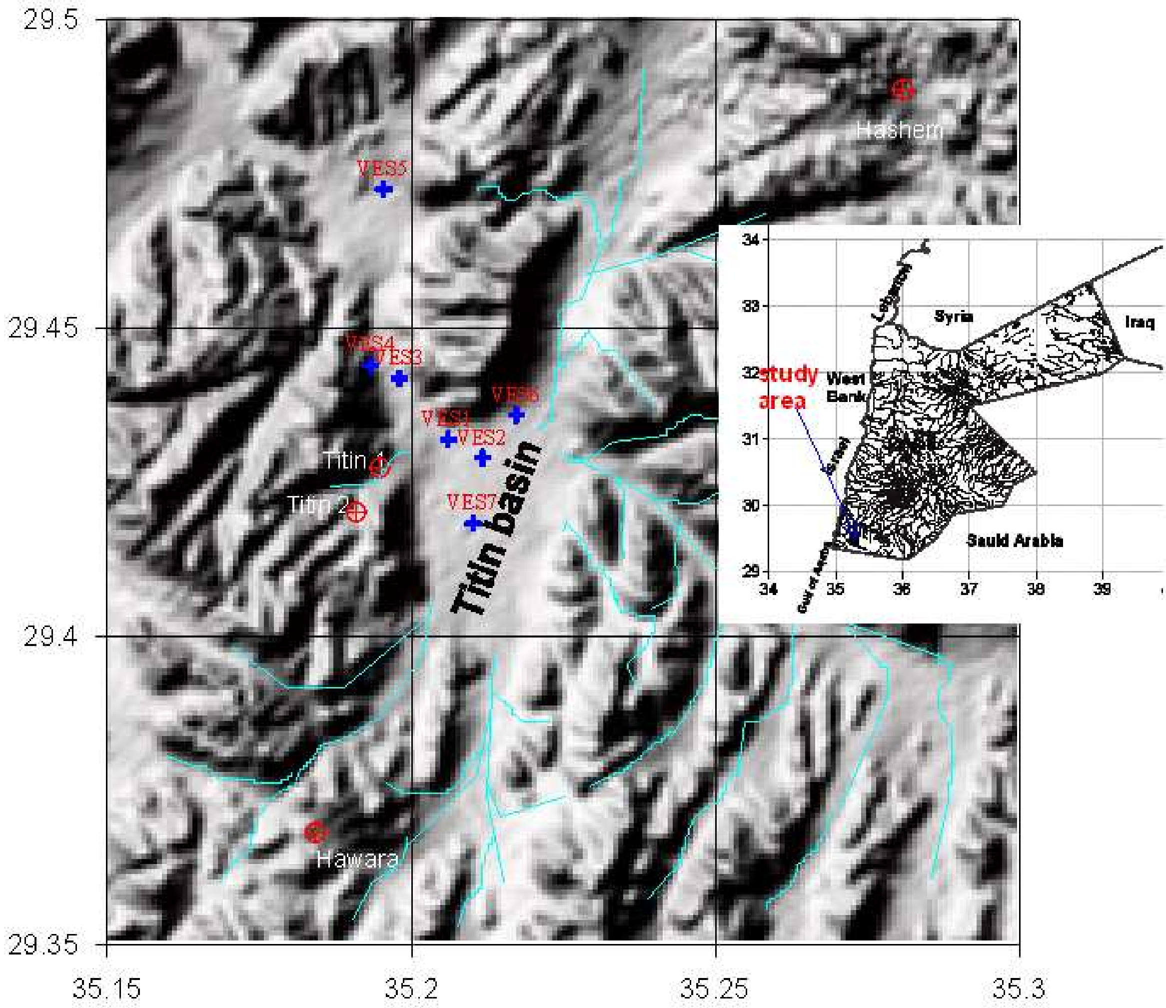


Fig. 1: Location map showing Titin basin shaped by a shaded relief resulted from 90 meters resolution DEM. Blue crosses point to the locations of the geelectrical sounding profiles. Red circled cross' point to the springs and wells in the area. Light blue lines point to the drainage which is directed to the basin.

Titin valley (Fig. 1) locates to the east of Aqaba city and overlooks the Saudi borders between coordinates E 35° 15' - 35° 03' & N 29° 35' - 29° 05', with an elevation around 775 meters above sea level. The area is out of all municipal services and infrastructure, and the dwellers of the valley which count around 300 persons are from Bedouin origin, and depend mostly on livestock husbandry activities for their living. Furthermore, water scarcity conditions in the area form a serious trouble that recently forces the dwellers to leave this type of activity which is their only source of economic income, and on the other hand the traditional work they can practice.

2. Problem of the Study

Personal interviews with local dwellers in Titin revealed their crucial needs for permanent water supply to smooth their stressed living. As seen through the field work phases, Jordan Ministry of Water and Irrigation drilled more than 3 wells in different sites of the area with depths around 100 meters not to reach water bearing layers. Aqaba governorate authority daily supplies the dwellers with their needs of water with tankers.

3. Aims and Methods

Contributing to the sustainable development of the country through the role of the universities to serve the local communities in Jordan, a hydrogeophysical exploration was carried out in the study area aiming at finding groundwater resources for the Bedouin communities.
Reduced gravity survey measurements for the area were obtained from the Natural Resources Authority of Jordan (NRA) from the Department of Geophysical Survey to infer depths to basement and thickness of the alluvium, where resisitivty method was used to explore the layer sequences and water bearing zones.
Some very shallow wells around Titin in the granite outcrops (a type of perched aquifers) that have low yield were sampled and analyzed to define its quality. The American Standard Method for Water Analyses and German DI- Norms were used in analyses of different parameters.

4. Geology of the study area

Geologically, Titin area is a grabin basin filled with wadi sediments and alluvium deposits originated from granite basement by physical weathering which overlay the CAMBRIAN sandstone formations (Umm Ishrin and Salib) which in turn overlay the Aqaba Grnaite Complex basement, (Fig. 2). (NRA, 1987). Two major faults extend north-south and bound the basin forming a grabin.

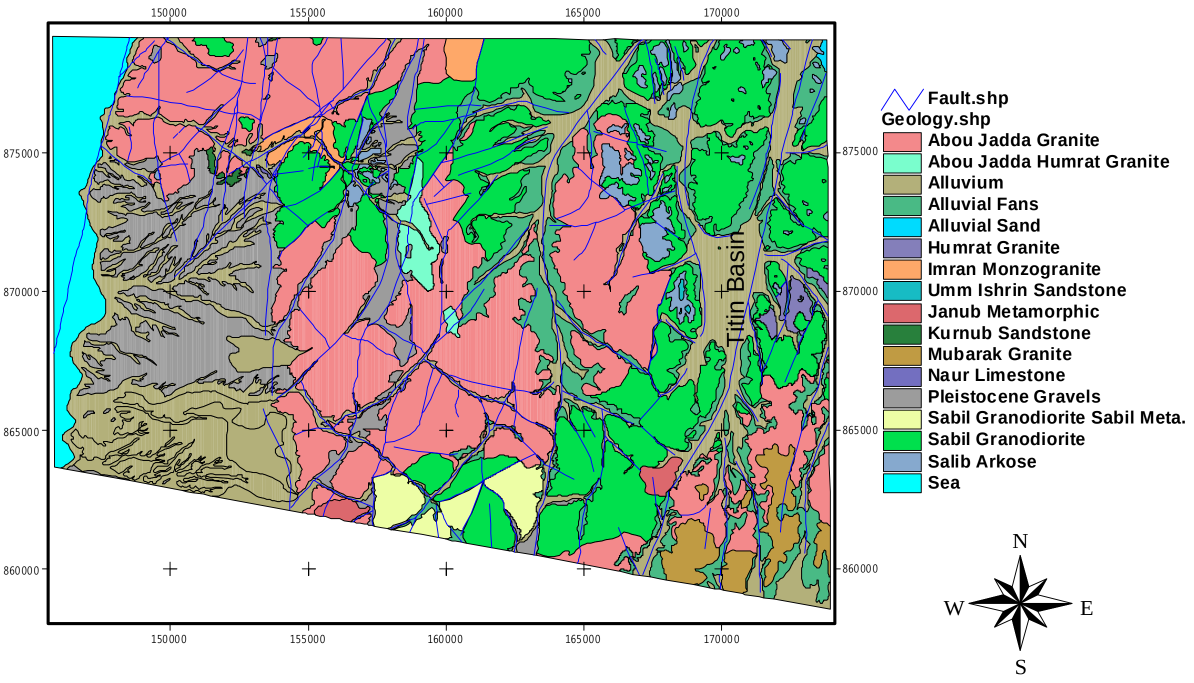


Fig. 2: Geological map of the Titin basin and the surround.

5. Data Acquisition

The first task in the research was to define the body of the basin according to its geometrical dimensions using gravity method. The promising areas that show thick deposits and deep basement from gravity were investigated geoelectrically to define depths of saturated formations.

5-1. Gravity Survey

Gravity measurements done by NRA in Titin basin were obtained and mapped using Surfer 8 (Golden Software) and represented in Figure 3. Area of Titin basin showed relatively the lowest values of Bouger anomaly.
The area around Titin basin and the basin itself are geologically composed of alluviums and sand formations which overlay the granite basement, accordingly, where ever the Bouger anomaly shows relatively low values, then this can be attributed to thick deposits and deeper basement (Fig. 4).

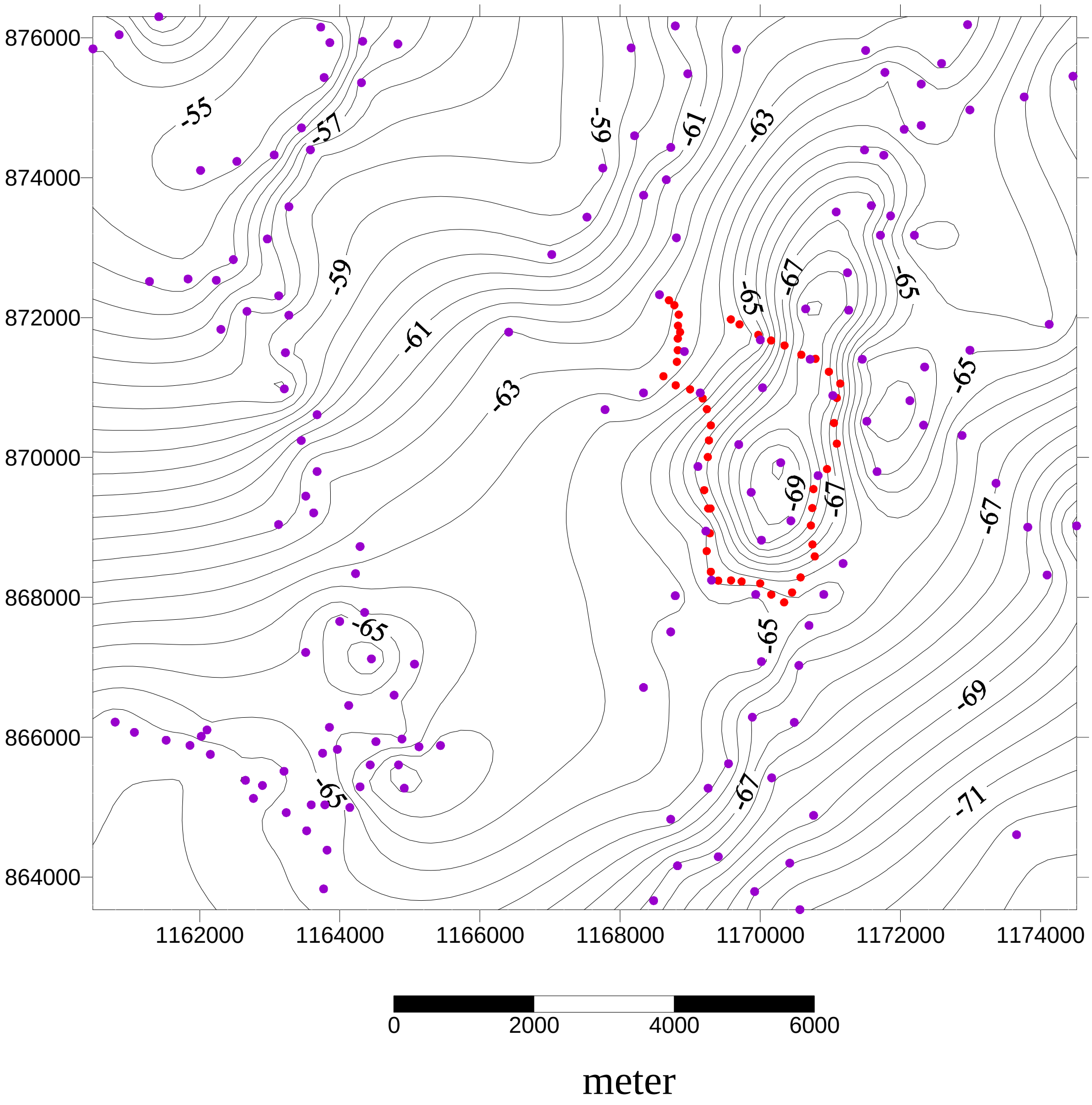


Fig. 3: Resulted Bouger anomalies in Titin basin and the surround. Red dots point to the boarders of the basin, while the pink points show the gravity measurement stations.

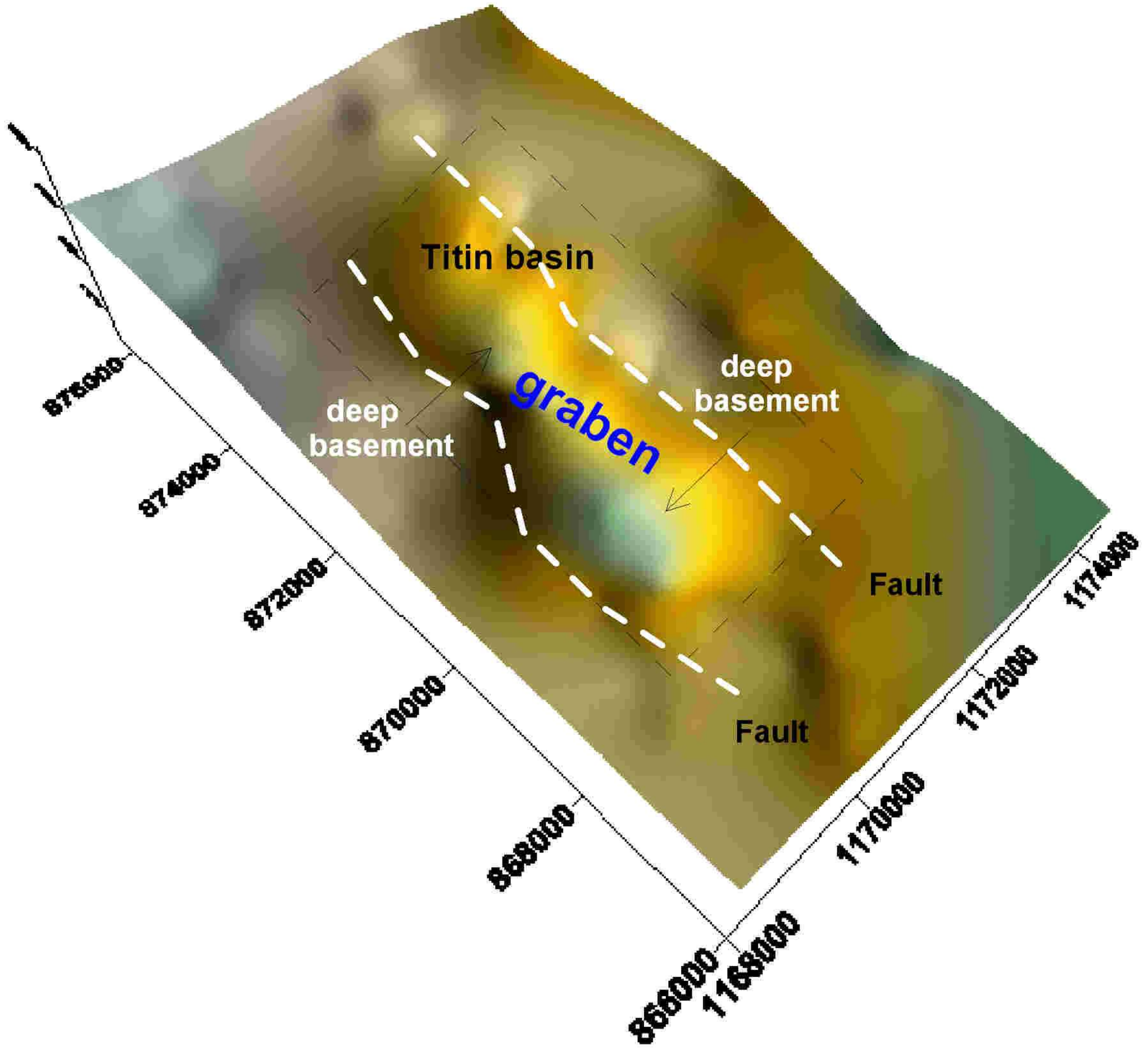


Fig. 4: 3D surface of the resulted Bouger anomalies in Titin basin. Two basins were defined to the south and to the north.

5-2. Geoelectrical Survey

Seven vertical electrical reisitivity soundings with a schlumberger array were carried out with a maximum current electrode separation ranges between 400-500m, the locations of all conducted VES are presented in Fig (1). Measurements were carried out using a Campus Geopulse Resistivity meter (Birmingham, England), it is a digital signal enhancement device incorporating a microprocessor gives resistance readings in Ω, mΩ, or μΩ as necessary, and capable of accurate measurements over a wide range of conditions. Global Position System (GPS) of type Magellan was used to determine location of soundings, where coordinates were transformed into Palestine Grid using converter software (ReprojectMe, 2002).

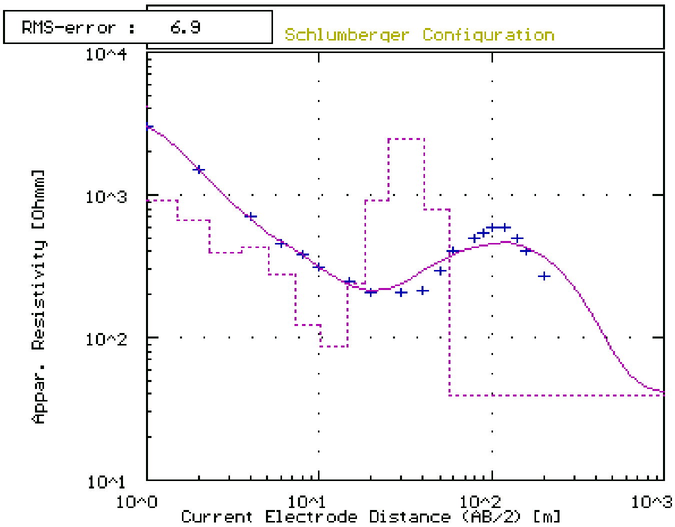
The apparent resistivity readings obtained from the field were plotted against half of the current electrode spacing (AB/2) on a log-log scale, a traditional interpretation techniques by curve matching and drawing auxiliary point diagram (Zohdy, 1989) was applied. Based on this preliminary interpretation, an initial estimation of resistivities and thicknesses of various geoelectrical layers was obtained, these preliminary estimations were later used as a start model for a fast computer-assisted interpretation RESIST written by (Velpen,1988). The results of interpretation were compared with the result of automatic interpretation software ATO written by (Zohdy, 1989). In this automatic interpretation the layering model is obtained directly from a digitized sounding curve, this approximation does not require a preliminary guess for the number of layers, their thickness or resistivities, and it does not require extrapolation of the first or last branch of the sounding curve to their respective asymptotes.

Geological Interpretation of the results

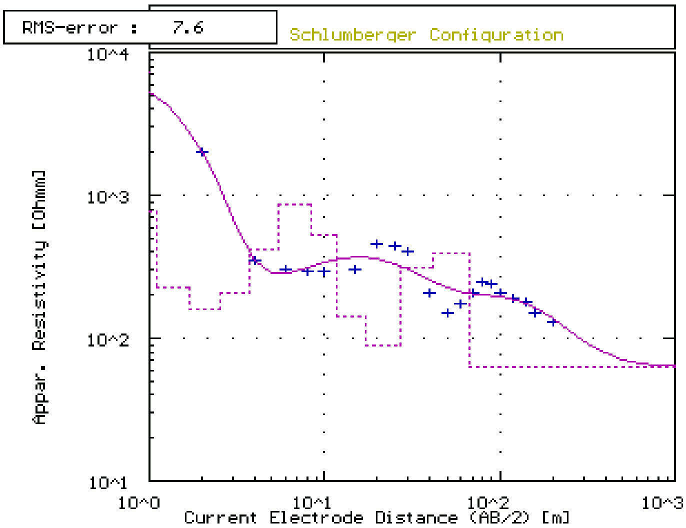
The geoelectrical and geological interpretation of the vertical electrical sounding, were basically based on the a qualitative interpretation of the field sounding curves, and correlation of all field sounding curves together taking into account the geological information more significance, since the area has no subsurface lithological logs or drilled wells. The simplified interpreted geoelectrical models of all VES are summarized in Table 1, where promising water bearing layers were marked with red color. The multilayer interpretation of two VES are shown in figures (5: a,b).

Table 1: Summary of the results of the simplified interpretation models of all VES in the study area.

VES No.	*Res.1 Ohm.m*	*Th.1 m*	*Res.2 Ohm.m*	*Th.2 m*	*Res.3 Ohm.m*	*Th.3 m*	*Res.4 Ohm.m*	*Th.4 m*	*Res.5 Ohm.m*	*Th.5 m*	*Res.6 Ohm.m*
VES1	2000	1	450	7	100	30	2200	25	40		
VES2	1400	1.7	120	10	450	25	240	18	110		
VES3	285	12	560	7	775	10	428	13	18.7		
VES4	118	8	410	5	1110	9	654	11	26.5		
VES5	307	45	550	60	477						
VES6	280	6.2	160	13	335	24	200	50	420		
VES7	7000	1	200	3	700	8	100	10	400	40	62



No	Res	Thick	Depth
1	4195.8	0.6	0.6
2	1481.7	0.3	0.9
3	924.6	0.6	1.5
4	669.1	0.8	2.3
5	398.1	1.2	3.5
6	433.4	1.6	5.1
7	280.6	2.1	7.2
8	121.7	2.9	10.1
9	87.0	4.3	14.4
10	237.9	4.2	18.7
11	907.5	6.2	24.9
12	2488.6	15.9	40.8
13	783.1	16.3	57.1
14	39.2	-.-	-.-



No	Res	Thick	Depth
1	7183.7	0.7	0.7
2	774.3	0.4	1.1
3	223.6	0.6	1.7
4	158.7	0.9	2.6
5	206.7	1.2	3.8
6	419.1	1.7	5.4
7	876.8	2.9	8.3
8	524.4	3.4	11.8
9	141.8	5.2	17.0
10	88.6	10.0	27.0
11	312.7	14.6	41.6
12	390.7	25.7	67.4
13	62.3	-.-	-.-

Fig. 5. a,b: Modeling results of the electrical layers in VES1, and VES 7.

6. Water quality

Four hand dug shallow wells were found with depths less than 4 meters for each one. Theoretically, their presence was explained as being perched types of aquifers, because all of them are existed in a small granite depressions filled with deposits. These wells or even springs (due to the locals) are (Ain al Hasheem, Ain Al Hwarah, Titin well 1, Titin well 2). The wells were sampled on their water and were exposed to chemical analysis and resulted in Table (2).

Figure (6) illustrates the locations of the samples on Pieper Diagram which in turn revealed two types of water, earth alkaline with prevailing Sulphate and earth alkaline with prevailing bicarbonate. Very high concentrations of nitrate and phosphate were found in Titin1 and 2, and this is attributed to some intended direct disposal of bio-wastes inside them by some of the dwellers as noticed through the field work.

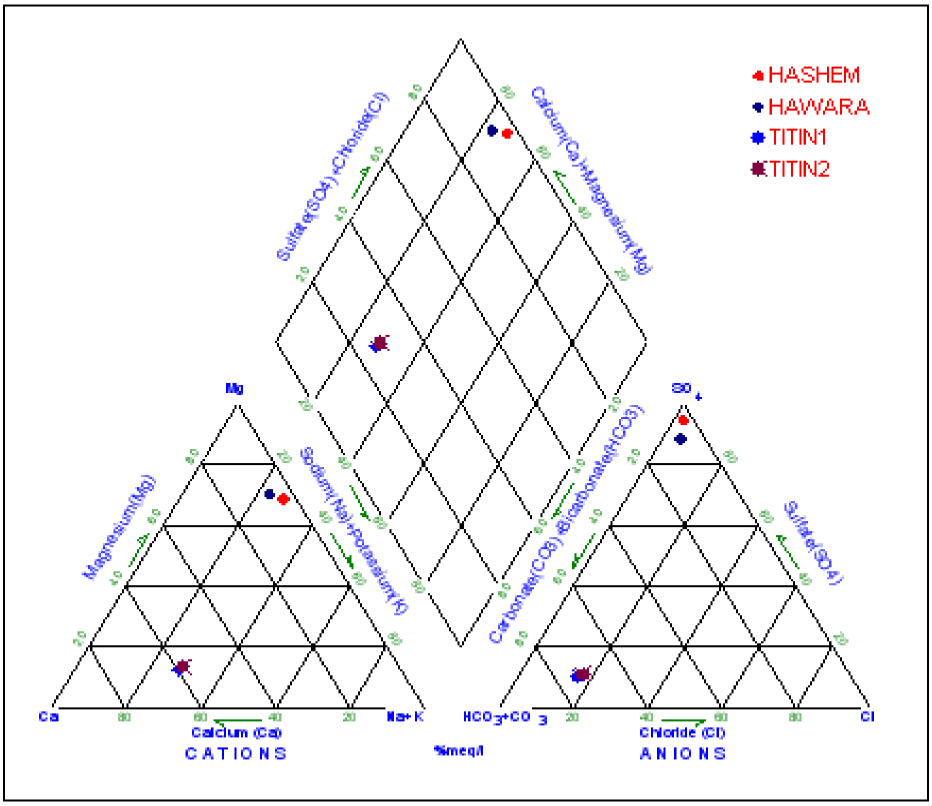


Fig. 6: Pieper diagram shows the type of water in some the shallow wells in Titin basin.

Table 2: Results of the chemical analyses of the wells of the study area.

Well name	East	North	E.C.	T.D.S.	pH	Milliequivalent/ liter									
						Na	K	Ca	Mg	Cl	HCO3	CO3	SO4	NO3	PO4
HASHEM	35.28408	29.44703	786	518	7.78	206.9	66.4	26.0	318.3	67.3	146.4	0	3554.22	1.1	0.92
HAWARA	35.18922	29.40467	940	620	7.40	110.3	156.3	48.0	318.3	60.2	146.4	0	1488.93	4.7	0.03
TITIN1	35.18914	29.25381	768	406	7.2	1057.5	73.5	2046.5	260.4	2873.0	22339.1	0	2480.2	19.46	0.021
TITIN2	35.18961	29.25414	842	434	7.27	1010.8	89.1	1889.1	265.7	2873.0	20550.1	0	2480.2	20.52	0.054

7. Discussion and Conclusions

Dwellers of Titin suffer lack of water supply and find no resources to practice their traditional job –livestock husbandry-. Titin basin which is filled with clastic sediments is the area where eight major wadis meet and drain their water. Al Farajat 2002, and depending on records of long term daily rainfall data in Aqaba, stated that thunder storms take place in the area of Aqaba (some tens of kilometers to the north west of the basin) several times in the one decade with relatively high precipitation amounts. This may allow good recharge opportunities of shallow aquifers, and consequently, may result in water bearing layers within the basin's alluviums.
Topographically, the northern part of Titin basin seems to have the shallowest point to the granite basement, and this was why when the Jordan Ministry of Water and Irrigation drilled three wells there found no water bearing layers.

Tectonically, two faults are bounding the basin, one to the east and the other is to the west, the named faults are shown on the geological map. The two faults can be delineated on the 3D surface model of the gravity in figure 4. The dramatic change in the gravity values in the eastern and western parts of the contour map in figure (3) indicate vertical types of faults. This emphasizes on that the basin body is a structural grabin.

Qualitative interpretation of the gravity survey reveals two sub-basins in the Titin grabin, one to the northern part of the basin and other to the southern part. Quantitatively, and depending on Reynolds (2000), and using the "half distance rule" the lowest point in the basin should be related with deposits thickness of about 70 meters. This is in an accordance with the values obtained from resisitivity survey which showed similar depth.

Bouger anomaly was found -65 mili Gal in areas with outcropped granite. In Titin basin the values started to decrease going southward reaching values around -69 mili Gal to reveal deeper basement than elsewhere in the surround.

In the multilayer interpretation presented in fig (5.a) the geological interpretation was based on the available geological cross sections in the study area and on the geological maps by NRA. The multilayer model was simplified into five geoelectrical layers based on the variations of resistivity values. The first geoelectrical layer has a high resistive dry alluvium deposits consist of boulders of granites and wadi sediments, the resistivity is more than 2000 ohm.m, with thickness of a bout (1m). The resistivity of the second geoelectrical layer decreases to around 400-500 ohm.m, with thickness of about 7m, this could be attributed to dry alluvium deposits and of wadi sediments, with higher amount of fine materials, the third geoelectrical layer has low resistivity reaches to about 100 ohm.m, with a thickness of 30m, could be interpreted as semi saturated zone, or a zone of highly moisture alluvium. The fourth geoelectrical layer is a highly resistive layer reach to more than 2000 ohm.m with thickness of a bout 20-30m, this layer could be attributed to the massive dry sandstone of Cambrian age. The resistivity decreases in the fifth geoelectrical layer to 40 Ohm.m with unknown depth.

The multilayer model presented in fig (5.b) of VES7 is located a bout 200m SE of VES1. The simplified geological model may be reduced into five geoelectrical layers. The first one is composed of dry alluvium with granite boulders of wadi sediments having very high resistivity reaches to a bout 7000 ohm.m, with thickness of 1 meter. The second geoelectrical layer has an intermediate resistivity of about 200 ohm.m with thickness of 3-5m, this layer could be interpreted to be an alluvium deposits with highly amounts of fine materials. The resistivity is being higher and reaches to a bout 800 ohm.m in the third geoelectrical layer, and this could be attributed to a dry alluvium deposits and wadi sediments consist mainly of granites boulders as a result of the physical weathering from the nearby uplifted basements during storm events. The fourth geoelectrical layer shows relatively very low resistivity reaches to 90 ohm.m, the depth of this layer is a bout 15-20m, with thickness of a bout 15-20m, this zone could be attributed to be a semi saturated zone or a high moisture alluvium deposits. Below this promising zone presents a high resistive layer where the resistivity reaches to about 400 ohm.m and thickness around 40m, this could be attributed to the massive dry sandstone of Cambrian age. The resistivity decreases below this layer to an unknown depth.

From simple qualitative and quantitative modeling on gravity measurements done in the basin, the depths to basement were revealed to reach about 70 meters to its southern part and less than that in the northern part. Side wadis surround the basin with the frequent thunder storms that take place in the area several times in the one decade are able to recharge the aquifer. It is believed that these recharge amounts of water collected with time joined the bottom of the basin which is sealed in the bottom by the impermeable granite basement. VES 7 conducted on the southern part insured that and showed lower values of resistivity than elsewhere in the basin at depths of about 60 meters. Having these facts, the southern part of the basin is promising and should be taken into consideration by any future drilling plans for water purposes.

The quality of the groundwater found in some shallow perched aquifers in the area was found to be of fresh type with TDS less than 620 mg/l. The area is out of intensive human and related activities, this allows water qualities in the basin prone to at least the animals husbandry.

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