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Delineation of the Contacts between various formations in the Hit-Kubaiysa area using the 2-D electrical resistivity method

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Abstract:

The 2D electrical resistivity method was applied in four selected locations between Hit-Kubaiysa regions, Al- Anbar Governorate, western Iraq. This technique was implemented using the Wenner-Schlumberger array in four survey lines, each line covers 1190m distance. The robust least squares method was used for obtaining the inverted models. The absolute error percentage was less than 0.1%. On the lights of interpretation results, two zones were delineated in the locations of two inverted sections: the first zone represents the Euphrates Formation, while the second zone represents the Dammam Formation. While, in the locations of the other two sections, three zones were found: the first zone represents the Euphrates Formation, the second zone represents the Ana Formation that lies under the Euphrates Formation forming thin beds with a thickness ranging between (10-15 m) approximately, and the third zone represents the Dammam Formation. It is also concluded that the resistivity method is a powerful tool in detecting the contact between the various deposits, even when there is convergence in resistivity contrast if it is applied in a perfect manner theoretically and in the field.

Keywords: 2D Resistivity; robust inversion; contacts delineation, electrical methods

تحديد الحدود الفاصلة بين عدة تكوينات في منطقة هيت- كبيسة باستخدام طريقة المقاومة الكهربائية ثنائية الأبعاد

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الخلاصة

تم تطبيق طريقة المقاومة الكهربائية ثنائية الأبعاد في أربعة مواقع مختارة بين منطقتي هيت-كبيسة، ضمن محافظة الأنبار، غرب العراق. تم تنفيذ هذه التقنية باستخدام ترتيب فنر-شلمبرجير في أربعة خطوط، يغطي كل خط مسافة 1190 مترًا. تم استخدام طريقة المربعات الصغرى القوية للحصول على الموديلات المعكوسة. كانت نسبة الخطأ في القيمة المطلقة أقل من 0.1٪. على ضوء نتائج التفسير ،تم تحديد نطاقين في اثنين من المقاطع الجيوكهربائية المعكوسة : يمثل النطاق الاول تكوين الفرات، بينما تمثل المنطقة الثانية تكوين الدمام. بينما في المقطعين الاخرين تم تحديد ثلاثة انطقة : يمثل النطاق الاول تكوين الفرات، والنطاق

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الثاني يمثل تكوين عانه الذي يقع تحت تكوين الفرات بشكل طبقات رقيقة بسمك يتراوح بين (10-15 مترًا) تقريبًا، بينما يمثل النطاق الثالث تكوين الدمام. كما استنتج أن طريقة المقاومة النوعية الكهربائية هي طريقة فعالة في كشف الحدود بين الرواسب المختلفة، حتى عندما يكون هناك تقارب في تباين قيم المقاومة، إذا تم تطبيقها بطريقة مثالية نظريا وحقليا.

1. Introduction

Geophysics has played a useful part in subsurface investigations for many years and gets better results in their various and wide applications. The Electrical resistivity method is one of the geophysical methods that were developed in the early twentieth century, but it has become widely applied since the seventies as a preliminary step in groundwater-bearing layers exploration such as determining the thickness, source of water, location, extension and the depth of these layers in a 2-D form [1], [2].

The 2-D electrical methods are considered to be the most suitable tool for, groundwater investigation, cavities, delineating the boundaries of the formations, and the contact between the sedimentary cover and the basement [3], [4], [5], [6] Delineation of the contacts between the geological formations is an important issue in determining the groundwater bearing zones.

The study area and surroundings have been investigated using different techniques. . Mohammed et al.[7] used the Vertical Electrical Sounding (VES) and 2D resistivity in determining the distribution of pollution in groundwater in the Hit area. Ali, [8] studied the geological situation using the radioactivity evidence in Hit – Kubaiysa, the results showed that many areas have high radiation concentrations, and based on that, the extension of the Abu Jir faults zone was delineated. Noon,[9] investigated the groundwater using a 2D electrical resistivity imaging technique in Western Ramadi, southern of the study area, the result was good in showing the lateral and vertical variations of resistivity and thickness within each electrical horizon for shallow depths. More studies using the resistivity technique were conducted in different areas of Iraq such as Al-Juboury et al., [6] determined the groundwater aquifers southwest of Samawah City, southern Iraq, by using a 2D resistivity imaging survey. Zghair et al., [10]using 2D electrical resistivity imaging to evaluate soil investigations at Palm Towers within Al-Muthannā Airport land., Baghdad, Iraq, and the result was a good way to evaluate the soil.
Because of the large resistivity transition zone in the reverse section, it is difficult for the interpreter to determine the boundaries between the groundwater aquifer layers and the surrounding layers. When there is a boundary between clastic and non-clastic sediments, it is very effective to minimize this broad zone to a narrow one. However, the robust inversion of apparent resistivity reduces a transition zone between an aquifer and above or beneath impermeable layers,[11][12], and gives sharp edges, which enables us to define the boundaries between the layers more accurately. Therefore, this study is an attempt to identify a boundary between the groundwater aquifer layers and surrounding sediments by applying the 2D ERM surveys at various locations with different rock layers with the guide of the lithology and the thickness of the beds in the well that was previously drilled by the General Commission for Groundwater. The accuracy of this method was then examined by using the reverse section to calibrate the well data with the 2D results.

2. The study area

2.1 Location of the study area

The study area is located between Hit and Kubaiysa areas within Al-Anbar governorate western Iraq as shown in Figure (1), the coordinates of survey lines in the study area are illustrated in Table (1)

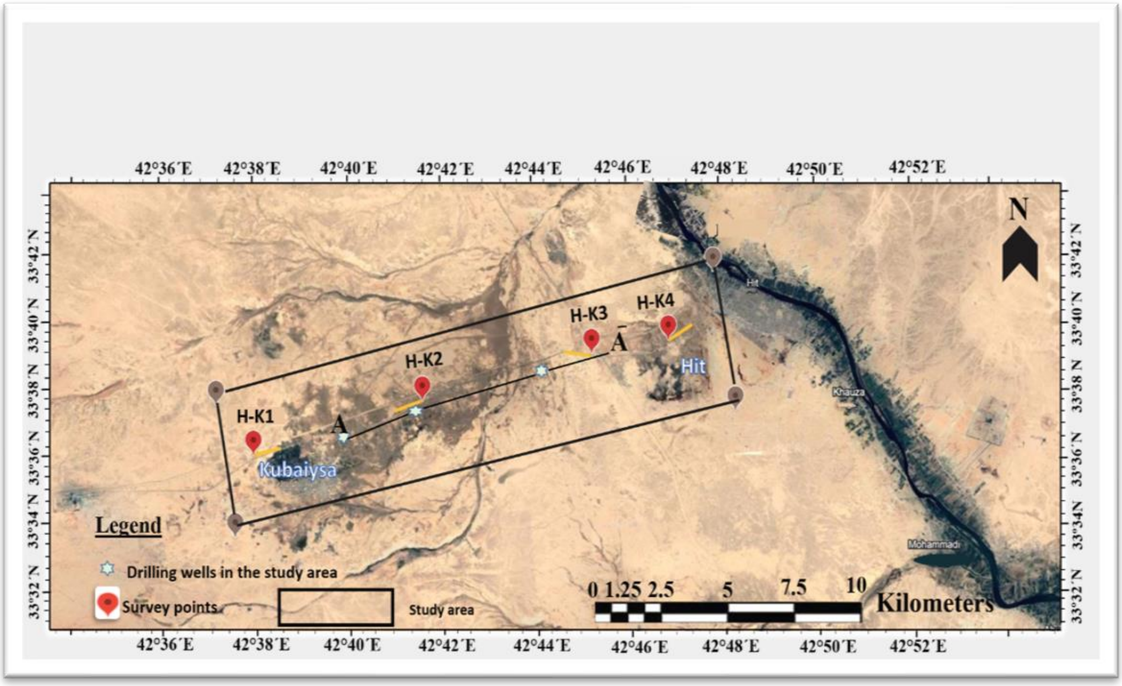

Figure 1: Hit- Kubaiysa area showing the locations of the four 2D resistivity lines (HK1, HK2, HK3 and HK4) carried out in current study.

Table 1: shows the coordinates of resistivity lines in the study area

Section name	Coordinates of the first electrode	Coordinate with UTM	Section direction
H-K1	N 33° 36′ 02.1" E 42°35′ 21.86"	N 3720475.74m E 276324.56m	N73°E
H-K2	N 33°36'52.88" E 42°40' 07.15"	N 3721871.62m E 283714.66m	N64°E
H-K3	N 33°37'32.48" E 42°44' 05.57"	N 3722926.89 m E 291175.37m	N90°E
H-K4	N 33°37'41.66" E 42°47' 04.85"	N 3723137.75 m E 294513.20m	N59°E

2.2 Geological conditions of the study area

The study area is located within the Abu Jir faults zone, which is a part of the stable shelf within the Afro-Arabian platform [13]. The Euphrates fault zone occupies most parts of the eastern edge, and the study area represents the border between the stable and unstable shelf[14]. This region consists of a group of faults that extend along the Euphrates River in southern Iraq and have the same direction and extend (northwest - southeast) in a narrow range. It composed of sedimentary rocks ranging from the middle Miocene to the lower Eocene covered with different types of Quaternary sediments (Fig.2). According to the drilling wells by General commission for Groundwater, 2014, as shown in figure (3), these sedimentary rocks consist of limestone with marl, which forms the Euphrates Formation, and limestone with dolomitic limestone, which forms the Dammam Formation, with sediments of a layer whose depth ranges from 0-5 m. consist of clay, sand and gravel that make up the Quaternary deposits. Jassim abd Goff, [13]stated that the study area is built up of sedimentary rocks ranging in age from lower Oligocene to Pliocene, with different types of Quaternary deposits (Pleistocene-Holocene), which serves as a drainage area for the flowing mineral water in the Hit-Kubaiysa area.

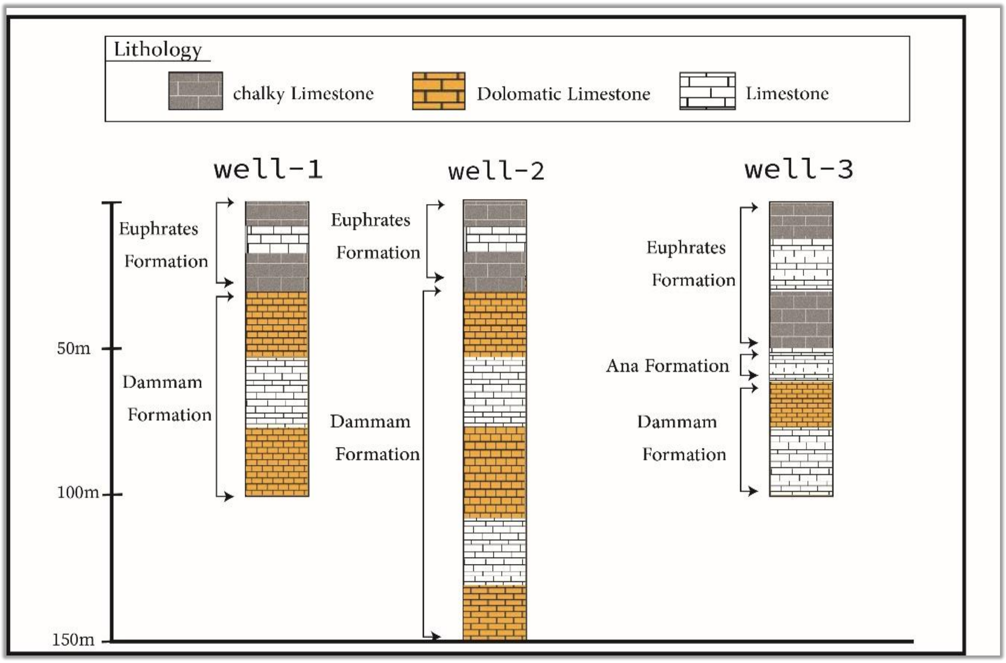

Figure 2: Stratigraphic columns show the drilling wells by the General Commission for Groundwater in the study area[15]

2.3 Hydrological setting of the area:

The Dammam Formation is considered a productive hydrogeological unit, which is a mostly confined aquifer, characterized by the presence of many fractures, cavities and karst materials, and these characteristics play a major role in the hydraulic properties of the reservoir and also in the distribution of groundwater. The flow of the groundwater in the study area is towards the Euphrates River[16].

3. Materials and methods

All fieldworks were done in cooperation with the General Commission for Groundwater, in addition, the geological, hydrological, and topographical maps were collected from previous studies.

The SYSCAL Pro device was used to collect the geophysical data between Hit- Kubaiysa, directed NE in western Iraq. The Wenner–Schlumberger configuration was applied, to delineate the contacts between the formations in the study area. Four survey lines with 2D resistivity method were achieved, every line with a length of 1190 meters and 120 electrodes, and the electrode spacing is 10m was used for all lines, and many sites were determined to cover the study's aims.

These lines were distributed along the study area, where the Wenner-Schlumberger configuration is the same as the Schlumberger configuration when (n) factor = 2 measurements, whereas, (n) factor (is the ratio of the space between the potential pairs (a) to the electrodes (na). According to Loke, [17] as the factor "n" increases, the sensitivity increases and becomes more concentrated under the central electrode (a) from 1 to 6, the sensitive patterns of the Wenner-Schlumberger array as the n-factor rises more than 1 (Wenner array) to 6 (Schlumberger array).

The PROSYS II program was used to remove bad data (noise that is usually caused by failure during the survey, examples include breaks in the cable, very poor ground contact at an electrode, forgetting to attach the clip to the electrode, connecting the cables in the wrong direction etc.) If there was a small amount of bad data, it could be removed manually using the manual filter; if there was a large amount of bad data, it could be removed automatically using the automatic filter [18], [19]. In order to reduce the RMS error ratio, the second step of the RES2DINV program is carried out in two ways: first, by selecting the bad data from field data in profile form, and secondly, by removing the percentage of bad data from the bar chart before repeating the iteration of the inversion subroutine [20], [21].

In the next step, data was processed using RES2DINV software, which uses mathematical algorithms to determine the best subsurface resistivity model, using Finite-difference due to the topography in the study area, the inversion method using the Robust Inverse Model Constraints Method due to its capability to visualize the distinct limits separating resistivity contrast zones by minimize the total absolute values of the spatial variations in the resistivity model [22], [23].

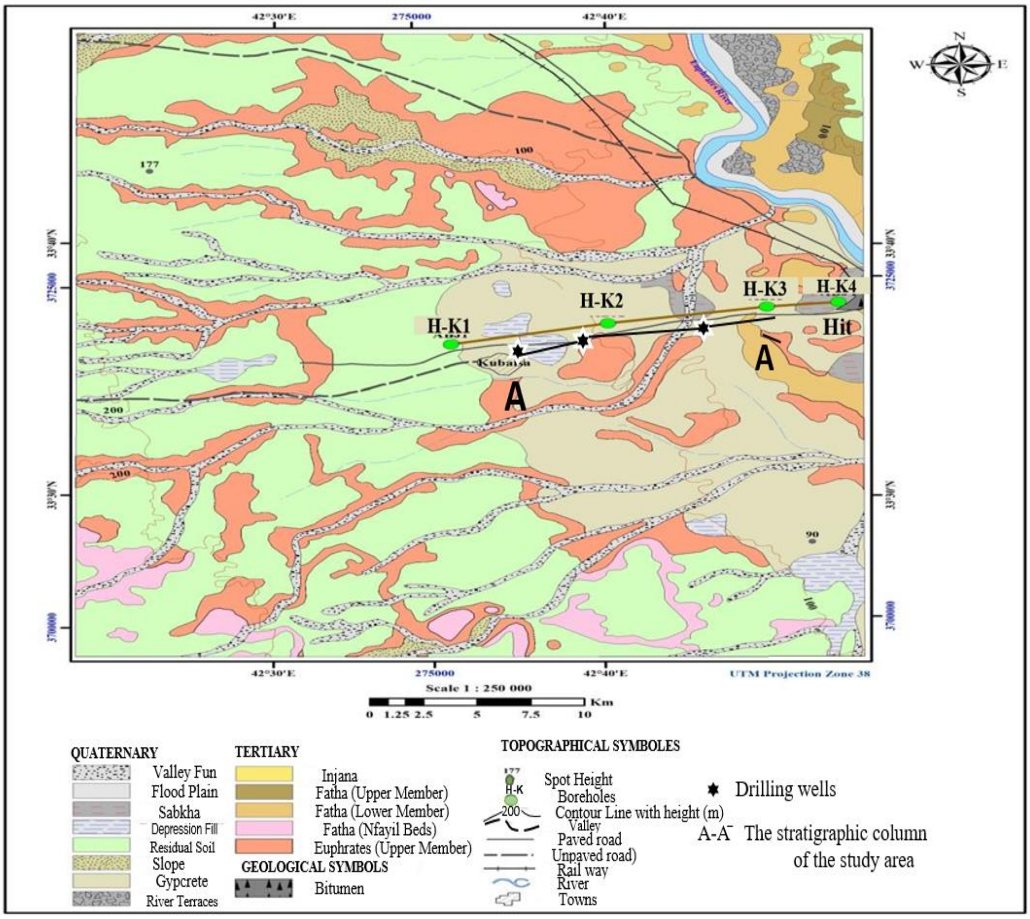

Figure 3: the geological map of the study area and the surroundings [13]

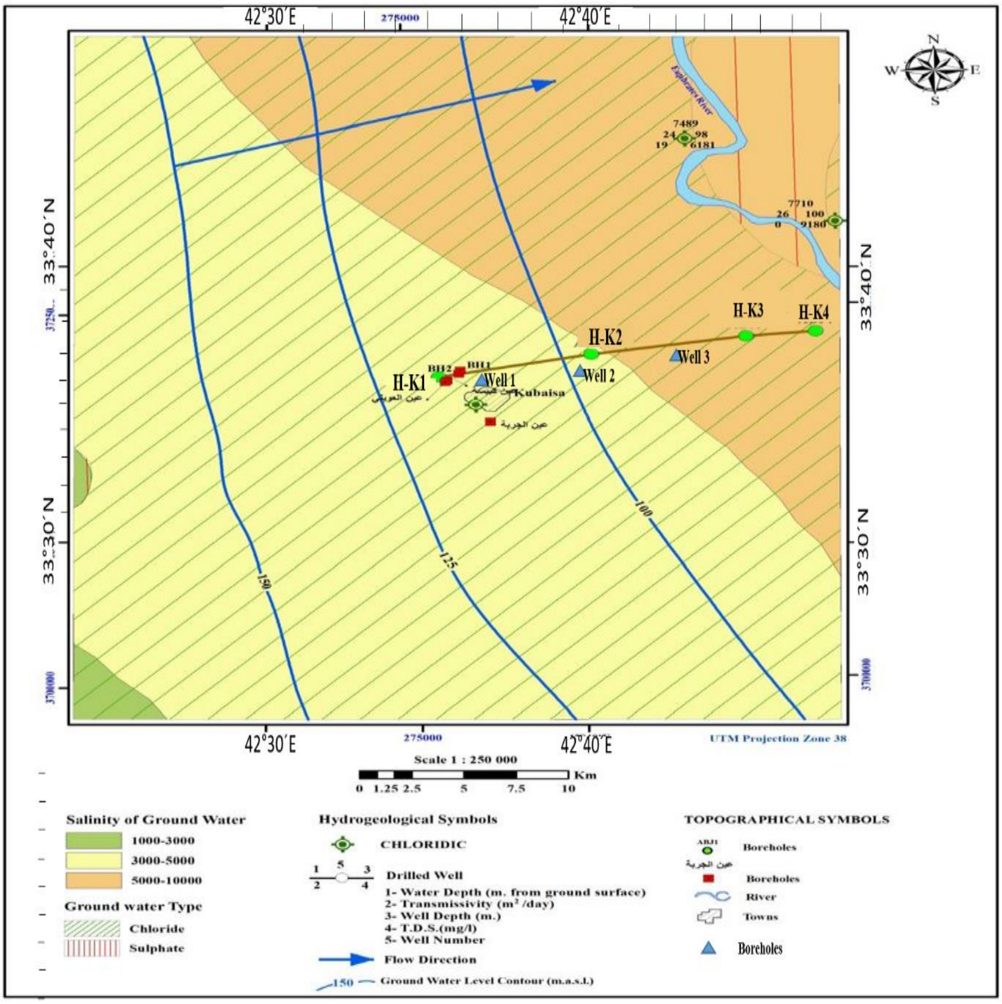

Figure 4: Hydrological setting of the area showing the flow direction [13]

4. results and discussion:

The inverse model H-K1 shows two main resistivity zones as shown in Figure (5), which can be described from the youngest layers to the oldest as follows:

The first zone represents the Euphrates Formation with quaternary deposits comprised of gravel, sand, limestone, and marl, according to the information of the drilling wells (well1 about 460m west of the first line) (fig. 3) in the study area by the General Commission for Groundwater., The resistivity of this zone ranges from (6.26 - 19.6) ohm.m with a depth of about 35m.

The second zone represents the Dammam Formation, starting from the ground surface to the depth of 35m level, related its resistivity ranges between (19.6 – 108) ohm.m, and composed of limestone and dolomitic limestone.

The inverse model H-K2 shows two main resistivity zones, as shown in Figure (6). The resistivity gradually increases with depth, due to the nature of Al-Dammam Formation sediments, which consist of solid limestone and dolomitic limestone, which are characterized by high resistivity, so that's why the resistivity increases with depth the section could be described from the youngest layers to the oldest as follows: The first zone represents the Euphrates Formation with a depth of 35m, covered with quaternary deposits. its resistivity ranges between (3.54- 19.6) ohm.m. This zone is composed of limestone and marl, according to the information of drilling well 2 in the Zaltouh village area, about (340m) from the second line survey, as shown in Figure (3).

The second zone represents the Dammam Formation, with a depth starting from 35m and resistivity range between (19.6 - <108) ohm.m. It is composed of shaley limestone with dolomitic limestone, according to the drilling wells in the Zaltouh village area (well2), near the study area.

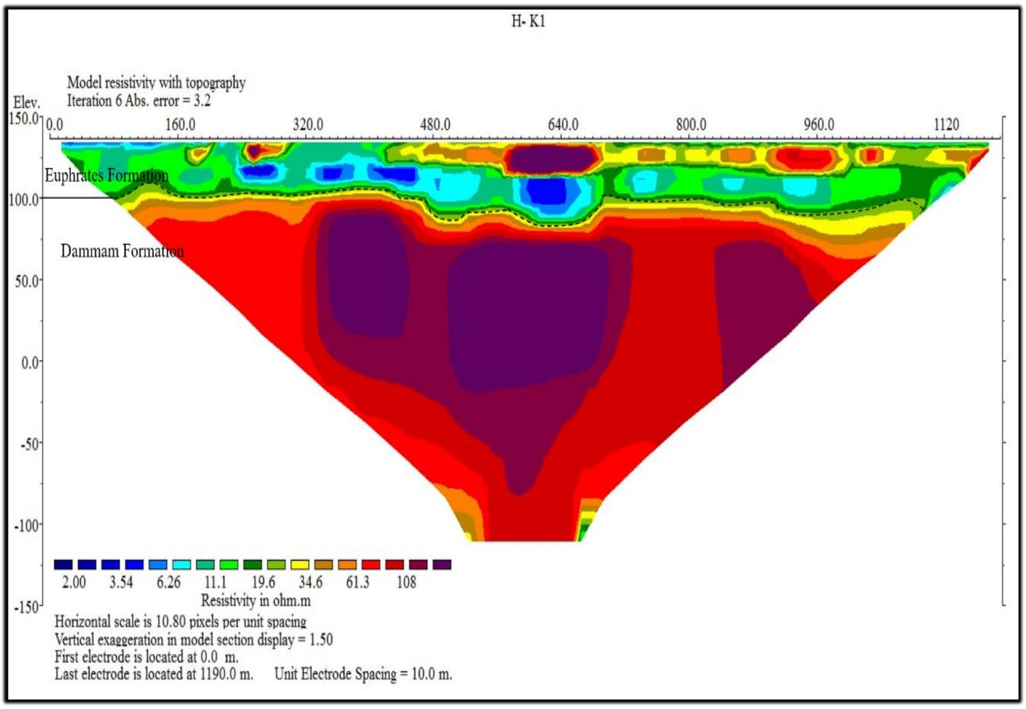

Figure 5 : Inverse model of survey line H-K1, the dashed line refer to the contact between the formations

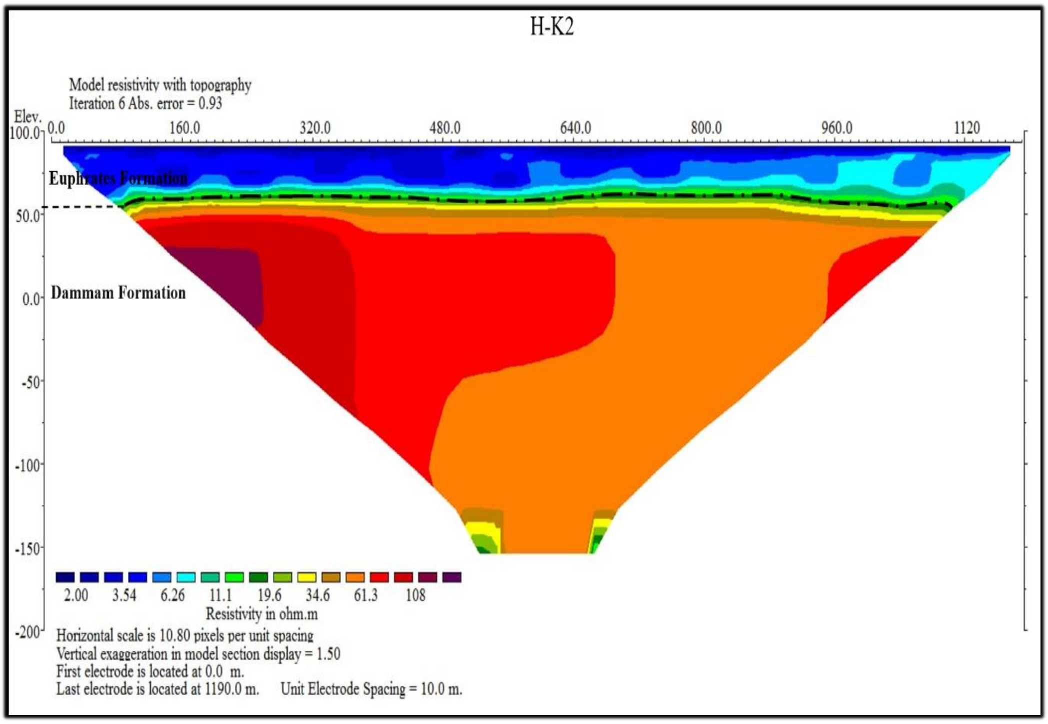

Figure 6 : Inverse model of survey line H-K2, the dashed line refer to the contact between the formations

The inverse model H-K3 illustrates three zones as show in figure (7):

The first zone represents the Euphrates Formation, comprised of limestone with marl which corresponds with the stratigraphic column of well3 which is about 329m from the third survey line (fig. 3). Its depth extends about (110m) from the surface, with resistivity values ranged from (3.54-19.6) ohm.m.

The second zone represents the Anah Formation, with resistivity values reaching (19.6-34.6 ohm.m), its depth about (123 m) from the ground surface level with a thickness of about 13m. It is composed of solid limestone, according to drilling well (well3) (Fig.3).

The third zone represents the Dammam Formation, which is composed of limestone with dolomitic limestone; according to the drilling well (well3) as shown in figure (2), its depth starts from 123m from the ground surface.

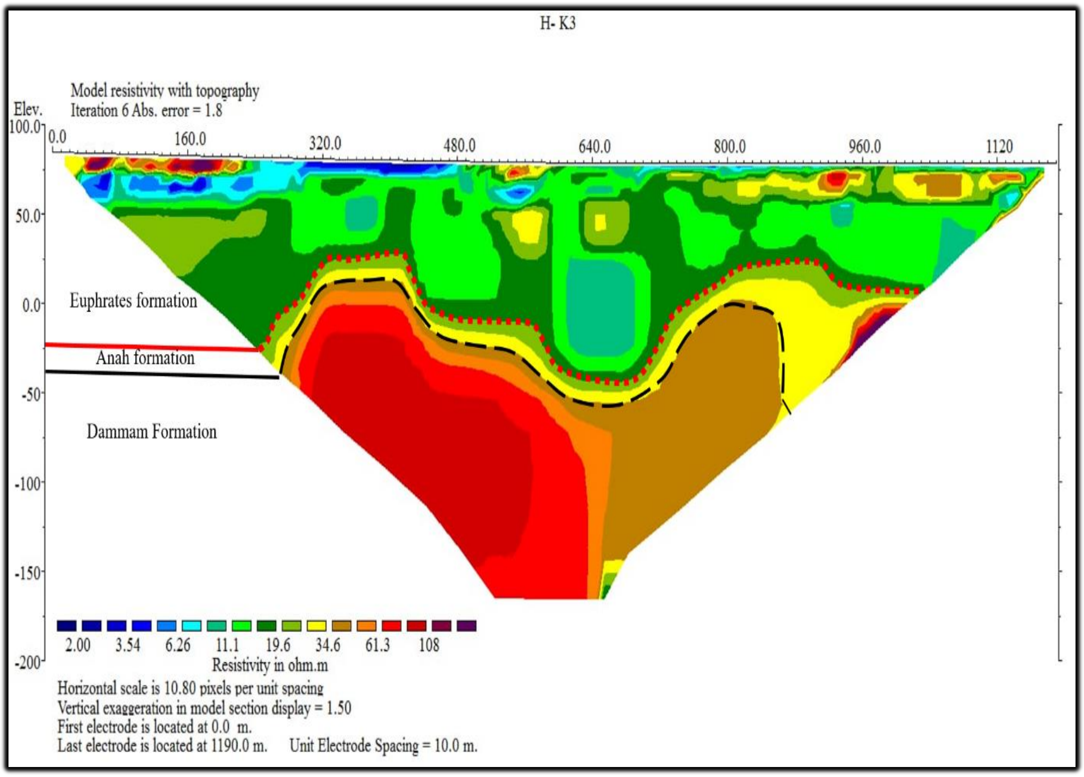

Figure 7: inverse model of survey line H-K3, the dashed line refers to the contact between the formations

The inverse model H-K4 illustrates three zones as shown in Figure (8):

The first zone represents the Euphrates Formation, consisting of thin layers of secondary gypsum interspersed with layers of marly limestone from the Fatha Formation [24], it's depth of about (74m) from the surface, with resistivity ranging between (3.54-19.6) ohm.m.

The second zone represents the Anah Formation, which appears as a thin layer with a thickness of about 12m, and a depth of about (88m) from the ground surface, composed of massive limestone [24].

The third zone represents the Al-Dammam Formation composed of limestone with dolomitic limestone [24], [25] its depth starts from (88m) from the ground surface level, and its resistivity gradually increases with depth, ranging from (34.6-108) ohm.m.

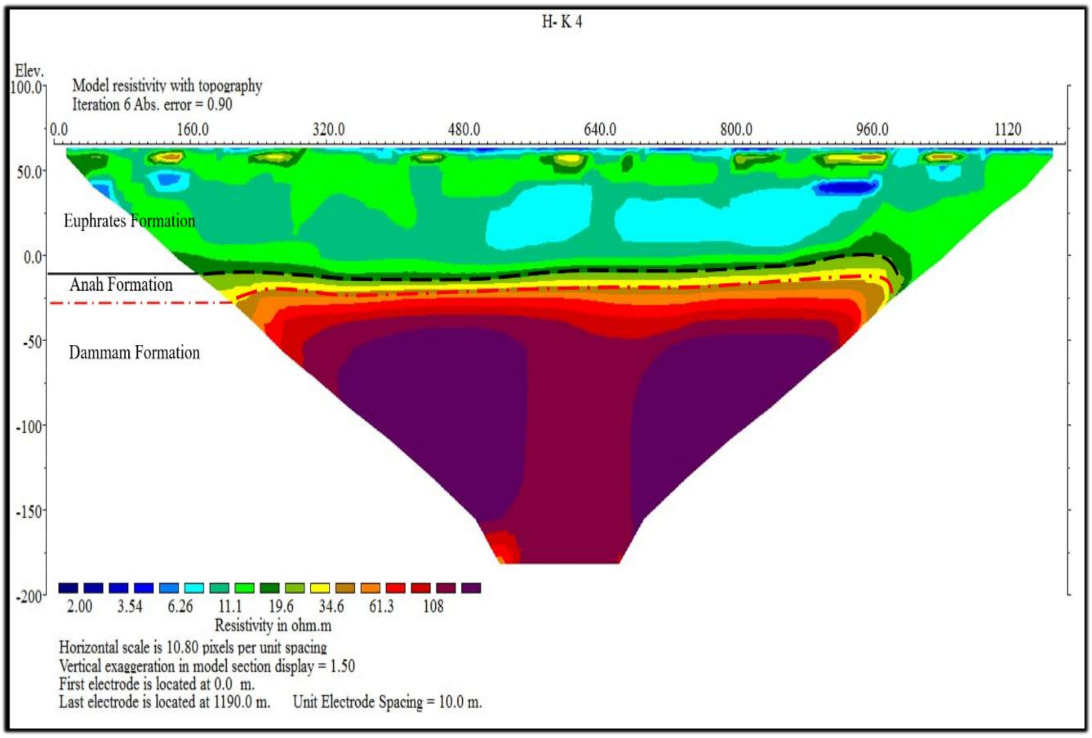

Figure 8 : inverse model survey of H-K4, the dashed line refers to the contact between the formations

The final potential image for the boundary between the geological formations with their values of resistivity in the study area is shown in Figure 9.

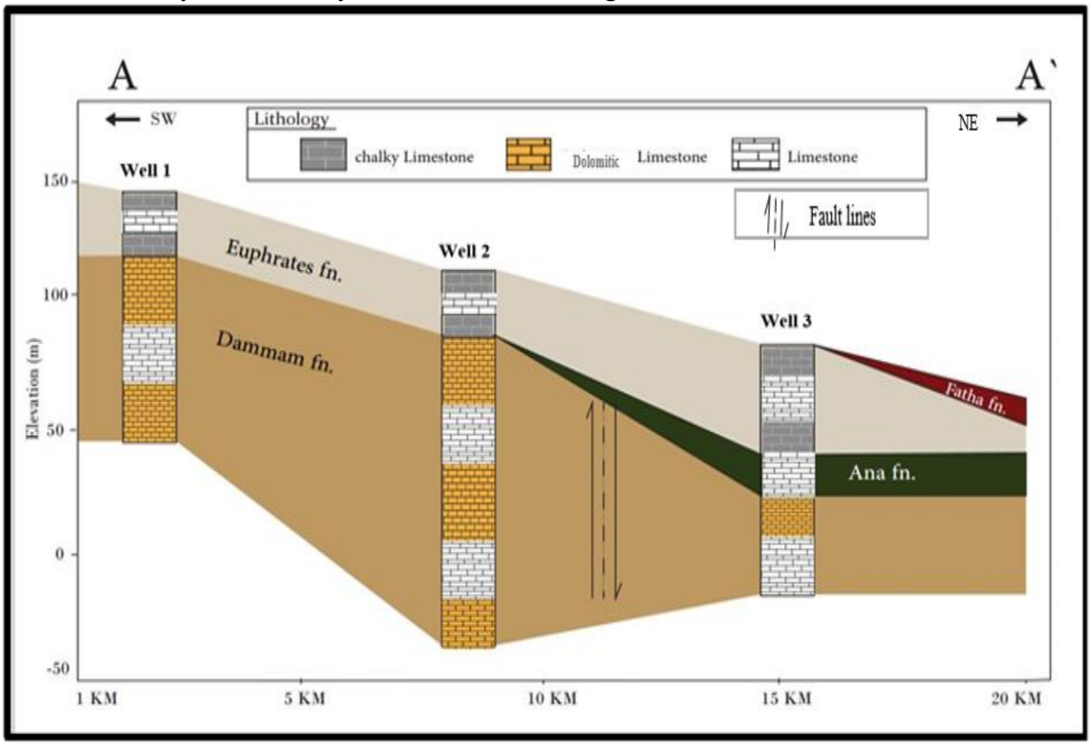

Figure 9: An imaginary geological Fence section for the formation in the study area with their resistivity values. The section is plotted based on the interpretation of the 2D resistivity data in the current study with a guide of the stratigraphy from the wells in the study area, the presence of the Fatha Formation in this figure concluded from the geological map of the area, the opening appears exposed as shown in figure 3, some sources say it reaches 20 meters[24], [26]

5. Conclusions

The main finding of this study is that 2D resistivity imaging could be considered a valuable technique for identifying the contacts between the various formations with the change of the groundwater bearing zone. This study can give several conclusions that can be summarized as follows:

1- In general, the inverse models of the 2D survey lines show gradients in resistivity where the resistivity increases with depth.

2. The survey region has two resistivity zones, as shown by the inversion survey models H-K1, H-K2 where the Euphrates Formation is represented by the first zone, which has low resistivity (range between 3.54-19.6 ohm.m). This is because the Euphrates Formation contains clay minerals with secondary gypsum of the Fatha Formation, which causes increasing in conductivity, while the second zone is characterized by the Dammam Formation, composed of limestone with dolomitic limestone with resistivity ranging between (19.6 – 108) ohm.m.

3- Inversion survey models of H-K3, and H-K4 illustrate three zones: The Euphrates Formation represented by the first zone, which has low resistivity (range between 3.54-19.6 ohm.m). This is because the Euphrates Formation contains clay minerals, while the second zone is characterized by the Anah Formation with resistivity reach to (19.6-34.6 ohm.m), with a thickness of about 13m, is composed of solid limestone, the third zone is Dammam Formation, resistivity ranging between (34.6 – 108) ohm.m, composed of limestone with dolomitic limestone.

4- These big differences in resistivity values within the same formation due to the nature of the Al-Dammam Formation contains fractures and gaps, which contain groundwater in this formation, and the higher the density of fractures and gaps, the higher the water content, so the resistivity decreases, while in the area free of fractures or in which there is a very low density, we find high resistivity.

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