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گۆڤاری زانكۆی سلێمانی كانونی یەكەم ٢٠٠٥ بەرگ ٨ (١) بەشی A لاپەرە(٧-١٦)

Electrical Imaging:
2D Resistivity Tomography as a Tool for Groundwater Studies at Mahmudia Village, West Sulaimani City, Iraqi Kurdistan Region

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Abstract

Electrical Imaging (EI) is a geophysical method, developed over the past several years that provide a two or three dimensional resistivity model of the subsurface. EI can be very effective in providing information on the distribution of aquifers, aquitard, impermeable rocks, soil-bedrock interface topography, fracture zone, fault and voids. This technique is used for the first time in Iraq in Mahmudia village, west of Sulaimani City. Five traverses were taken; more than 4000 readings were recorded using Wenner configuration with roll along technique. The data inversion was carried out by RES2DINV program using both finite difference and finite element mathematical methods. Two aquifers of different geological properties have been detected; one of them within the recent sediments while the other within the limestone beds of Sinjar Formation. These aquifers can be regarded as an excellent water resource for providing sufficient groundwater to the area for domestic and agricultural purposes.

Keywords: Electrical Imaging, Resistivity Tomography, and Groundwater

Introduction

The resistivity surveying method has undergone dramatic changes over the last decade. A major improvement since the early 1990 ´s has the development of 2D imaging surveys [1] that provides a more realistic model of the subsurface even in complex geological area. As we know, due to anisotropy of the earth material, the resistivity changes in x, y and z direction, so the greatest limitation of 1D resistivity sounding method is that it does not take into account horizontal changes in the subsurface resistivity. A more accurate model of the subsurface is a two-dimensional (2D) model where the resistivity changes in the vertical direction as well as in the horizontal direction along the survey line. The 3D resistivity survey and its interpretation model should be even more accurate, however at the present time, 2D survey are the most practical economic compromise between obtaining very accurate results and keeping the survey costs down [2]. Typical 1D resistivity sounding surveys usually involve about 10 to 20 readings, while 2D imaging surveys involve about 500 to 1500 measurements. In comparison, 3D survey usually involves several thousand measurements.

Several researches have been carried out in the world using 2D and 3D techniques such as: in mineral exploration [3- 5]. In the field of hydrogeological application, engineering and environmental studies there are [6- 11]. In Iraq there is no any previous study yet in this field, so the study under consideration is considered as a first attempt. The author selected an area located 25 km west of Sulaimani City that is surrounding Mahmudia village, Fig (1). Fortunately, there is a drilled well, of 120m depth, located 650m NE of the village, which was very helpful in comparison of results obtained from 2D

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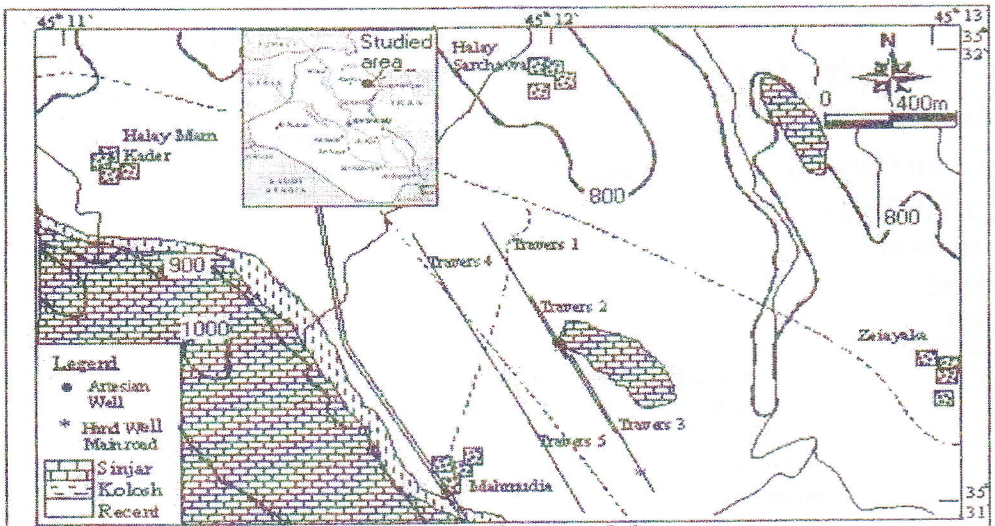


Fig (1) Location and Geological map of the area

interpretation. Mahmudia village is bounded by latitude (35° 31`-35° 32`N) and longitude (45° 11`-45° 13`E). Geologically, the area is located on a plain flat area of recent sediments, bounded from NE and SE by high ridge of Sinjar limestone Formation Fig (1). The dip of the limestone beds is 27° degree in the direction of 220°, its strike is similar to the orientation of the structural feature or the area. At NW of the village exactly beneath Sinjar cliffs black Shale beds of Kolosh Formation was cropping out. From the structural point of view the studied area is located within the core of the major Bazian anticline that extends in NW-SE direction forming the Bazian Basin. Inside this basin many large blocks of Sinjar Formation were scattered forming high uplifted areas. No surface water exists in the area except two weak springs, which have a discharge equal to 1.8 L/S. They dried up during last few drought years.

Instrumentation And Field Procedure

A new modern computerized type of resistivity meter was used in this study. The complete system consists of Syscal Jr switch-72 (IRIS) resistivity meter, portable computer, switching unit (link box), six reels of multi-core cables with take-out at electrode points, 72 electrodes and their jointing wire, car battery and chargers. The multi-core cables are of reverse type and have take-out string equal to 10m (a=10m).

Syscal Jr switch-72 is a new all-in-one multimode resistivity imaging system; it is designed to perform automatically pre-defined sets of resistivity measurements with roll-along capability. The six strings of cable with 12-electrode take-out are connected together on the back of the resistivity meter. The EI system automatically energizes different electrodes (4-electrode per each reading) to measure apparent resistivities at new horizontal location and depth. A series of 72 stainless steel electrodes are driven 10 to 25 cm into the ground at a fixed interval equal to 10m. The total length of the spread was 720m.

Before going to the field, the sequence of datum points of measurement was prepared by using ELECTRII software. For the current study 812 datum points per each sounding have been plotted. The type of array used and other optimum field parameters such as amount of current &

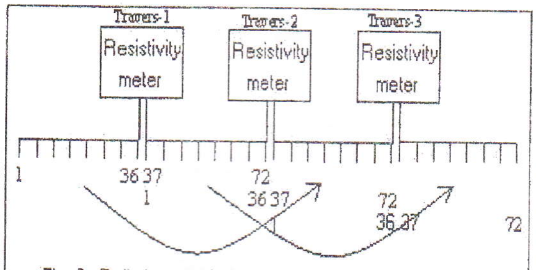


Fig (2) Roll alomg technique used for traverses 1,2 and 3

voltage, No. of minimum and maximum stacks, time and quality factor are tested and selected depending on a previous fieldwork in the area. These parameters were normally entered into a text file, which could be read by a computer program. After reading the control file the computer program then automatically selects the appropriate electrodes for each measurement and then stored in the computer. To obtain a good 2D picture of the subsurface and to get the best results, the measurements in the field carried out in a systematic manner so that, as far as possible, all the possible measurements are recorded. This will affect the quality of interpretation model obtained from the inversion of the apparent resistivity measurements [12].

The choice of the best array for the field survey depends on the type of the structure to be mapped, the sensitivity of the resistivity meter and the background noise level. Wenner array technique was selected, for the five traverses, due to its strong signal strength and its sensitivity to vertical changes in the subsurface resistivity. The Wenner array is good in resolving vertical changes (i.e. horizontal structures), which is the geological characteristic of the subsurface area. Only for the traverses close to the Sinjar Formation out crops the roll along technique was used. Detail about this technique is given in fig (2).

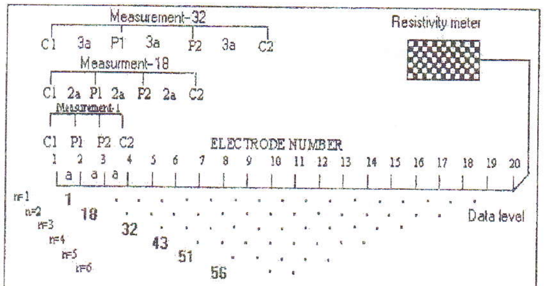


Fig (3) Location of datum points for Wenner arrangement.

Pseudosection Data Plotting

To plot the field data, the pseudosection contouring method is normally used; the horizontal location of the points that placed at the mid-point of the set of electrodes was used to make that measurement. The vertical location of the plotting point is placed at a distance, which is proportional to the separation between the electrodes. Another method, has been used in the present study, is to place the vertical position of the plotting point at the median depth of investigation, or pseudo depth of the electrode array has been used Fig (3).

The pesudosection of the sounding gives approximate picture of the true resistivity distribution and it is also considered as an initial guide for further quantitative interpretation. Other useful practical application of these pseudosections is for picking and removing bad apparent resistivity. Such bad measurement usually stands out as points (spots) with high or low values.

Data Inversion and Interpretation

The inversion of resistivity data is inherently non-unique. To obtained a mode that is closest to the real geology, other available information should be included in the inversion process in the form of constrains, [13]. The inversion of the sounding is carried out by RES2DINV,

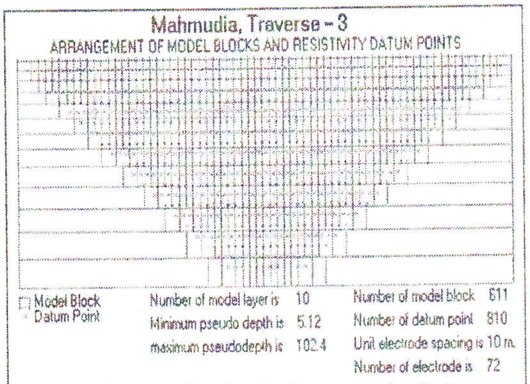


Fig (4) Subdivision of the subsurface into rectangular blocks

which is a computer program that will automatically determine a two-dimensional resistivity of model the subsurface for the data obtained from electrical imaging surveys. The 2D model used by the inversion program consists of a number of rectangular blocks as shown in Fig (4).

The arrangement of the blocks is loosely tied to the distribution of the data points in the pseudosection. The program automatically chooses the optimum inversion parameters for a data set. However, the inversion parameters are modified in this study depending on the geological situation of the field. Geological and structural survey of the area as well as geological column of the well are included constraining the inversion process.

Another important factor is the quality of the field data; good quality data usually show a smooth variation of apparent resistivity values in the pseudosection. All the soundings give very good quality, little appearance of irregularity and spots that show high or low resistivity than surrounding have been seen.Bad data points are removed from the data set to avoid their effect in the process of inversion. These data are exterminated by the aid of plotting the data in profile from that helps to highlight the bad datum points and remove them from the data set manually, Fig (5).

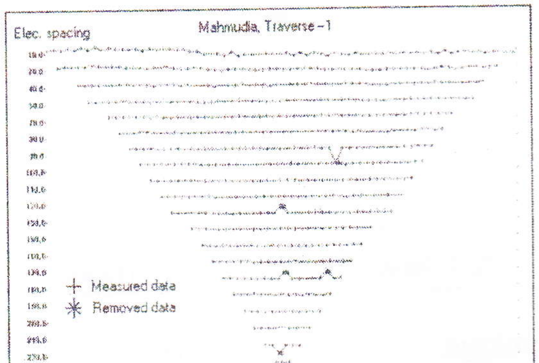
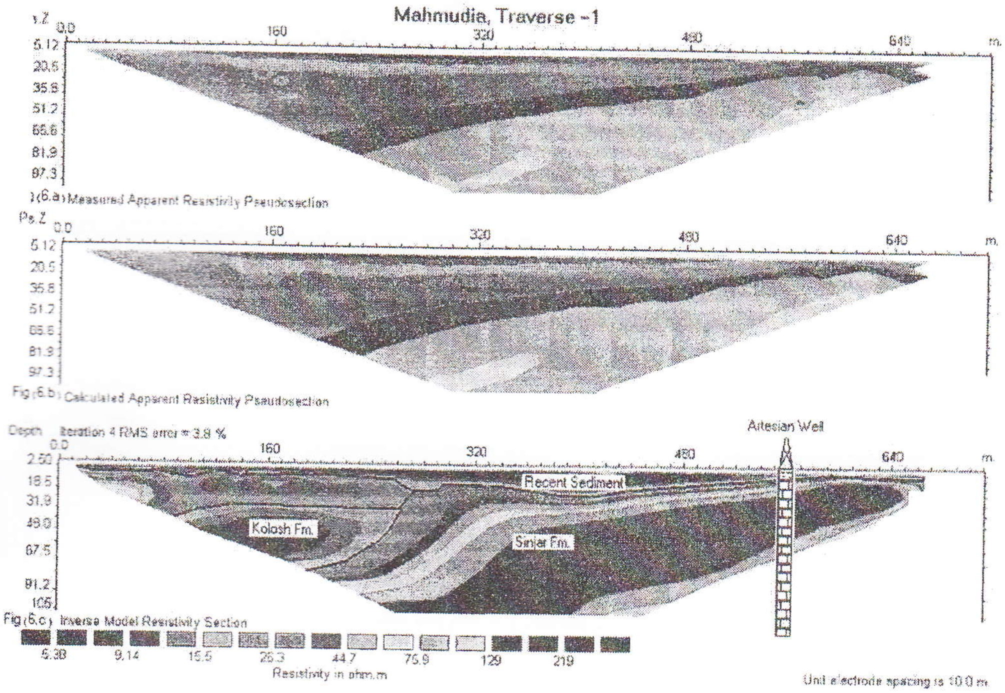


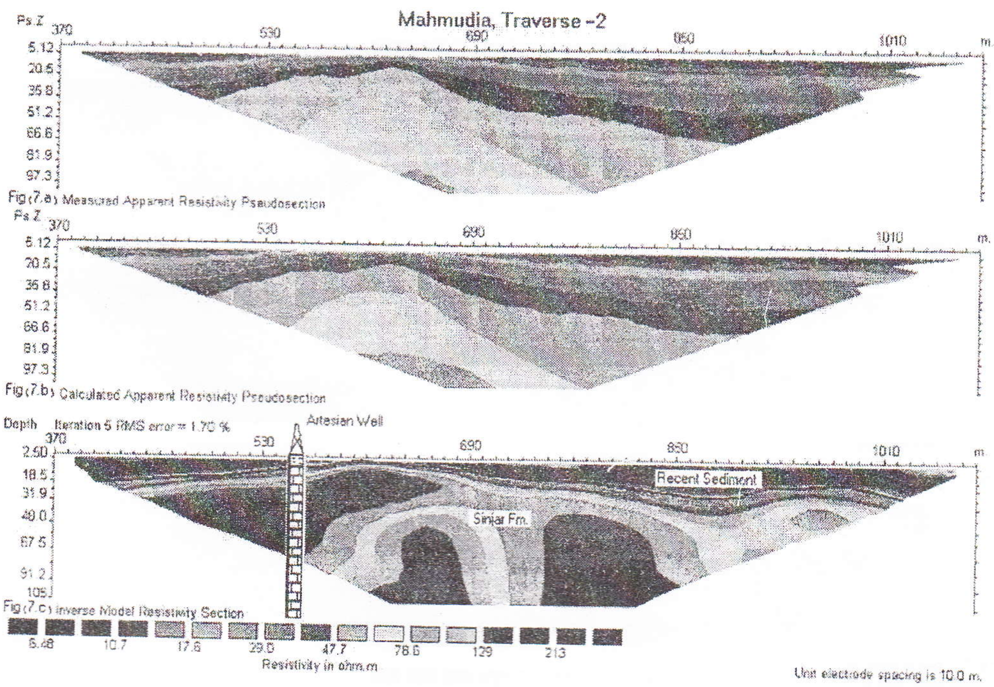
Fig (5) Exterminate of bad datum point manually

The inversion of the soundings is carried out using two mathematical methods, finite-elements and finite-difference. No significant variations were detected between the inverse sections calculated by these two methods, except that the resistivity of Sinjar Formation at depth 90m. was higher slightly.

The large ridge of Sinjar rocks cropping out NE of Mahmudia village, most likely, represents inter-fingering feature rather than a remaining sliding block from the large eroded anticline of the Bazian Basin. The two main evidences supporting this situation are its strike (= 130°) and the direction of the dip (=220°), which are the same as the strike and dip of the two outer NE & SW limbs of the major anticline.

The first traverse, Fig (6), shows a very nice picture of the subsurface. The top section, Fig (6.a), represents plotting of measured apparent resistivity in the field. The section displays a very good quality data. The resistivity increases gradually with depth and it is range between 4 and 50 ohm.m. Calculated apparent resistivity pseudosection, Fig (6.b), is similar to the measured apparent resistivity except that slight smoothing in some places was made and some spots have been removed. The last section, Fig (6.c), shows inverse model resistivity section, which represents the true


Mahmudia, Traverse -1
Ps.Z
0.0
160
320
480
640
m.
5.12
20.5
35.8
51.2
66.6
81.9
97.3
Fig (6.a) Measured Apparent Resistivity Pseudosection
Fig (6.b) Calculated Apparent Resistivity Pseudosection
Depth
Iteration 4 RMS error = 3.8 %
Artesian Well
2.50
18.5
31.9
48.0
67.5
91.2
105
Recent Sediment
Kolosh Fm.
Sinjar Fm.
Fig (6.c) Inverse Model Resistivity Section
5.38
9.14
15.5
26.3
44.7
75.9
129
219
Resistivity in ohm.m
Unit electrode spacing is 10.0 m.


Mahmudia, Traverse -2
Ps.Z
370
530
690
850
1010
m.
5.12
20.5
35.8
51.2
66.6
81.9
97.3
Fig (7.a) Measured Apparent Resistivity Pseudosection
Fig (7.b) Calculated Apparent Resistivity Pseudosection
Depth
Iteration 5 RMS error = 1.70 %
Artesian Well
2.50
18.5
31.9
48.0
67.5
91.2
105
Recent Sediment
Sinjar Fm.
Fig (7.c) Inverse Model Resistivity Section
6.48
10.7
17.6
29.0
47.7
78.6
129
213
Resistivity in ohm.m
Unit electrode spacing is 10.0 m.

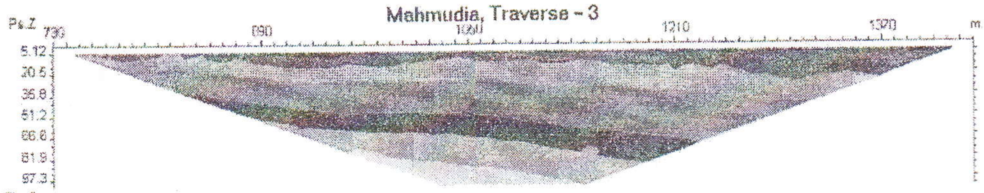


Fig (8.a) Measured Apparent Resistivity Pseudosection

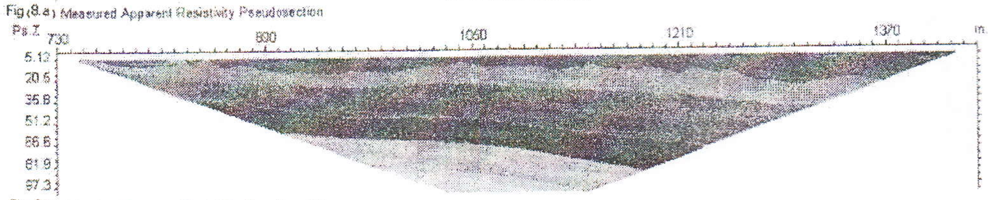


Fig (8.b) Calculated Apparent Resistivity Pseudosection

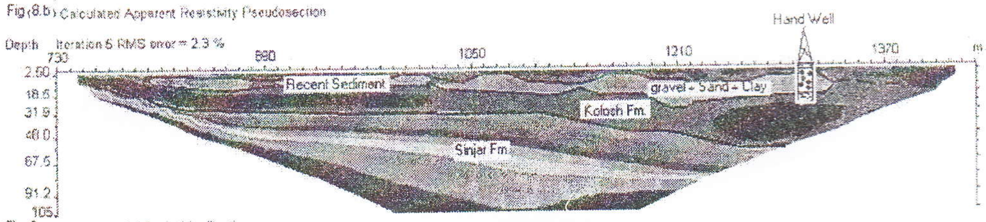
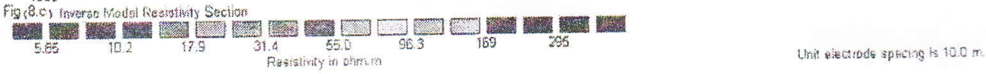


Fig (8.c) Inverse Model Resistivity Section



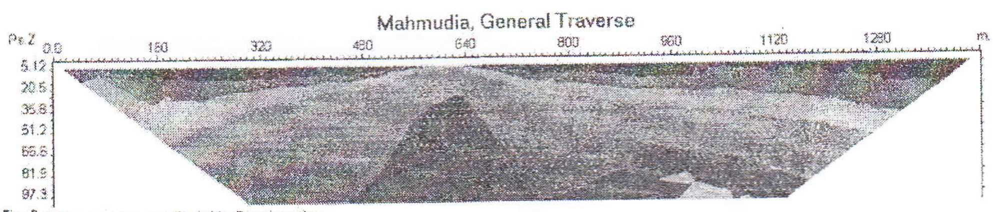


Fig (9.a) Measured Apparent Resistivity Pseudosection

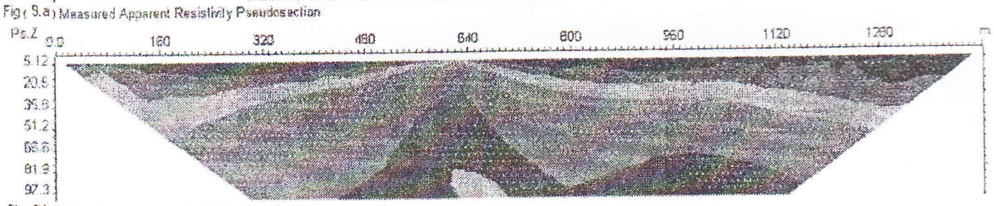


Fig (9.b) Calculated Apparent Resistivity Pseudosection

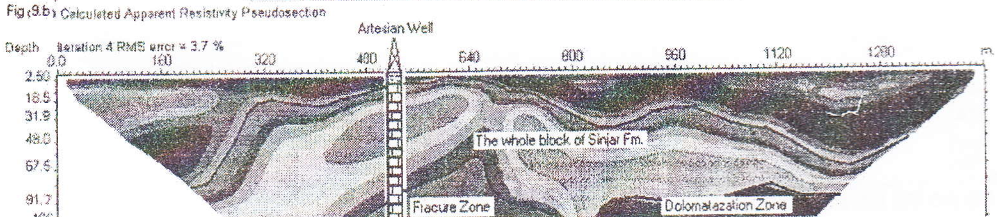


Fig (9.c) Inverse Model Resistivity Section

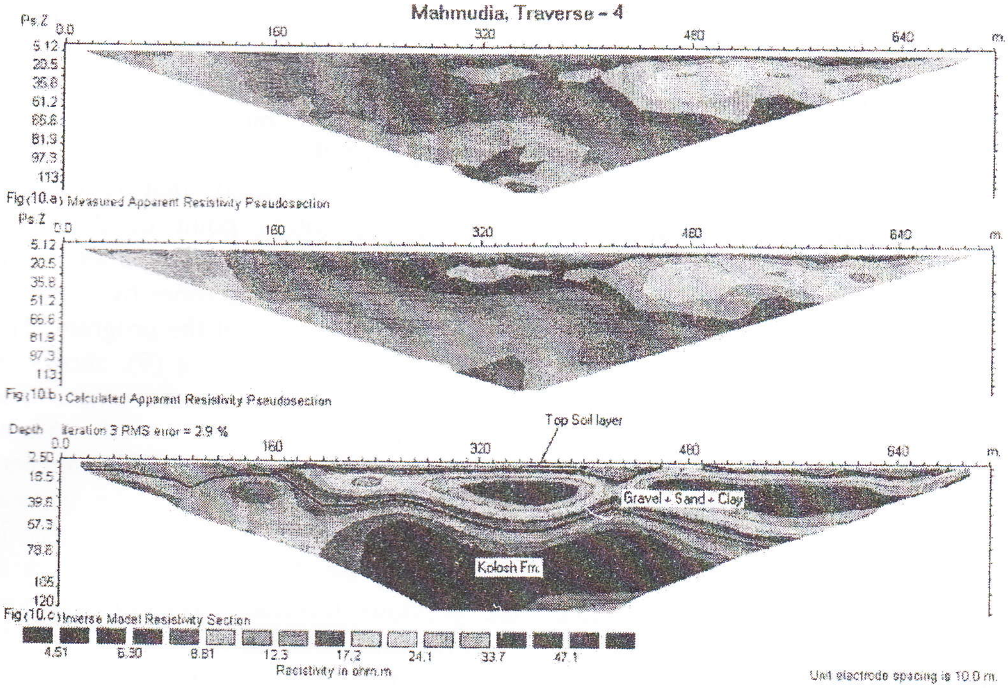


Fig.(10.a) Measured Apparent Resistivity Pseudosection

Fig.(10.b) Calculated Apparent Resistivity Pseudosection

Fig.(10.c) Inverse Model Resistivity Section

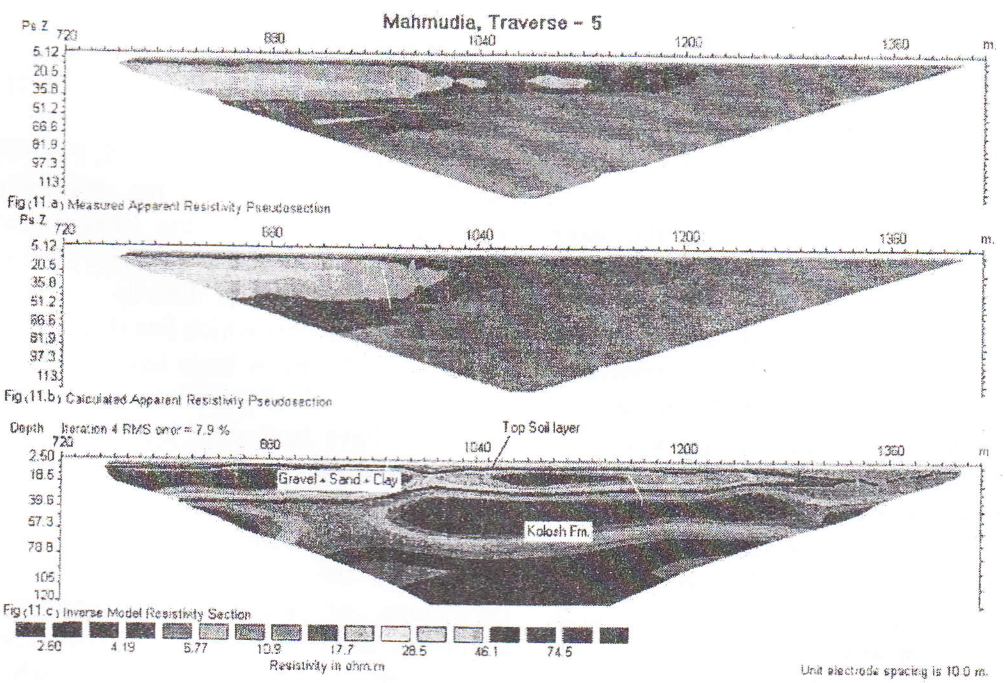


Fig.(11.a) Measured Apparent Resistivity Pseudosection

Fig.(11.b) Calculated Apparent Resistivity Pseudosection

Fig.(11.c) Inverse Model Resistivity Section resistivity of subsurface materials. A soil cover, blue color, of low resistivity ranges between 6 to 12 ohm.m and thickness of (1-20) m, is covering two different types of high resistivity materials. The first is located beneath electrodes (1 to 24) at depth of (6-9) m. It is composed of gravel, sand and clay materials of recent sediment underlain by low resistive Kolosh Formation. The second high resistive material is Sinjar Limestone Formation, which is cropping out 10 m NE of electrode 62, beside the well. NW direction, the rock unit of Sinjar Formation is buried to the depth of about 81 m below the location of electrode 19. The boundaries between different geological materials were identified depending on available lithological information from an artesian well, which have 120 m depth, and a hand dug well, 21 m depth. The resistivity of the Sinjar rock units have a wide range; it changes from 38 to 502 ohm.m, due to several factors such as; lateral change of physical properties, facies change, percentage of fracture and amount of dissolving materials in groundwater.

The general look at traverses 2 and 3, Fig (7 and 8), show the extension of the same geological situation of traverse one with slight differences. The near surface aquifer is also composed of gravel, sand and clay sediments, verified by coinciding geological column of the hand dug well at the location of electrode 115. The extension of this aquifer is interrupted by a large mass of pure clay materials below electrodes (88 to 103). So we can say that impermeable Kolosh Formation, which covers Sinjar limestone Formation in the whole area, underlies the near surface aquifer. The rock unit of Sinjar Limestone Formation, forms an excellent aquifer, the artesian well yield 14.6 L/S, has a depth starting from 4 m near electrode 66 to about 75 m below electrode 125 toward SW direction. This aquifer is traced to a depth of 105 m, which is the maximum depth of investigation.

For the sake of more illustration and comparison of the results a general cross section was constructed, that is through gathering the datum point of the three previous traverses in one single file. This file is interpreted several times by changing the default parameters of the program. The general inverse section, Fig (9), shows an obvious picture of the subsurface. The major inter-finger block of Sinjar Limestone Formation is clearly appears extending laterally 1200 m. The general section shows two characteristic phenomena, which were not appearing in the previous traverses. The first is low resistive zone detected below electrodes 46 to 65 at the depth of 55 m, which refers to highly fracture zone in the limestone beds. The Second high resistive zone detected at 90 m depth beneath electrode 85 to120 is more probably indicating dolomitization zone, which is wide spread in Sinjar Formation.

The other two traverses, 4 and 5, Fig (10) and Fig (11), clearly show the absence of Sinjar Formation while the impermeable Kolosh Formation occupy the large portions of the section and it is directly underlays the recent sediments which has thickness of about (10 to 42) m. A large lensoidal facies which composed of gravel, sand and clay sediments have been detected and it has a lateral extension about 1250 m. It forms the near surface aquifer and it is, most probably, the extension of near surface aquifer of the previous traverses. The percentage of gravel, sand and clay sediments could be easily identified from the increasing of the resistivity, which refers to increasing the ratio of gravel and sand, and decreasing the ratio of clay sediments, especially beneath location of

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گۆڤاری زانکۆی سلێمانی کانونی یەکەم ٢٠٠٥بەرگ ٨ (١) بەشی A لاپەڕە(٧-١٦)

بەکارهێنانی بەرگری کارەبایی دوو ئاراستە بۆ گەڕان بەدوای ئاوی ژێر زەوی لە گوندی مەحمودی یە ، ڕۆژئاوای شاری سلێمانی، هەرێمی کوردستان

بەختیار قادر عزیز

بەشی جیۆلۆجی / کۆلێجی زانست / زانکۆی سلێمانی /هەرێمی کوردستان -عێراق

پوختە

بەرگری کارەبایی دوو ئاراستە یەکێکە لەو ڕێگا جیۆفیزیاوی یانەی کە لەم چەند ساڵەی دوایی دا پەرەی سەندوە. بەهۆی ئەم تەکنیگەوە ئەتوانرێت چەندین مۆدێلی دوو یان سێ ئاراستە بۆ چینەکانی ژێر زەوی دروست بکرێت. ئەم ڕێگایە گەلێك بەکارە بۆ وەرگرتنی زانیاری لەسەر دابەش بوونی ئامارە ئاوی یەکانی ژێر زەوی، چینە وشکەکان، ڕووی نێوان چینە خۆڵەکان و بەردەکان، هەروەها درزو کەلێنە بەردی یەکان. یەکەم جارە ئەم ڕێگایە بەکاردێت لە عێراق دا ئەویش لە گوندی مەحمودی یە لە ڕۆژهەلاتی شاری سلێمانی. پێنج هێلی پشکنین وەرگیرا وە زیاتر لە ٤٠٠٠ خوێندنەوە تۆمارکرا بە بە کارهێنانی تەکنیکی وینەر (Wenner) . پاش شیکردنەوەی زانیاری یەکان بە پرۆگرامی کۆمپیوتەری (RES2DINV)دەرکەوت کە دوو ئاماری ئاوی جیاواز لە خەسلەتی فیزیاوی دا هەیە. یەکێکیان لە ناو چینە تازە نیشتوەکان (Recent Sediments) دایە و ئەوی تر لە ناو پێکهاتەی بەردی سنجاردایە (Sinjar Formation). ئەم دوو ئامارە ئاوی یە ئەتوانرێت دابنرێت بە دوو سەرچاوەی گرنگی ئاو لە ناوچەکە بۆ مەبەستی خواردنەوە و کشت و کاڵ.

المسح الكهربائى المجسم كادآة لتحرى عن المياه الجوفية فى قرية المحمودية، غرب مدينة السليمانية، اقليم كردستان

بختيار قادر عزيز

قسم الجيولوجى / كلية العلوم / جامعة السليمانية

الخلاصة

المسح الكهربائى المجسم هو احدى الطرق الجيوفيزيائية التى تطورت خلال السنين القليلة الماضية، تعطي هذه الطريقة تصوير ذات بعدين او ثلاثة ابعاد عن الطبقات التحت السطحية. يعتبر هذا التكنيك فعال جدا للحصول على المعلومات عن توزيع خزانات مائية، طبقات غير نفاذة، حد الفاصل بين التربة و الطبقات الصخرية وكذالك ايجاد اماكن الفوالق و الكسور و الفواصل. استخدمت هذه الطريقة لاول مرة في العراق في قرية المحمودية شرق مدينة السايمانية. تم مسح خمسة مقاطع كهربائية و سجلت اكثر من ٤٠٠٠ قراءة باستخدام اسلوب فينر (Wenner). فسرت المعطيات بواسطة برنامج الحاسوب (RES2DINV). اكدت نتائج التفسير بوجود خزانين للمياه الجوفية مختلفين في الصفات الفيزياوية . الاول ظهر في الطبقات الحديثة (Recent Sediments) و الخزان المائي الثانى وجد في طبقات الحجر الجير لتكوين سنجار (Sinjar Formation). يمكن اعتبار هذين الخزانين كمصدر رئيسي للمياه الشرب و الزراعة في المنطقة.

Received on 3/1 /2004 .Accepted 21 / 4/ 200 4 .

وەرگیرا لە ٣/١/ ٢٠٠٤ دا وپەسەندکرا ٢١/٤/ ٢٠٠٤.