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Resistivity Properties Of Limestone Rocks In Parts of Iraqi Kurdistan Region-NE Iraq

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Abstract

To evaluate limestone rocks from the hydrogeological point of view and indicating optimum resistivities for dry and wet conditions an electrical resistivity study was performed in 34 locations surrounding Sulaimani, Kirkuk and Arbil cities. About 181 VES points were conducted using Shlumberger configuration. The authors selected six geological formations composed of limestone rock for this purpose.The field data was interpreted manually Using Ebert method and by the aid of computer using IPI2win and Resixplus software. The optimum ranges of resistivity magnitudes have been determined for these geological formations in both wet condition (Forming aquifers) and dry condition (forming aquicludes). Among the studied formations Pila Spi, Sinjar and Aqra are appearing to be most suitable for making aquifers. While Kometan, Balambo and Qamchuqa Formations are frequently aquicludes.

Keywords:-Resistivity prospecting,Groundwater,carbonate rocks.

Introduction

The use of geophysics for both groundwater resource mapping and for water quality evaluations has been increased dramatically over the last 10 years due to the rapid advances in microprocessors and associated numerical solutions, [1]. The resistivity method is carried out to solve problems in hydrogeological fields and in both types of aquifers alluvium and karstic carbonate rocks. Several researches in the world were carried out relating to this topic such as; [1-3] in the field of determination depth, thickness and boundary of aquifers, indication interface between saline and fresh water carried out by [4,5], porosity and hydraulic conductivity of aquifer by [6,7], hydrogeological mapping in karsts by [8], contamination issue by [9]. Although the resistivity method has some limitations especially when the ground is Inhomogeneous and anisotropic, [10]. The depth of penetration is proportional to the separation between the outer electrodes, in homogeneous ground, and varying the electrode separation provides information about the stratification of the ground, [11]. Two types of resistivity meters were used, Terrameter SAS-4000 and Terrameter SAS-300C that are very applicable for prospecting of groundwater in sedimentary environment, [12].

Limestone rock is considered as one of the most important non-clastic aquifers in the world for storage of gas, oil and water. It is characterized by consisting of high percentage of fractures, joints and cracks as well as numerous voids, galleries and cavities formed due to high ability of carbonate rocks to the process of dissolving by ground water movement. Limestone rocks are widely

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spread in Iraqi Kurdistan region forming several great important aquifers for both oil and water in many places. Shortage of drinking water during the last few years attract our attention to perform an electrical resistivity surveying on most of those geological formations consisting of limestone rocks such as Pila Spi, Sinjar, Aqra, Kometan, Qamchuqa and Balambo Formations cropped out in (34) locations, Table (1). Structurally they are located on plunges, crests, and limbs of large or small anticlines trending NW-SE, Fig (1).

Table (1) Distribution of sites on the geological formation

Name of geological formation	Pila Spi Formation		Sinjar Formation		Aqra Formation		Kometan Formation		Qamchuqa Formation		Balambo Formation	
	No	Name	No	Name	No	Name	No	Name	No	Name	No	Name
Name of the locations	1	Tangisar	9	Glazarda2	14	SoraQalat	18	Khalakan	25	Gawrade	30	Qawella
	2	Glazarda1	10	Gawradeh	15	Khalan	19	Chaq-Chaq	26	Sedar2	31	Kotramar
	3	Hanara	11	Kani	16	Darbandok	20	Azmir	27	Sose	32	Geldara
	4	Zhaly darband	12	Shaitan2	17	Shosh	21	Sedar1	28	Sharsten	33	Garmadara
	5	Kani Shaitan1	13	Qalasoora2			22	Goza Raqa	29	Sofian	34	Mirmam
	6	Qalasoora1		Daq			23	Darbarula				
	7	Sofisan					24	Surdash				
	8	Barda Azaban										

Fig. (1) Location map of the studied area, modified from Microsoft Encarta, 1988-1997.

Description of Geological Formations

1- Pila Spi Formation

It wad described for the first time by (Less, 1930) in [13]. Its type locality is situated in Pila Spi area located at southeastern part of high folded zone of Iraq. According to [13] it was deposited in late lower Eocene-Upper Eocene cycle, in shallow lagoon environment. The formation consists of two parts. The Upper part is well-bedded,bituminous, chalky and crystalline limestone with bands of white chalky marl with chert nodules towards the top. The lower part shows well bedded hard porous, or vitreous bituminous or white, poorly fossiliferous limestone with algal or shell section. The thickness of the formation varies roughly between 100-200m. bituminous.

2- Sinjar Formation

Its type locality is around Jeble Sinjar near Mamissa village and was described by Keller (1941) in [13]. The formation consists in its type area of limestone showing elements of algal reef facies, and shoal nummulitic facies. The thickness reaches 176m in its type area; in other areas thickness is variable, usually between 100-200m.The Formation had been deposited under variable environment conditions. Its lower contact unconformable with Kolosh Formation and is characterized by intense repetition and interfigaring between them. The Upper contact is also unconformable with clastic Gercus Formation.

3- Aqra Formation

The limestone of Aqra Formation was first described by Bennett (1945) in [13], from the Aqra anticline in the high folded zone, Northern Iraq. Lithologically, it is composed of limestone, silty or sandy limestone, locally silicifed and dolomitized occasionally impregnated with bituminous materials. The thickness of the formation ranges from 100m to about 200m. The age of the formation is Maastrichtian. The depositional environment of this formation is of reef, shoal reef and detrital fore reef. In Sulaimani-Qalachwalan area it is represented as a tongue within the Upper Part of Tangero Formation, the boundary between them is gradation.

4- Kometan Formation

It was described by Dunnington (1953) in [13] for the first time. The type locality of the formation appears in Kometan Village. It is composed of light gray, hard massive and highly jointed limestone, which is partly silicified or cherty. The age of Kometan Formation is related to the Turonian-Lower Santonian and it is most probably deposited in deep neritic open sea environment. The total Thickness of the formation is about (100-160) m.

5- Qamchuqa Formation

Most of the high ridges of mountains in Kurdistan region is made up of Qamchuqa limestone formation. Its age returns to lower Barrimian to upper Albian. The formation is sub-divided into two parts, lower Qamchuqa limestone composed of massive limestone with silt and quartz constituents and may be dolomatized in some parts. The thickness of the lower

part ranges between (250-300) m. The upper Qamchuqa part is hardly compacted limestone and has a thickness range between (50-250) m.

6- Balambo Formation

Wetzd first described it in (1947) in [13] in Sirwan valley near Halabja town. The total thickness of the formation is about (400-550) m. Lithologically, the formation is composed of fine crystalline, well bedded, blue ammonitiferous limestone locally siliceous and radiolarian limestone with intercalation of olive green marl and dark blue shale. The age of the formation is related to the Valanginian - Turonian and it is deposited in a marine deep bathyal and offshore pelagic sediments.

Interpretation

Qualitative interpretation

A first appraisal of an area hydrogeologically can often be obtained by merely looking at the shapes of the field curves and the ranges of apparent resisitivity values. Comparison of curves leads to the recognition of the type curves and enable the curves to be divided into groups. Each group may represent a specific geologic or hydrogeologic condition; so all the sounding curves can be classified into the following groups:

1-The field curves of the Pila Spi, Sinjar and Aqra Formations are characterized by the dominant of H & HK-types, Fig (2,3 and 4). While in the other three formations Kometan, Balambo and Qamchuqa H & HK-types are appearing in two locations only these are Mirmam and Sharesten villages, Fig (5,6,and 7).

2- The H, A and AA-types of field curves are very common in the Kometan, Balambo and Qamchuqa Formations.

3- KH-type field curves are also a characteristic feature of Kometan, Qamchuqa and Balambo Formations and it does not appear in the first three geological formations.

4-The four-layer cases are dominant in all locations and it is cover %75 of the field curves. Others (3-layers and 5-layers) are forming %25 of the total field curves. The qualitative interpretation denote to the classification of the geological formations into two groups according to shape of the field curves. The first are Pila Spi, Sinjar, and Aqra Formations, the second group are Kometan, Qamchuqa, and Balambo Formations.

Quantitative interpretation and discussion

All field curves are interpreted manually using Ebert's method by partial curve matching with a set of standard master curves of two layer cases by the aid of the auxiliary set curves. The results were checked by the aid of computer using two different types of software (IPI2win and ResixPlus).

The results of quantitative interpretation were compared with the geologic column of 13 wells in the studied area. The first group of formations Pila Spi, Sinjar, and Qamchuqa, appeared in both wet (aquifer) and dry (aquiclude) conditions. While the second group, Kometan, Qamchuqa, and Balambo, appeared only in dry condition. A bout (41) VES points on Pila Spi

formation have been analysed. The optimum resistivity value of the Pila Spi formation aquifer ranges between 28.6 and 90.3 ohm.m, Table (2.A). When the same formation is in an aquclude state, it

has a resistivity of 91 to 400 ohm.m, Table (2.B). The overlap has been observed for wet and dry conditions at resistivity value of about 90 ohm.m, due to the influence of the lithological composition of the formation as described before. The Sinjar formation is also consider as an excellent aquifer if structure, elevation, and hydrogeological situations are suitable. The interpretation of (27) soundings denotes that the formation also appears in both wet and dry conditions. When it is aquifer it has a resistivity value of 27 to 75 ohm.m, Table (3.A), while aquclude case displays a wider range of resistivity, which varies from 99.7 to 2500 ohm.m, Table (3.B). Akra Formation is considered as a weak aquifer that is clarified through several wells drilled in some of the villages under study. The main reason returns to the large quantity of bituminous materials disseminated through most of the fractures, joints, and voids, which exist in the rock. Analysis of (22) soundings on Aqra Formation shows that the convenient magnitude for wet condition is ranging between 31and 86 ohm.m, Table (4.A), while resistivity has magnitudes of (150-400) ohm.m represent dry condition of the formation, Table (4.B).

The second group of formations, which are Kometan, Balambo and Qamchuqa, are studied through (91) sounding points. All field curves had been denoted to the aquclude characteristics of these rocks in all selected sites of the study although these sites have different structural, geological and hydrogeological conditions. Kometan formation was covered by (38) soundings. They show wide range of resistivity value ranging between 200-2045 ohm.m, Table (5). While the (26) soundings on the Balambo Formation show the resistivity of about (250-2500) ohm.m for the dry condition, Table (7). The interpretation of (27) soundings on the highly fractured and cavernous Qamchuqa Formation denote to wide range of resistivity values ranging between 110-5000 ohm.m, Table (6). In light of above information and the recent wells which were drilled in some villages located on these formation, the authors conclude some factors to cause dryness of the second group (Kometan, Balambo and Qamchuqa Formations):

1-The Formations of this group are not confined as the first one from top and bottom by impermeable beds.

2- Most of their fractures and joints are cemented by calcite and other minerals.

3- They are forming ridges of mountainous area, their elevations are too large with respect to the adjacent area that cause to rapid movement of groundwater to the low relief are by gravity.

4- The high dip angle of layers leads the water to migrate along the bedding plane.

5- Kometan and Balambo formations have little ability to be dissolved; hence, cavities, voids, and galleries are not characteristic features and rarely have been seen in. Qamchuqa Formation on the other hand is cavernous but due to its large thickness, it is characterised by low level of groundwater table.

Conclusions

1-Only ten locations denote to the existence of groundwater (aquifers) among the total 34 locations under consideration. Others are dry (aqucludes).

2- Geological formations can be classified into two groups; the first is Pila Spi, Sinjar and Akra formations. They are aquifers in some sites under investigation where structural situations and hydrogeological conditions are suitable, and aqucludes in others. The second group is Kometan, Qamchuqa, and Balambo Formations they are aqucludes in all sites even under different geological conditions.

3- Optimum resistivity value for Pila Spi formation as an aquifer is (28.6-90.3) ohm.m, for Sinjar is (27-75) ohm.m, and for Aqra is (31-86) ohm.m. They are considered as aqucludes when the resistivity ranges between (91-400) ohm.m, (99.7-2500) ohm.m, and (150-400) ohm.m respectively.

4-From the total (181) sounding curves, all the geological formations have been aqucludes approximately above the resistivity exceeds (100) ohm.m in different depths and different geological, structural and hydrogeological conditions.

5- Kometan and Balambo formations investigated in (12) sites, about (64) sounding curves were performed all denote to the disability of these rocks to be aquifer at least to investigation depth of approximately 200 m. This is ensured through several dry deep wells drilled in the two mentioned formations.

Resistivity values of the studied formations

Table (2) Pila Spi Formation **A- Wet condition**

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Kani Shaitan	35 38 26 44 58 09	998	220/35 N50W	50-62	25-45	50.5-58.9	52-56.5
Qala Soora	35 27 34 45 20 09	1068	210/17 N30W	44	59.4	28.6	68.5
Sofisan	35 28 49 45 07 21	859	230/55 N50W	79.1	32.1	90.3	30.6
Tangisar	35 26 23 45 17 53	962	170/20 N80E	71.1	65	64.5	70.5
Zhalay Darband	37 27 30 45 08 25	755	235/35 N35W	62.5	105	65.1	104.1

B- Dry condition

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Barda Azaban	35 51 28 44 55 55	562	030/17 N35W	91-400	37-122.1	89-320	33-126
Glazarda	35 26 25 45 23 26	1220	050/44 N35W	99	39	127.9	36.7
Hanara	35 18 11 45 16 08	1140	220/40 N40W	88-200	35	92-200	35 5

Table (3) Sinjar Formation A- Wet condition

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Daq	35 15 20 44 45 33	648	170/35 N80E	28.6	12.5	32	9.7
Kani Shaitan	35 38 50 45 00 15	930	220/35 N50W	30-75	25-80	27-68.5	29.1-91

B- Dry condition

Location	atitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Gawrade	35 45 02 45 01 46	1420	285/11 N15E	850-1500	50	465-621	58-97
Glazarda	35 26 25 45 23 26	1145	050/44 N35W	105	48	99.7	40.2
Qala Soora	35 28 10 45 20 24	1134	215/35 N35W	3600	64.7	2500	66

Table (4) Aqra Formation A- Wet condition

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Darbandok	36 39 20 44 23 20	760	220/40 N35W	60.5-73.2	43.5-90.2	50.3-81.6	44.1-92.9
Khalan	36 40 30 44 22 40	570	220/40 N35W	31.1-40.2	160.5	28.5-36.3	168.9
Sora Qalat	35 46 32 45 26 59	970	070/45 N20W	86	60	78.2-84.5	1-73.2

B- Dry condition

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Shosh	36 47 52 43 45 21	820	220/70 N35W	160.5-473.2	4.5-25.2	150.3-481.6	4.1-25.9

Table (5) Kometan Formation Dry condition

Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Azmir	35 33 10 45 29 13	1032	220/35 N35W	380-1200	6.8	736-738	6.3
Chaq-Chaq	35 36 30 45 23 20	789	070/35 N35W	275-1100	1-9.5	239-2045	1.5-83.1
Darbarola	35 29 32 45 31 23	614	220/40 N40W	230	16.8	291	16.9
Goza raqa	35 30 28 45 31 41	744	220/40 N32W	432	50	431	55.8
Khalakan	36 01 23 44 50 34	1020	215/48 N55W	300-930	7	200-950	8.4
Sedar	35 58 18 45 04 25	645	050/20 N50W	400-900	6-32.1	274-721	2-108
Surdash	35 50 58 45 06 53	945	040/22 N40W	630-800	19-71.4	960	19.1

Table (6) Qamchuqa Formation Dry condition

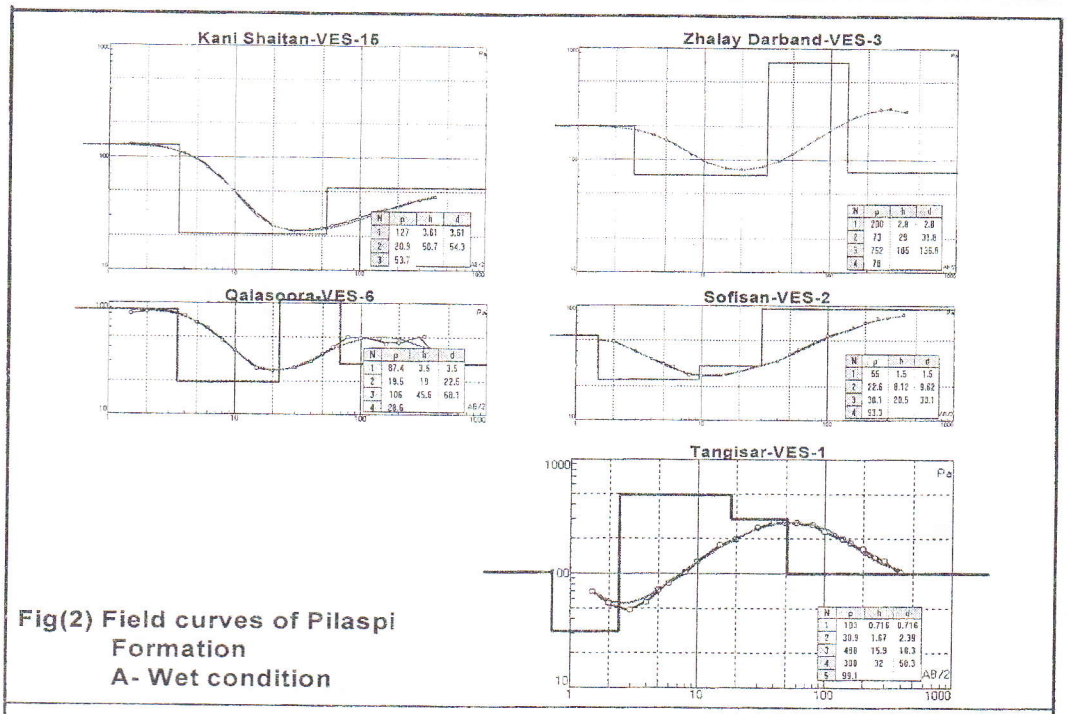
Location	Latitude Longitude	Elevation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Gawrade	35 51 20 45 18 30	1120	040/50 N40W	3000-38000	45	50000	37.5
Sedar	35 58 18 45 04 25	680	050/20 N50W	3000-7000	70-145	2500	173
Sharsten	36 16 07 44 50 09	859	050/30 N41W	600	17.2	600	12.5-17.3
Sofian	36 03 45 45 06 34	940	140/20 N40W	130	18.1	110.5	15.1
Sosea	35 58 44 48 21 29	810	240/50 N38W	200-725	49.9	205-492	35

Table (7) Balambo Formation Dry condition

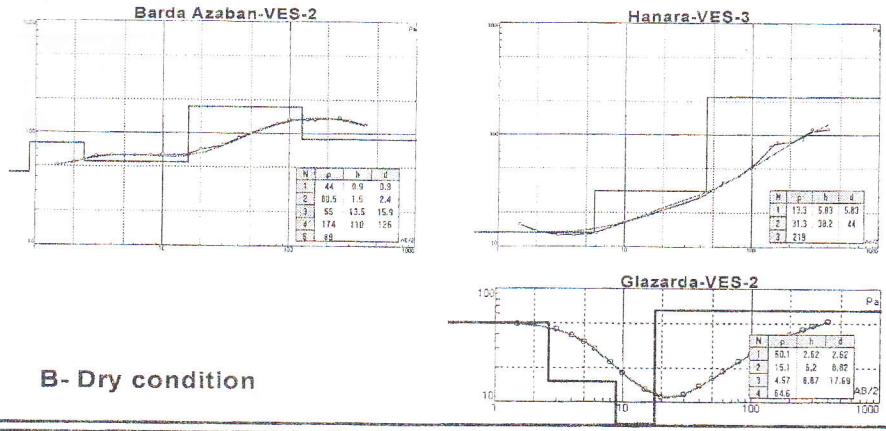
Location	Latitude Longitude	levation (m)	Dip Strike	(Ebert Method)		(Computer Method)	
				Resistivity Ohm.m	Depth (m)	Resistivity Ohm.m	Depth (m)
Garmadara	35 30 08 45 36 42	984	030/55 N30W	2000	32.4	2213	31.4
Geldara	35 31 01 45 39 57	1240	040/03 N35W	250-420	68.8-79	252-498	73-76.5
Kotramar	35 30 35 35 43 44	938	030/20 N30W	700-1005	12.8-30.4	324-953	8.7-61.8
Mirmam	35 50 58 45 06 53	812	200/12 N50W	500-2500	16.8-70.8	638-1447	1.8-70.5
Qawella	35 27 38 45 46 57	1110	048/45 N35W	390-1450	30.4-80.8	654-1500	24.5

Table (8) Shows range of resistivities for wet & dry condition

Formation	Condition	Type of the field curve	Number of Sites	Optimum Resistivity Ohm.m
Pila Spi	Wet	H, HK	5	38-80
	Dry	HKH, HA, HQ	3	88-400
Sinjar	Wet	H, QH	2	27-75
	Dry	HKH, HA	3	99-2500
Aqra	Wet	HKH, HA, HK	3	28-86
	Dry	KH	1	150-481
Kometan	Wet	-	-	-
	Dry	KH, AA, HA	7	130-2045
Qamchuqa	Wet	-	-	-
	Dry	KH, HA, HK, AK	5	110.5-50000
Balambo	Wet	-	-	-
	Dry	KHA, HA, KA	5	324-2500



Fig(2) Field curves of Pilaspi Formation
A- Wet condition



B- Dry condition

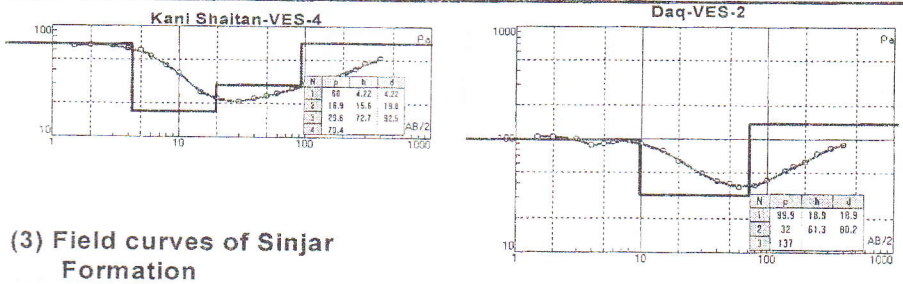
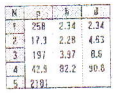
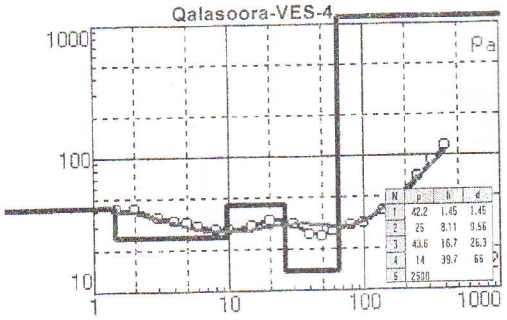


Fig (3) Field curves of Sinjar Formation
A- Wet condition

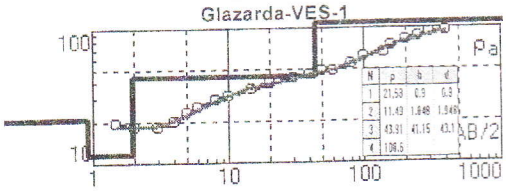
Gawradee-VES-2



Qalasoora-VES-4

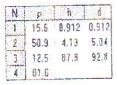


Glazarda-VES-1

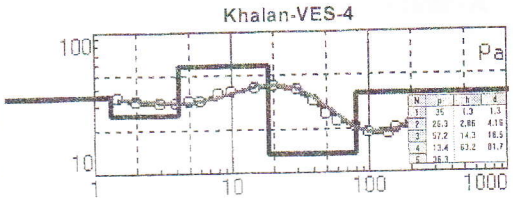


B- Dry condition

Darbandok-VES-1



Khalan-VES-4



Sora Qalat-VES-1

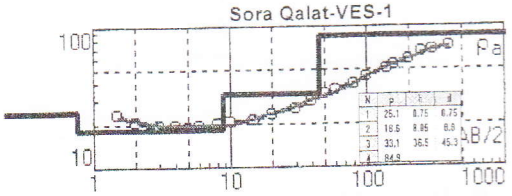
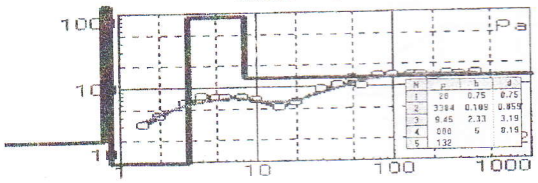


Fig (4) Field curves of Aqra Formation
A- Wet condition

Shosh-VES-1



B-Dry condition

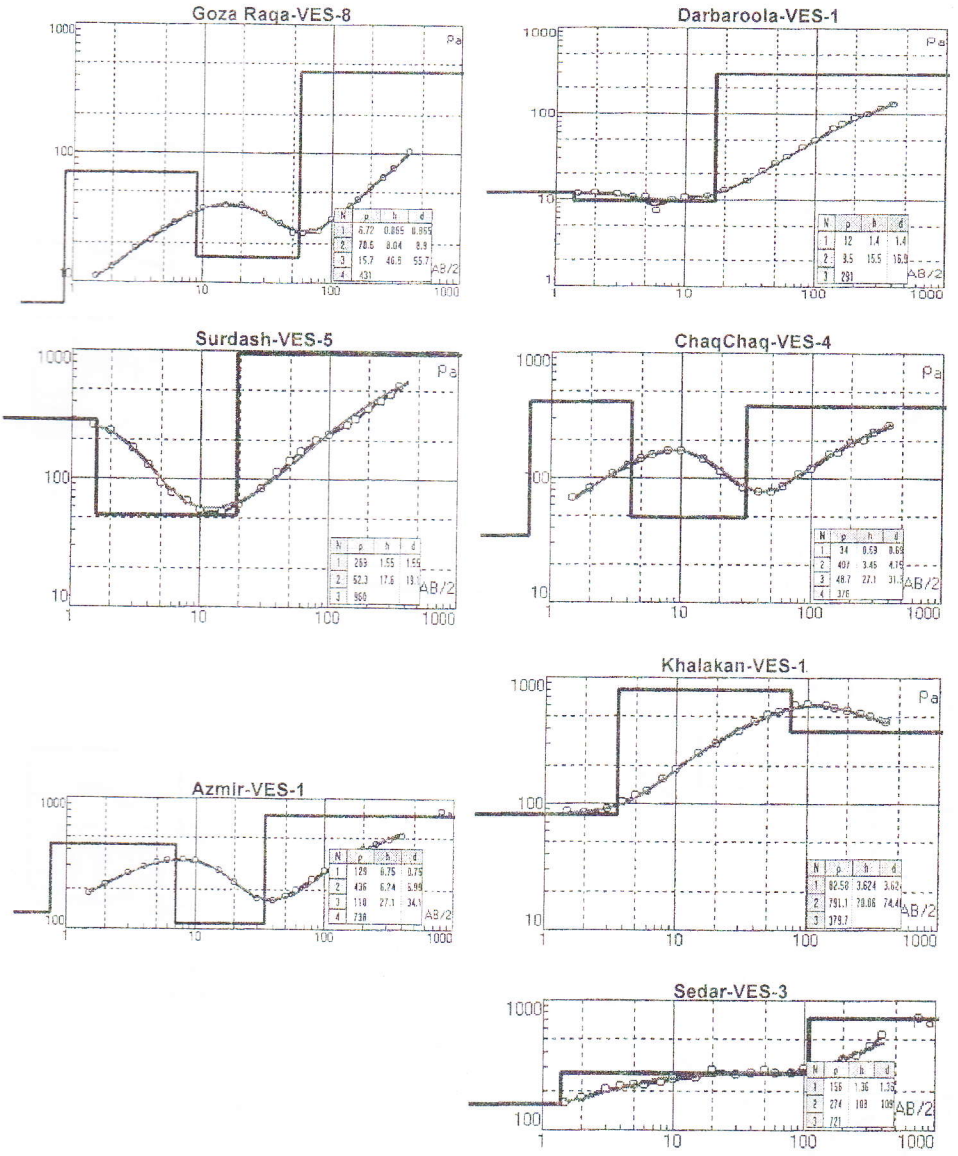


Fig (5) Field curves of Kometan formation
Dry condition

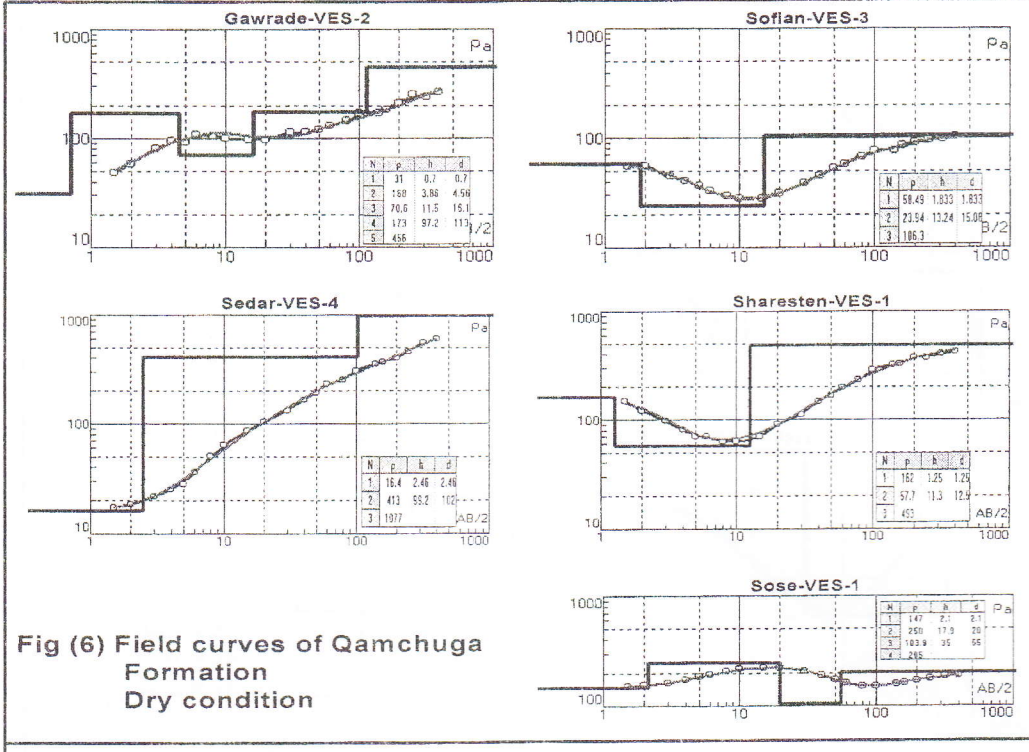


Fig (6) Field curves of Qamchuga Formation Dry condition

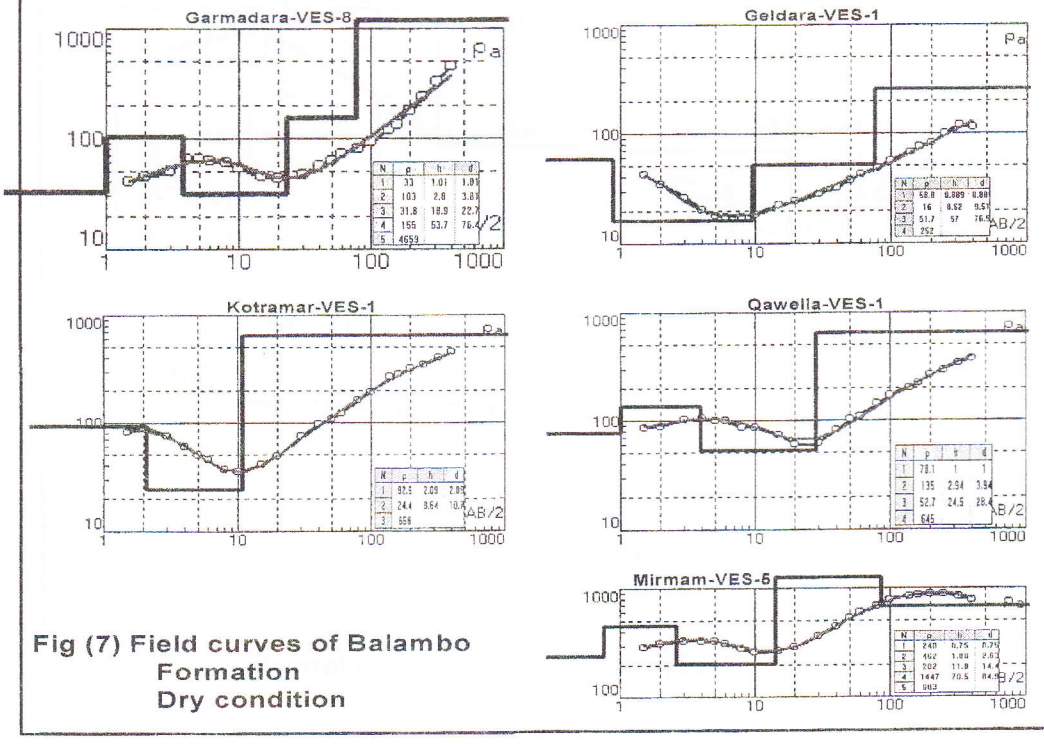


Fig (7) Field curves of Balambo Formation Dry condition

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خەسڵەتەکانی بەرگری کارەبای بەردی لایمستۆن لە هەندێك شوێن لە هەرێمی کوردستان-باکوری ڕۆژهەڵاتی عێراق

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پوختە

پشکنینی بەرگری کارەبایی ئەنجام درا لە ٣٤ شوێن لە دەورو بەری شارەکانی سلێمانی و هەولێر و کەرکوك بۆ هەڵسەنگاندنی بەردی لایمستۆن لە ڕووی هایدرۆجیۆلۆجی و دۆزینەوەی باشترین بەرگری جۆری بۆ هەردوو حاڵەتی ووشك و تەری ئەم بەردە. ئەویش بەبەکارهێنانی تەکنیکی شلومبەرجەر لە ١٨١ خاڵی پشکنینی کارەبایی ئەستونی. شەش جۆر پێکهاتەی جیۆلۆجی جیاواز هەڵبژێردرا کە بەردی لایمستۆنیان تێدابوو بۆ ئەم مەبەستە.

زانیاری یە کێلگەی یەکان شی کرانەوە بە ڕێگای دەستی و هەروەها بە بە کارهێنانی هەردوو پڕۆگرامی کۆمپیوتەری (RESIXPLUS) و (IPIWIN). باشترین بڕی بەرگری بۆ ئەم پێکهاتە جیۆلۆجیانە دۆزرایەوە کاتێ ئاماری ئاوی دروست نەکەن یان کاتێك وشك بن. لە نێوان پێکهاتە جیۆلۆجیەکاندا پێکهاتەی پیلاسپی و سنجار و عەقرە زۆر لەبارن بۆ دروستکردنی ئاماری ئاوی لەکاتێکدا پێکهاتە جیۆلۆجیەکانی وەك کۆمیتان و بالامبۆ و قەمچوغە بەزۆری وشکن.

خصائص المقاومة النوعية للصخور الجيرية في بعض مناطق إقليم كوردستان-شمال شرق العراق

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الخلاصة

تم إجراء مسح مقاومة كهربائية في ٣٤ قرية محاطة بمدن السليمانية، أربيل و كركوك لغرض تقيم الصخور الجيرية من الناحية الهايدروجيولوجية وتحديد امثل المقاومة لها لكلا الحالتين الجاف والرطب باستعمال ترتيب شلمبرجر. مسح ما مجموع ١٨١نقطة جس كهربائي عمودي. تم اختيار ستة تكوينات جيولوجية حاوية على صخور جيرية لهذا الغرض.

فسرت البيانات الحقلية بواسطة طريقة ابرت التقليدية وكذلك بواسطة برامجي الحاسوب (RESIXPLUS) و (IPIWIN). تم إيجاد مديات مقاومية مثالية لهذه التكوينات في حالتي الرطب و الجاف. أظهرت النتائج بأن تكاوين بيلاسبي ، سنجار و عقرة اكثر ملائما لتكوين خزان مائي جوفي بينما التكاوين كوميتان بالامبو و قمجوغة غالبا ما تكون جافة.

وەرگیرا لە ٢٠٠٤/٤/٢٠ وپەسەندکرا لە ٢٠٠٥/٢/٢١.
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